

London Metropolitan University

**Business Cycles, Interest Rates, and Market Volatility:
Estimation and Forecasting using DSGE Macroeconomic
Models under Partial Information**

**Dissertation for award of
PhD in Economics**

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Abstract:

Even long before the recent financial and economic crisis of 2007/2008 economists were more than aware of the insufficiencies and a lack of realism in macroeconomic modelling and model calibration methods, including those with DSGE methods and models, and spelled the need for further enhancements. The issues this research started addressing even before the 2008 crisis imposed demand for improvements, was use of single, fully informed rational agents in those modes. Consequently, the first part of this research project was aiming to improve the DSGE econometric methods by introducing novel solution for DSGE models with imperfect, partial information about the current values of deep variables and shocks, and apply this solution to imperfectly informed multiple agents with their different, inner-rationality models. Along these lines, this research also shows that DSGE models can be extended and suited to both, fitting and estimation of long-term yield curve, and to estimating with rich data sets by extending further its inner-mechanism.

In the aftermath of the 2008 crises, which struck at the beginning of this research project, and the subsequent, extensive criticism of DSGE models, this research analyses the alternative causes of the crisis. It then focuses on identifying its possible causes, such as yet unknown debt accelerator mechanism and the related, probable model miss-specifications, rational inattention, and as well, a role of institutional policies in both the development of the crisis and its resolution.

And finally, in a response to many of the critiques of the, usually monetary policy oriented DSGE models, this research project provides another set of novel extensions to such models, aiming to bring more of Keynesian characteristics suited to a more active, endogenous fiscal policy deemed needed in the aftermath of the crisis. This project, henceforth, extends the NK-Neo-Classical synthesis monetary DSGE models with a novel, endogenous, counter-cyclical fiscal policy rule driven by news and unemployment changes. It then also shows overall benefits of the resulting, mutually active, monetary-fiscal policy for both capital utilisation and overall economic stability.

Acknowledgements

This research builds upon my MSc dissertation, Perendia (2006)², done also at LMU, and an early, conference presentation of some of its results in Pearlman and Perendia (2006), and it, to some extent, replicates for reference parts of that MSc thesis where they are deemed important and relevant for following this research but are not available publicly, on-line, as in e.g. in Pearlman and Perendia (2006). These are in mainly in Appendices 1-4 at the end, whilst other appendices at the end of this report are also deemed auxiliary information so that the main thesis contains around 69,000 words without the appendices with the auxiliary information at the end of this research report.

The following dissertation should be considered as a complement, and in a conjunction with the two publications to which this author contributed as part of this PhD research program and that have been available in the public domain since 2012:

a) Levine, Pearlman, Perendia and Yang (2009-2012), a work spanning several presentations and versions until it's publication in Economic Journal in 2012,

b) Perendia and Tsoukis (2012), available as Dynare 2012 conference paper,

which are, consequently, not reproduced in this dissertation report but they each represent contribution to science and have already gained recognition and citations in literature, to different levels, and, to which this author contributed approximately proportionally according to the number of their respective authors.

The following dissertation therefore mainly presents additional discussion, results and related, unpublished smaller projects, and, as well as a report on an additional piece of a research work, that on the roots of the recent 2007/08 crisis.

The first part of this research project was conducted within a joint, EU FP7 funded

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MonFisPol project³, aiming to show the benefits of new econometric methods for optimising monetary and fiscal policies and their related models⁴. The rest of this research was also motivated by similar aim to address their combined efforts.

I would also like to thank very much for all the support, assistance and support I received from my mentors, and supervisors: Prof. J. Pearlman, Dr. C. Tsoukis, Prof. R. McFadden, Dr. B. Akinwande, Prof. D. Bartlett and Dr. S. Dal Bianco, as well as my other, external co-authors: Prof. P. Levine and Dr. B Yang for their work, perseverance and support in getting our joint publication through the many versions and trials before its final publication. My special thanks go to A. Justiniano for making his BayesDSGE available for our initial, experimental work and also, to the CEPREMAP Dynare team founded and led by M. Juillard for the years of mutual work collaboration and support on augmenting Dynare project which was so essential for this research. I would like to thank all other staff of LMU Post-graduate school and particularly, Ms. C. Francesconi for dealing and supporting me with all the very many of the administrative issues that arose over the prolonged period this thesis took place to be completed, and to my dear friend, M. Coughtrie who helped me in formulating complex economics problems in as plain English as it possibly can be done. As this, part-time, research took its substantial part over the time spent working in several European countries and other UK cities, I also thank the Faculty Library of Social Sciences of University of Copenhagen for the generous open access to many of the latest or recent publications on pertinent subjects in English language, and their friendly support staff for their generous opening hours. Similarly, my thanks also go to the academic staff of Universities of Copenhagen, Edinburgh School of Economics and Science-Po Paris where I was allowed to attend their regular guest seminars and engage in the follow-up discussions on macroeconomics over the respective and, for this research influential years.

³ Seventh Framework Programme for Research (FP7) of the European Commission's Socio-economic Sciences and Humanities (SSH) Program from October 2008 to September 2011 under grant agreement SSH-CT-2009-225149.

⁴ One of the aims of the Monfispol consortium project (<http://www.monfispol.eu/>) was to provide a PCL'86 Partial Information solution for estimation and an IRF simulation to Dynare DSGE package (<http://www.dynare.org/>) users, a project the author participated in from 2009-2010. This research is also a background for the resulting joint research report and publication of Levine, Pearlman, Perendia and Yang (2009-2012).

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Part 1: Introduction and Background Literature

1. Introduction

1.1 A Summary and Motivation

This research is a bit atypical as it evolved over relatively long time, spanning different periods spent in different European countries while I was working on different professional projects, most of which turned to be related or relevant to this research. However, probably most importantly, it also spanned the world's biggest financial and economic crisis since the 1929 crash and the Great Depression. On the other hand, due to its relatively longer running, some of the results were published in earlier or mid-stages of its full development, whilst some of the work was paralleled by others and published by them before the whole dissertation completed, making thus, some of the work nearly or completely obsolete.

The recent financial and economic crisis of 2007 spelled the need for a different approach than the policies usually implemented in times of recession, and, contrary to expected policy recommendations by IMF for a tightening approach, the fiscal stimulus oriented New-Keynesian (NK) policies of government intervention have prevailed in the most of the countries that have been substantially affected by the crisis, notably the US and the Euro-zone.

Also, as the first part of this research project was conducted within a joint EU FP7 funded MonFisPol project⁵, aiming to show the benefits of new econometric methods for optimising monetary and fiscal policies and models, so the rest of this research was also motivated by similar aims to address improvements of tools and methods for both policies and their possible combined work.

⁵ Seventh Framework Programme for Research (FP7) of the European Commission's Socio-economic Sciences and Humanities (SSH) Program from October 2008 to September 2011 under grant agreement SSH-CT-2009-225149.

This research will therefore analyse the role of governments in both the development of the crisis and its resolution, and provides some justification for such NK approach. In chapter 6, I will also analyse in more detail the development of the 2008 crisis and how much that crisis resulted from the bursting of the housing debt bubble, itself inspired by the low inflation and interest rates that the governments were expecting and their central banks maintained as their targets.

1.1.1 Methodological focus: DSGE Models and Dynare Software

The main focus at the very start has been on issues of imperfect (partial) information in Dynamic Stochastic General Equilibrium (DSGE) models used by macroeconomic policy-making and planning bodies such as central banks and on their relation and dependence on various aspects and the role of information and decision-making.

Note: However, in some instances this project will be using different methodologies such as VAR or Granger cause analysis when appropriate, as additional tool, or as an alternative tool when DSGE could not be used such as the analysis of the Great Recession and the crises of 2007/2008.

1.1.1.1 Dynare Software for Estimation of DSGE models

The main computational and methodological toolkit used for this research will be the Dynare software package⁶, a widely used application for solving, estimating and simulating DSGE models, developed initially in Matlab language by Prof. M Juillard and maintained by a team of developers at CEPREMAP (Adjemian et al. (2011)).

Dynare solves and provides IRF simulation of the models up to third order Taylor approximation around the steady state using perturbation mechanism (Collard and

⁶ Dynare is free to use but it requires either Matlab, which is not free software kit, or the free Octave package which emulates Matlab environment and programming language syntax but which is rather slower than Matlab (<http://www.gnu.org/software/octave/download.html>).

Juillard (2001b), and Schmitt-Grohe and Uribe (2002/2004)). It however estimates only first order Taylor approximation (i.e. linearised) model's parameters' posterior distributions using Bayesian inference methods by applying observable data on Kalman Filters.

Dynare also provides for Bayesian VAR estimation along the lines of Sims and Zha (1996) and the DSGE-VAR combination for model miss-specification assessment and comparison based on del Negro Scharfheide (2004) and del Negro Scharfheide Smets Wouters (2007). After its enhancements for Pearlman solver and PCL86 partial information, it was used in this research reports as well as in Levine, Pearlman Perendia and Yang (2009-2012).

However, most of the classic DSGE models make a computationally simpler assumptions of asymmetric full information about shocks is available to the economic agents but not to the institutional (e.g. central bank's) econometricians. According to the critics, such models henceforth fail to take into account that only partial information is available to all the economic agents.

In line with the main aims of this research to address the most frequently voiced criticisms of both classical and NK DSGE models and tools (see Chapter 3) aiming for more realistic assumption of absence of full information and that of individual economic agent's limited ability to process it in fully rational manner in time-restricted decision making process, one of the sections (Chapter 5), provides and test improvements to DSGE modelling based on in making corrections to the two critical assumptions:

1. that all agents have full information available at their disposal (and, though less explicitly mentioned, are also assumed to be able to process it also correctly and on time), and,
2. that one single representative aggregate agent may then form fully rational expectations and be sufficient to represent aggregate economic behaviour.

As a part of this research, an extension was built into Dynare package to deal with partial information assumption based solution, this extension itself being based on the solution to the partial information model developed by Pearlman, Currie and Levine (1986),

Some of the results of this part of research were published over successive years and finally in Levine, Pearlman, Perendia and Yang (2012) and the research had a few other dimensions brought in.

1.1.2 Rationality and Information

Firstly, aiming, to address issues of rational agent, it was deemed important first to address in depth nature of rationality and rational thinking with limited information (Ch. 4), either by its in-availability (bounded rationality), or by rational optimisation of its use (rational inattention), dwell into the realms of animal spirits and neuropsychology driving our decisions through developments of neuroeconomics. One of additional aims and results of this apparent diversion was to identify if there are reasons for the duality of two models of rationality in economics, that of the so-called rational choice theory and the other, the rational expectations (RE) decision.

Broadly speaking, one can argue that most but the simplest information based “rational” decisions are boundedly rational, performed within limitations of the bandwidth of information medium and system at disposal and based on rational inattention aiming to abstract from excessive information deemed to be unimportant or less important and make assumptions deemed acceptable aiming to reduce size and complexity of the problem and focus on the problem in an isolation, a methodological approach comparable to “bracketing-out” in phenomenological epistemology.

Some of the work developed on the subject of rationalisation over the period of this research (and earlier) has been in meantime superseded by the publication of Daniel

Kahneman's comprehensive volume of work, Kahneman (2011)⁷, that is integrating much of his and late Amos Tversky's work with the many other earlier works, some of which this research was also drawing upon. However, this research then follows-up to complement and fill gaps in other theoretical literature and to point-out the likely reasons for which our own empirical analysis results (i.e. Levine et al. 2008-2012) can be correct when showing that only a minority of economic agents act on basis of rational expectations using full available information at the time.

Similar limitations, however, in turn then apply to most if not all of the scientific research and academic projects (including this one) as well as various mathematical or other conceptual models, thus, economic models too. So we have an inherent methodological limitations in that scientists and policy makers can only make rational inattention simplified models of the reality or the other agents' behavioural decisions based on rational inattentions simplified reality and, in turn, that of policy makers' decisions anticipations.

1.1.3 Great crises as tests for economic models

Following the 2007-08 crisis, however, an additional aim became to identify any important issues or omissions with macroeconomic modelling that either lead to the crisis or prevented its early diagnosis and to draw a path towards improving economic (and mainly the DSGE) models and policy decision making so that such omissions, if made, can be avoided in future.

By analysing the complexity of preceding events that led to both of the two big economic crises, the 1930s Great Depression and the recent 2007 crisis (so called “Great Recession”), one may conclude that the causes and errors leading to them may have been far more complex than mainstream publications are indicating. This may have been in part due to the individual academic researchers affinity to simplify and abstract the related complexity (i.e. perform bracketing mentioned earlier) and focus

⁷ “Thinking Fast and Slow”

attention on just a single, or a limited, related group of factors, such as, e.g. roles of the financial intermediaries.

The focus however still remained the role of information, its completeness based and economic agents' ability to fully comprehend and rationally process the information and form rational expectations, the limitations imposed by bounded rationality and rational inattention and their role in the evolution of the crisis.

Though apparently departing from the main theme of DSGE modelling, this research then shows a bigger picture of more systemic and complex issues that were contributing to the overall process leading to the 2007/8 crisis rather than just limitations of insufficiencies of DSGE tools (that many authors tend to blame) or any other econometric tools or methods. It, instead shows likely importance of the effects of liquidity shortage shock and its causes, but also, the effects of an under analysed debt-accelerator and of the possibly inadequate information (or omitted data) for the evolution of the crisis. Any miss-specification or rational inattention and the resulting data omission, if occurred, would, however not be specific to any one particular methodological approach such as DSGE.

1.1.4 Information and unemployment fiscal rule

The research completes with additional extension to DSGE models which show importance of effects of expectation changing information shocks (news) and of the active, endogenised role of government fiscal spending, e.g. in pursuing post-crisis recovery, and in particular, when reacting to deviations in employment and to those shocks to the expectations.

The innovations tested there and the results are in line with the recent return to Keynesian theory of fiscal spending as important contributor in the post-crisis recovery after years of its theoretical neglect.

We there show that government has a role in protecting viability of its economy and the welfare of its citizens and that its actions and intention to play such protective, countercyclical role need also to be publicly visible so to achieve even greater effect even if not fulfilled to its full planned or publicised financial commitment level.

This may appear to be in contrast with the more traditional monetarist approach which is at least neglecting if not side-lining the role of public spending in recovery, whilst favouring the role monetary policy lead by an independent central bank as the sole mechanism of macro-economic control.

Whilst the fiscal and the monetary policies can be decided and effected independently by the government and the independent central bank, it is still left to be affirmed if it is more optimal to pursue a closer cooperation between the two bodies and coordination of their policies in general, and especially when monetary policies are almost ineffective in a near-zero interest rate regimes like the one following the 2007-08 crisis.

1.2 Structure of the Thesis

Part1, Introduction, Chapter 1:

Dissertation begins with an Introduction and overview of contemporary dynamic macroeconomic analysis and forecasting models used by macro-economic research and policy institutions⁸.

Chapter 2:

A discussion of some perceived insufficiencies in modern economic modelling theory and practice that may have contributed to the development of the later crisis, namely, assumptions of fully rational and fully informed agents, bounded rationality and rational inattention .

⁸ Competitive market micro-economic games of asymmetric information are not in the focus or scope of this research.

Part 2, Chapter 4:

Introduction and an overview of literature on rationality and rationalisation

Chapter 5: Economic model based on alternatives such as Partial Information (PI) DSGE methodology but using heterogeneous and adaptive-rational agents acting in models of imperfect information conditions are considered as important improvements over those insufficiencies.

It also includes further experimental analysis into PI DSGE and simulations of the effects of partial imperfect information and reactions of agents according to what information they have at their disposal.

Part 3, Chapter 6:

An in-depth analysis is then made to some of the perceived main causes of both the 1930s Great Depression and, more so, the recent 2007 crisis (so called “Great Recession”). Along the lines of this research, an additional factor contributing to the crisis is analysed and identified to potentially be a form of informational insufficiency, i.e., a potential form of a rational inattention. As it appears, important information on private debt, both the household and the SME business one, may have been omitted or under-estimated on the part of major institutions such as central banks.

Part 4, Chapter 7:

Effects of news and the resulting change in economic agent's expectations based on such information are analysed in context of advanced DSGE models together and in conjunction with a role government countercyclical spending, the actual or at least publicised intention for spending, in maintaining strength of its economy midst pending unemployment.

1.3. A Short Summary of Main Contributions to the Literature:

1. **Estimating effects of Partial Information:** The first innovation is the implementation of a solution to the RE DSGE partial information model developed by Pearlman, Currie and Levine (1986). It provided background work for further research and publications with Professors J. Pearlman and P. Levine on correcting DSGE estimations and shock simulation effects since the more traditional DSGE models and methods make inappropriate information assumptions and assume that economic agents have full access to all relevant, needed measurements of economic shocks. Within this research:
 - a) a reduced Smets and Wouters (2003) PCL86 extended DSGE models was also extended with an alternative Kalman Filter solution for a Bernanke & Boivin (2003) and Boivin and Giannoni (2005) M-FAVAR like extension for augmenting the estimation using a much larger number of additional data series (factors).
 - b) This solution was then extended with multiple Taylor rule type equations for fitting the US treasuries based yield curve spanning several decades (Perendia 2008).
 - c) After extending Dynare DSGE package with a PCL partial information solution making it available for its broad use, we showed that a partial information heterogeneous DSGE model indicates a balanced presence of both adaptive and rational expectations among the broad spectrum of economic agents (see Levine et al. 2008-2012), with some causes and implications extensively elaborated within this research (Ch. 4).
 - d) In addition, simulations were run to show how different assumptions of partial information series observations affect the IRF responses of a standard DSGE model.
2. **Recessionary debt accelerator:** Another, more theoretical contribution of this research is to show that one, so-far less known and researched, but potentially crucial factors may have led to both, the recent 2007-08 financial and economic

crisis known as the Great Recession and potentially the Great Depression. This research introduces a new type of a recessionary accelerator, namely the **recessionary debt accelerator**, a down-spiral recessionary trend resulting from a consumption restriction amidst liquidity shortage among the small private borrowers, this shortage, in turn, resulting from a contractionary interest rate shock, as the major factor in development of both, 1930s and 2007 economic crises (see more below in chapter (6) and Perendia 2015)

3. **Unemployment driven fiscal rule and effect of news:** The third group of innovations of this research are the extension of the standard DSGE model (e.g. Smets and Wouters (2007) in our case) that include two factors affecting consumption and growth. It introduces firstly news shock with the resulting change in consumers' expectations, and, secondly, a simple, J.B. Taylor like, novel endogenised fiscal policy rule based on both unemployment and the news related rational expectation changes. We then also find that such rule driven fiscal intervention can act as countercyclical accelerator on consumption. The research results assert importance of counter-cyclical fiscal intervention strategy for facilitating an economy out of a recession or a crisis (see chapter 7 and Perendia and Tsoukis (2012)). It then discusses and argues for balanced, active fiscal and monetary policies in times of recessions.

The work concludes that extending classic DSGE models estimations and simulations with partial information, heterogeneous agents and, even more so, the news, the fiscal and yield curve rules provide much better parameter estimates and data fit than the classical, full information and reduced data models. It then provides some recommendations for future enhancements.

2 Review of Literature on Macroeconomic Modelling

2.1 An Overview of Macroeconomic modelling and Forecasting

Modelling and forecasting dynamic phenomena goes hand in hand. Forecasting usually refers to predicting an out-of-sample behaviour of phenomena in some future time. This is, at least, in relation to the data sample one has at hand, though, this may be done for past periods to perform model calibration within a sample (e.g. performing forecasts in 2011 for 2008 using data 1980-2007).

One cannot forecast and get good results without decent models. Models' quality is usually also tested for their ability to explain a posteriori or predict a priori behaviour of some multi-dimensional spatio-temporal dynamic phenomena.

The older static IS-LM models of macroeconomic equilibrium are usually evaluated from a system of equations of exogenous and endogenous variables. Such models were suitable for analysis of factor-change dynamics and their effects on the stability of long-run equilibria. However, the older models were not taking an explicit consideration of the (time) length of the impacts and the related time dimension dynamics.

Many authors have emphasised insufficiencies of the old “static” IS-LM models of macroeconomic equilibrium. The very nature of the free market as a competitive economic process is to be time-dynamic and static equilibrium is never observed. Virtually all of economic measurements are performed in a state of dis-equilibria (Ferguson and Lim (1998), pp 1).

Diebold (1998) explains why large-scale Keynesian structural macro-models and forecasting based on them faded away for various reasons. These included their lack of suitability for conditional forecasting and the Lucas critique that showed that the rules of decisions they are based on would change with policy change. Such models were replaced by Lucas-Sargent like models, which incorporate rational expectations into the

structural model, and they are still in use.

This development was complemented by the rise of discrete time-series, VAR and unstructured models. However, policy change analysis requires that structural models, dynamics and dis-equilibria can be modelled as either continuous processes using a set of structural differential equations (Ferguson and Lim 1998), or, more frequently, as discrete-time series using difference equations or other techniques outlined below.

2.1.1 The Main Categories of Macro-economic Models

The literature (e.g. Diebold 1998, Dieppe and Henry 2004 and Issing 2004) outlines five main categories of dynamic macroeconomic modelling strategies, most of which are used at central banks (such as ECB, or BoE) which may employ a suite of different models to improve reliability of their forecasts.

1. Non-structural statistical time-series without theoretical underpinning. The demise of Keynesian models was followed by re-development of non-structural and unconditional forecasting models based on auto-regression, difference equations and stochastic behaviour and used for impulse propagation analysis. Those models include Cointegration-ECM models.
2. Vector Auto-Regressive (VAR) - all-endogenous variable models suitable for empirical analysis of time-series characteristics of economic factors, their statistical interactions and their shock-impact responses without the restrictions and constraining assumptions imposed by a domineering theoretical framework. They however, are not without their limitations, such as sensitivity to structural change, unsuitability to account for Rational Expectations and hence the Lucas Critique.
 - a. The Structural VARs overcome some of the limitations (and reduce the

flexibility of VARs) by allowing some structural model rules or pre-calibrated parameters to be imposed. This then allows for a better economic interpretation of disturbances. However, aiming to overcome some of the remaining limitations of VAR and Structural VAR (SVAR) models, such as the relatively small number of variables and time-series they can handle⁹ and suffering from the so-called “price puzzle” forecast anomaly¹⁰, Bernanke et al. (2004/2005) are building upon their earlier work (Bernanke and Boivin 2003) and that of Stock and Watson (1999)¹¹ and suggest a new, Factor-Augmented VAR (FAVAR) method. This method combines the SVAR analysis with recent developments in non-parametric, principal component analysis based dimension reduction and Bayesian likelihood factor estimation for large data sets by nesting “smaller” VAR estimates.

b. Bayesian VAR estimation overcomes many hurdles of the model size restrictions on both the recursive (standard) and the restricted (structural) VAR models (see Waggoner and Zha (2000), Waggoner and Zha (2003)) and for regime switching models with Rational Expectations (Sims, Waggoner and Zha. (2008)).

3. Small size, several reduced-form equations used for analysis of specific changes in monetary policy and expectations (e.g. Phillips Curve and optimising models used at BoE).
4. Medium sized, complete structural, “inter-temporal” macro-models based on systems of simultaneous equations derived from a comprehensive theoretical framework and used for policy change simulation and forecasting. They tie the

⁹ inclusion of additional variables in standard VARs is severely limited by degrees-of-freedom problems.

¹⁰ the conventional finding in the VAR literature is that a contractionary monetary policy shock is followed by an increase in the price level, rather than a decrease as standard economic theory would predict.

¹¹ For example, Bernanke & Boivin (2003) build upon the work of Stock&Watson (1999) who conclude that “the best-performing forecast for inflation is an augmented Phillips curve forecast that uses a new composite index of aggregate activity comprised of the 168 individual activity measures”.

theoretical framework with a close fit to data and may contain lagged and forward-looking data and expectations to reflect the dynamics of the system.

5. Dynamic Computational General Equilibrium (CGE) models: Initially developed in 1970s, the early, calibrated and static CGE models were often micro-founded, structured, budget constraints, real economy and long run equilibrium oriented models calculated around steady state though there are extensions for non-steady state calculations. Dixon and Rimmer (1998) develop a widely used MONASH dynamic CGE model. Burniaux and Truong (2002) extend the global trade analysis project (GTAP)¹², with energy sector extended (GTAP-E) CGE model and Beckman, Hertel and Tyner (2011) delivers a GTAP-E CGE models with improved validation techniques applied to petroleum energy sector. For more recent examples and developments in use of forward looking dynamic CGE (DCGE) models for optimising corporate income taxation in US, see Bhattacharai, Haughton, Head and Tuerck (2017).
6. Dynamic Stochastic General Equilibrium (DSGE or SDGE) models developed initially in 1980s are similarly based on comprehensive theoretical foundations and are used to associate shocks and the economic system's responses based on forward-looking expectations. Initially used for analysis of RBCs they are now used for short to mid-term forecasting and optimisation of the economic responses. Many of the recent DSGE studies show significant superiority of DSGE over unrestricted VAR, Structural S-VAR and the Bayesian B-VAR forecasts, especially for longer term forecasts (e.g. Smets and Wouters (2002) and (2003), (denoted SW02 and SW03 henceforth), and Boivin and Giannoni (2005)).¹³
7. Heterogeneous agents simulation models such as EURACE (der Hoog, et al., 2009) use Monte-Carlo simulation of economic agents segmented by various

¹² See <https://www.gtap.agecon.purdue.edu/models/current.asp>

¹³ This work concentrates on such models and explains them in more detail.

criteria such as geographic position and economic role whilst integrating a large variety of traditional micro and macro- economic models. It is however important to note that the recent developments in areas of both, DSGE and DCGE models makes those models suitable for large a very scale disaggregation and simulation of a large number of heterogeneous agents: firms and households, in both, closed and multi-country open economy models (see for example a 15,000 variable DCGE model of Fair Taxation in a highly disaggregated model of US economy in Bhattarai, Haughton and Tuerck 2016).

2.1.2 Combined method and Large Models:

Choosing the “right” model for an economic institution or a central bank has been proven to be a futile task. Contrary to the opinion of Diebold (1998) of the “death” of large macro models and suggestion that the recent tendency is to keep those models relatively small, the recent practice at the central banks is to maintain complex models (e.g. ECB's Area-wide model - AWM and BoE's Macro-economic Model), or, as US Fed, a rather large, data-rich models. To reduce the effect of errors and improve estimation precision, the major national and international institutions (e.g. US Fed¹⁴) maintain thousands of time-series¹⁵ and use a combination of aggregate indices, several macro-models and VAR techniques. They then create their estimates usually on a basis of informal or a formal heuristics and the weighted average of the results obtained from different models¹⁶.

2.1.3 Forecasting of the rational agents' behaviour

¹⁴ US Federal Reserve Board model

¹⁵ Observers of Alan Greenspan's chairmanship, for example, have emphasized his own meticulous attention to a wide variety of data series (Bernanke & Boivin 2003).

¹⁶ “*Small models have many advantages, including most obviously simplicity and tractability. However, we believe that this divide between central bank practice and most formal models of the Fed reflects at least in part researchers' difficulties in capturing the central banker's approach to data analysis, which typically mixes the use of large macro-econometric models, smaller statistical models (such as VARs), heuristic and judgemental analyses, and informal weighting of information from diverse sources.*” (Bernanke & Boivin 2003)

As mentioned earlier, the forecasting of rational agents' behaviour has become an integral part of forecasts of economic dynamics as a step in resolving the Lucas critique issues of dynamic changes in the market agents' forward-looking rational expectations.

To address this issue, in addition to large models, the some institution or a modeller, (e.g. Bank of England, BoE, suite of models) uses also special, small “optimising” models to estimate the optimal behaviour of microstructure agents (see below). Optimising models are used to estimate and project the rational, dynamic, inter-temporal optimal behaviour of microeconomic actors such as individuals and private organisations. They estimate the agents' optimal reactions to macro-economic shocks. They assume that the actors are identical and that they rationally and dynamically optimise their behaviour. The starting point is the standard inter-temporal budget constrained agent behaviour optimisation equations (the equations below and their explanations in the Notes are reproduced from BoE documentation):

$$\begin{aligned} & \text{Maximise } E_0 \sum_{t=0}^{\infty} \beta^t U(C_t) \\ & \text{subject to } A_{t+1} = (1 + r_t)A_t + YL_t - C_t \end{aligned} \quad (2.1.3.1 - \text{Note}^{17})$$

These assumptions imply the inter-temporal Euler equation:

$$E_t U(C_{t+1}) = \frac{1}{\beta(1+r_t)} U(C_t) \quad (2.1.3.2)$$

For example, when applied to an agent's investment behaviour using the Consumption CAPM (C-CAPM) it yields an equation characterising the agents' optimal decision to invest:

$$P_{it} U(C_t) = E_t [\beta U(C_{t+1}) (D_{i,t+1} + P_{i,t+1})] \quad (2.1.3.3 - \text{Note}^{18})$$

Taking into account estimates of the time-series properties of consumption using the Auto-regressive moving averages (ARMA) technique, the real yield on an n-maturity

¹⁷ where U is utility, β is the pure subjective rate of time preference, r is the real interest rate, and A , YL and C denote the real level of financial wealth, labour income and consumption respectively. $E_t(.)$ denotes the expectation formed at time t .

¹⁸ where P_{it} is the real price of the asset at time t , and $D_{i,t+1}$ is the dividend payment on the asset between t and $t + 1$.

bond is then given by¹⁹:

$$r_{nt} = -\ln \beta + \frac{\gamma}{n} E_t[c_{t+n} - c_t] - \frac{\gamma^2}{2n} Var_1[c_{t+n} - c_t] \quad (2.1.3.4 \text{ Notes }^{20} \text{ and }^{21})$$

The FRB/US (US Fed) uses two alternative representations of the economy: an auxiliary VAR and the main model. They utilise weighted levels of past and future fundamentals to derive the value of decision variable. The FRB also uses “Polynomial adjustment costs” (PAC) to model the high order of auto-regression²² within the Euler error correction model (ECM) of agents’ decision-making (Muehlen 2001).

2.1.4. Trap of the self-confirming equilibria

Sargent (1999) and, Sargent, Williams and Zhao (2006) point to occurrences of so-called trap of self-confirming equilibria. These equilibria are imperfect rational expectation equilibria that are usually sub-optimal and highly inflationary-biased. Sargent and his co-authors claim that they result from partial irrationality on the side of governments (or monetary policy authorities) that create incorrect beliefs of the Phillips curve. These self-confirming equilibria are based on inferior, least square regression methods that tend to predict incorrectly high inflation and employment policies based upon the incorrect estimations of the PC direction. They then argue for the importance and future use of (expectation augmented) Phillips curves in macro-economic models based on RE.

¹⁹ Although this by-proxy estimate of real interest rates is useful for analysis of an agent’s behaviour, the long-term real interest rates, both in the MM and internationally, are assumed to be set on the international financial markets independently of domestic developments. However, this assumption is not reflected in the empirical findings which show that the UK’s real interest rate has for several years been lower than expected by the international financial markets.

²⁰ where E_t and Var_t denote the conditional expectation and variance respectively, and γ is the coefficient of relative risk-aversion.

²¹ In another example, the models were used to estimate the behaviour of a firm and assess the impact of the Working Time Directive. It derived that the WTD would reduce labour demand through an increase of effective wage for an increased relative level of training and recruitment costs.

²² This high order of autoregression in behaviour of consumers may be due to spending habits, i.e. “lifestyle rigidity”

2.2. Introduction to modern monetary policy and inflation targeting²³

Following the oil crisis and the resulting economic recession of 1970s that was accompanied with the high inflation, interest rates and market volatility, monetary policy changes were introduced in the early 1980s. Clarida, Gali and Gertler (2000) (CGG 2000) show that, since the early 1980s, the new Volcker-Greenspan interest rate rules have had a stabilising effect on the US economy. They show that pre-1979 and pre-Volcker policies were often rather “accommodating” of inflation and, for example, let short-term real interest rates drop in times of high inflation or left space for bursts of both output and inflation due to self-fulfilling expectations. Those “sunspot” market volatilities were based on the agents’ correct expectations that the Fed will maintain low short-term interest rates which will drive demand, prices, and, thus, inflation to rise even further²⁴.

This perception led to the seminal Lucas critique ((Lucas (1972), (1973), (1975), (1976)), and work of Kydland and Prescott (1977) which identified an inflationary bias when the monetary policy authority follows a time-consistent policy and does not commit to a rule. The consistent (optimal) policy was defined by Kydland and Prescott (1977) as the choice of policy π at each point in time, the current and the future, that maximises the previously agreed-upon objective function $S(x, \pi)$ and based on the previous actions of agents x . Without getting involved into how the objective function is agreed upon²⁵, such backward-only looking policy is made without taking into account forward looking agents who take into consideration their own, and, when

²³ Inflation targeting tools at the disposal of the central banks are mainly two-fold: either directly expansionary (contractionary) monetary actions in case of inflation falls (increases) or the adjustment of the policy interest rate at which it lends to financial institutions: rate increase to reduce inflation through the sale, or its decrease in expectation of inflation lowering below its target, mainly through purchases of short term securities (inc. gov. bonds).

²⁴ CGG note that there are research papers that try to explain this by over-optimistic under-estimates of the production gap and related under-estimates of NAIRU, or, according to Orphanides (1997), that their preliminary over-estimates of potential output.

²⁵ However, though most authors assume the government is benevolent and takes action that satisfies households, it is not realistic to assume all households will be satisfied with it or consider it optimal. Even Pareto optimal policy may not be perceived as satisfactory by the majority of the average representative households from all sides of political spectrum because it is not unique. Governments tend to be benevolent predominantly to their own voter base and the target representative agent may be chosen from there or as a weighted average of their voters and another target base.

known, the others' expectations of the future policies²⁶.

Their argument started a long-term, still ongoing, discussion in economics on differences between consistent and discretionary policies²⁷. Time consistent policies can be predicted and accounted for in the agent's plans and the policy effects can then be diminished. Discretionary policies are however shown to be suboptimal in the long run. During the resulting discussion in the late 1970s and early 1980s, the roles and advantages of policy credibility and the related state-contingent rules in controlling inflation over the time-consistent or discretion based re-optimisation policies, have been considered as being proven and accepted

A new style of monetary policies are based on Rogoff's (1985) recommendations and the definition of an independent, "conservative" central banker who adjusts monetary policy according to the pre-defined rules. These are usually contractually agreed with the government, widely published and known to other economic agents. Such policies are in line with what is frequently called the "conservative bias" that tailors policy in line with the needs of the business community and market stability. Such an approach is perceived to have greatly contributed to policy credibility and reduced pure forward-looking time-inconsistent discretionary behaviour described by Kydland and Prescott (1977).

Consequently, an increasing number of independent central banks have, since the early 1980s, pursued inflation targeting and interest rates instrument based control rules. These have mostly been on the lines of those pioneered by J B Taylor (Taylor (1993)), initially on basis of only lagged data on output and inflation. Such inflation targeting rules have found, with few variations, their way in a large number of macro-economic

²⁶ Note: The example they give, building on flood plain and forcing the government to build protection, is not appropriate. It is simply an example of a policy that has not been implemented consistently – the mentioned absence of a law prohibiting building on a flood plain that was not put in place and hence discouragement was just nominal. It is more an example of a government policy that was not given full support, power and mechanism of execution due to insufficient funds or deliberate manipulation.

²⁷ This issue is not new, however. For example, the 18C French Revolution (as many similar ones) was fought mainly for the establishment of consistent business and market rules and the fairness of the market game against the absolutist discretionary rights of the royals and the aristocracy ruling at the time.

models, in particular, ones aimed at that problem and used in central banks.

In addition to the lagged data on output and inflation, the most of the modern rules extend the original Taylor (1993) model by incorporating forward-looking rules. These are usually based on Rational Expectations of future economic values such as the expectations of inflation and output. Examples are the inflation forecast-based (IFB) rules in Batini et al. (2005b) or the inflation forecast targeting (IFT) rules in Svensson and Woodford (2003). Those combined backward - and forward-looking inflation forecast targeting rules collapse to a simple, original backward looking Taylor type rule as a special case in steady state of economy.

Since its introduction in New Zealand and Canada, and subsequently in most of the industrialised countries, this approach is widely believed to have greatly contributed to the reduction in inflation. This was the case particularly where there was a lack of credibility of older, central government lead discretionary, temporary optimal and time-inconsistent inflation policies that were often perceived as short-term opportunistic optimisation, thus, resulting in consistent inflation bias.

2.2.1 Introduction to Taylor rule and its origins

A major development point in interest rate targeting occurred when John Taylor estimated and provided as a future “ideal” (long-term optimal) normative rule as its interest rate equation (Taylor (1993)). The original “Taylor rule” equation for optimisation of the interest rate i_t as a function of the past interest rates, either the current ($j=0$) or of the currently expected future inflation rate $\pi_{t, t+j}$, ($j>0$)²⁸, the production gap²⁹ ($y_t - y_{nat,t}$) and the monetary policy shock mp_t , has had few variations

²⁸ Note: Following Batini et al. (2005b) i_t and π_t in this equation are neither real nor nominal, observed but deviations from the mean, difference between the observed data (when available, e.g. $\pi_{obs,t}$ in our case) and unobserved means, r^* and π_t^* respectively. In addition, we estimate the mean, real inflation π_t^* and unobserved real interest rates r^* , and use the later in the calculation of the (quarterly) future discount coefficient β as $\beta=1/(1+r^*/100)^{1/4}$.

²⁹ Many DSGE models identify the production gap as the difference between production at time t and the “natural production”: either production in steady state or production in the model economy without

and modifications and can be expressed as:

$$i_t = \rho i_{t-1} + (1-\rho)[\theta_\pi E\pi_{t,t+j} + \theta_y (y_t - y_{nat,t})] + mp_t \quad (2.2.1.1)$$

where ρ , θ_π and θ_y are inflation forecasting based (IFB) monetary policy reaction (i.e. feedback control) rules' parameters that will be estimated and mp_t is a simplified IID³⁰ monetary policy shock given by ε_{mpt} .

The policy maker balances between a quick return and a smooth inflation path to the target after the shock, and sets nominal interest rate accordingly. Parameter ρ defines the degree of interest rate smoothing – the higher it is, the lower are the effects of inflation or production gaps on the resulting interest rate. The feedback parameters θ_y and θ_π define the speed of the correction. The higher they are, the higher the effects of the inflation and the output gap on the interest rate will be. In addition, the higher the effect is, quicker the economy will react to eliminate either or both of the gaps: between the expected (forecasted) and the target inflation rate, or the output gap. Index j is the policy horizon - this is the number of periods ahead during which the policymaker is looking for the feedback³¹. In some forms of the equation, the employment gap is used instead of the output gap, but rarely so. Adherence to the rule became subject to much discussion just prior and after the 2008/8 crisis and this research is covering later on in the section on the causes of the crisis. (Appendix 8 contains some more technical details on the original rule and, as one of the side result of this research, it there shows how the rule form can actually be derived directly from the pre-existing financial market economics (bond) interest rate determination methods. Similarly, Appendix 7 shows how Taylor rule can be extended with additional yield curve terms for their estimation and possible forecasting.)

frictions and rigidities (e.g. price and wage stickiness). This similarly applies to consumption too. In the estimated model, equations 10 and 11 define natural rates of consumption and output respectively and define natural equilibrium as a reference for estimating consumption and output gaps respectively.

³⁰ Independent and identically distributed random variable.

³¹ In our model $j=0$ and $E\pi_{t,t+j} = \pi_t$

2.2.2 Inflation Forecast Based (IFB) Rules

As mentioned above, Dynamic stochastic general equilibrium (DSGE) methods, initially developed to simulate and predict real business cycles (RBC) have been found to be a valuable tool in forecasting effects, and development of remedying strategies for implementing Taylor rules for successful targeting of inflation. Batini and Pearlman (2002) state that there are two main types of forward looking, forecast based inflation targeting:

1. The so called Inflation Forecast Targeting (IFT) rules (e.g. Svensson and Woodford 2003) that aim to optimise the economy and usually minimise the central policy (usually welfare) loss function whilst penalising expected deviation of inflation from its given target,
2. The so-called “simple” Inflation Forecast Based (IFB) rules originate from the seminal Taylor (1993) work, but, like IFT rules, they also respond to the inflation forecast rather than focus on current inflation as Taylor’s (1993) rules do. In addition, the mere simplicity of those rules makes them more acceptable and credible within the business community.

Batini and Pearlman (2002) also state for IFB rules that

*“...they are usually good approximations of optimal feedback rules. However, as these rules are not fully optimal, they can lead to dynamic instability or indeterminacy. A standard result in the literature is that to avoid indeterminacy, the monetary authority must respond aggressively (i.e. with a coefficient above unity) to expected inflation”*³² (See also Levin, Wieland and Williams (2001)).

In another report Batini, Levine and Pearlman (2004) apply IFB rules on a small open economy. They indicate that the problem of indeterminacy is even more serious in an open economy whilst most of the literature tends to avoid the treatment of these

³² As we will see later, application of the IFB rules based aggressive response policy may have had a crucial role in bursting the bubble and the 2007/08 crisis (the so called “Great Recession” crisis).

problems in the more realistic open economy situation³³. They also find that the problem of indeterminacy is even higher if Central Banks, such as the US FED and ECB do, use consumer price indices (CPI) as their target rather than producer price indices (PPI).

2.2.3 Additional issues with central bank inflation targeting rules

Many authors (e.g. Worell 2000 and Wray 2014a) have raised the issue of the extent to which central bankers can be making decisions beyond and independently of the usual democratic process and that of related central bank accountability to the democratic institutions. Even Lucas was aware of that issue when he closed his famous critique of backward-looking econometric estimation strategies (Lucas (1976)) with a less discussed and publicised call for the policymakers to forecast their citizens' (i.e. market agents') future responses. This was advocated so that the policymakers could be more in “...*accord ... with preference for democratic decision making*” (Lucas (1976)).

One way this call could be met is by using rather more advanced methods of economic agents' decisions modelling and forecasting technology. However, a commonly accepted approach is, instead, to assume a position of delegated responsibility for social welfare maximisation (or, more often, welfare loss minimisation) within independent central banks' models. Stokey (1991) outlines the difference between the Ramsey outcome and no-commitment outcomes. As most of the authors, she assumes in both cases that the agents will choose option x that maximises overall welfare.

2.2.4 Inflation Targeting in Emerging Economies

Some of the emerging economies of Central and Eastern Europe, namely the Czech Republic National Bank (CNB) in the late 1990s adopted so called “Net “ price targeting (Mishkin (2007)). The ‘Net’ price targeting involves targeting only a portion

³³ As we will see later, even the US economy in the more recent years with high inflows and outflows of capital can not be considered as closed.

of the overall (headline) CPI, for example, only those prices which are not subject to government control and regulated (e.g. milk, rents, etc....) and are not exogenous supply prices (such as oil).

However, by reducing the target price bundle, inflation targeting policy may be both ineffective and create unwanted effects (Mishkin (2007)). If a bundle is relatively small compared with the overall CPI and overall inflation is decreasing (increasing) but the bundle index is moving in opposite direction, a country may impose a tightening (loosening) inflation targeting (interest rate) policy when, instead, the opposite should be applied.

Mishkin (2007) finds that there is however the danger of an additional effect of inadequate (e.g. net) targeting, that is, self-fulfilling inflation (deflation). Higher (lower) than necessary interest rates may fuel rather than correct the high inflation (deflation). This occurs as economic agents seeing a higher (lower) than necessary interest rate may read it as a signal of a high (low) forecast of inflation and adjust their inflation expectations and prices accordingly but incorrectly. This then instead fuels destabilising market price volatility, especially when the credibility in the central bank and its ability to control inflation has not been established yet.

The above effects may thus have severe consequences on the overall economy. They may increase a destabilising volatility of overall growth instead of providing a counter-cyclical, stabilising effect.

Similarly, Mishkin (2007, pp 376) states that CNB's net inflation construct indeed turned to be more volatile and it led to targets being missed more than would have been case with the headline inflation. Mishkin also stated that a narrow net inflation target might be difficult for the public to understand and to adjust-to in their plans. This in turn may damage central banks' credibility, which may have especially bad consequences when such credibility is still being established.

Due to those problems, in 2001 the Czech Republic abandoned Net inflation targeting for headline (overall) measured by CPI because, as CNB explanation goes, the *“headline inflation covers more comprehensively price development in the economy and that it is more relevant for decision of economic agents... [and] monetary policy should also be better able to affect inflation expectations”* (Jonas and Mishkin 2005, pp 362).

Also, following an introduction providing a comprehensive overview of discussion on Taylor rule for inflation targeting, Caporale et al. (2016) engage in analysis of evidences of use of non-linear Taylor rule as opposed to the classic linear ones based on Taylor(1993) estimated and discussed usually. They are both, quoting other authors who find it in UK and other developed and developing countries that use different thresholds to trigger parts of the rule, namely the output gap. They then estimate both, linear and threshold versions of the augmented rule with three forward-looking values and, as well, exchange rate as potentially more suitable and significant for smaller and open economies. Applying GMM estimation method they find that the threshold non-linear Taylor rule fits better the historical data from the most of the smaller countries they analysed.

2.2.4.1 Comment

Despite Czech's bad experience with the net targeting, both the US and Serbia entered into their own versions of net (i.e. “base”) price index targeting seven years later with possibly even a smaller proportion of targeted price bundle (i.e. excluding energy prices). Thus potentially distorting the real measure of inflation even more and thus running even a higher risk of applying inadequate interest rate policy and the higher risk of a destabilising volatility. The distortionary effect of a relatively small net inflation target domain (compared with the headline) may also work in the opposite direction and lead to a low base inflation forecast (compared with headline) which then may lead to an inadequate decrease in the interest rate and depreciation of the domestic currency.

2.2.5 Discretionary and Commitment Based policies

Another issue of volatility relates to discretionary versus commitment based monetary policies adopted by independent or less so independent central banks and government-led fiscal policies. In-depth analysis of this issue is beyond the scope of this research and it is mentioned here only for a reference.

Many authors (e.g. Levine, McAdam and Pearlman (2006)) show the advantage of commitment-based policies over discretionary ones. One may argue that the difference is analogous to the known advantage of rule by law based economic systems over the (hopefully benevolent) dictatorship rule based ones. The policy by rule or by commitment take-out a substantial level of uncertainty in forming Rational Expectations in comparison to the discretionary (or dictatorship) based system for its agents who then can reduce uncertainty driven price volatility.

Both myopic, and those not so governments and central banks may find commitment based strategies sub-optimal over time and try to renege their policies in short term. This possibility however introduces uncertainty and increases the volatility of both real and financial markets.

This is not to say that, according to the authors, a benevolent dictatorship may not be advantageous for faster development and growth in the underdeveloped and export based economies, e.g., those that seek foreign investment and provide high returns based on low wages over the relatively shorter periods of fast growth. However, systems governed by publicly known laws (rules), provide additional public information and constraints, which, in general, should further reduce uncertainty and hence price volatility.

It is however needed to say that, complicated or constrained rules and laws should not become overly complicated to be modelled by its agents, or overly constraining so to lead economies to constrained standstills. (e.g. Levine, McAdam and Pearlman 2006).

However, in-depth discussions on Central Banks' optimal policy and the uniqueness of the equilibria, though referred to through the review, are beyond the scope of this research.

2.3 Credit markets frictions and credit rationing

2.3.1 Financial accelerator and credit markets frictions

The seminal ideas on agency costs, net worth and financial accelerator effects expressed by (Bernanke and Gertler (1989) and Bernanke et al. (1999) (BGG later on)) revives the importance of Fisher's 1933 notion of on "debt-deflation" and his and Keynes' analysis of Great Depression³⁴. Bernanke and Gertler (1989) introduce a notion of a financial accelerator as a non-linear, pro-cyclical, market fluctuation in response to fluctuations in the corporate borrowers' net-worth and the reciprocal (counter-cyclical) lender's agency costs due to asymmetric information. They take up the NK approach and restate the importance of the financial sector for the real economy. They assume that previous work based on Modigliani, which states that financial markets have little or no effect on the real economy, is a pragmatic approximation rather than an incorrect approach. They believe it is an approximation that does not represent the more extenuating situations of recessions or depressions, when cash starved banks cannot provide sufficient credit to companies, leading to corporate bankruptcies. The financial accelerator is a feature that amplifies the shocks in the credit markets and generates a systemic effect - so called "positive-feedback" to the cyclical behaviour of the markets: either further slowing an already declining economy, or in up-turns, accelerating further an already growing economy.

They analyse the effects of what they think is the main mechanism of financial

³⁴ Fisher claimed the Great Depression was triggered by a spiralling effect of pessimism, debt liquidation and resulting asset deflation leading to credit deflation and liquidity constraints. It was also prolonged by the high debt in the financial sector and general deflation at the time.

accelerator – asymmetric information induced agency costs³⁵. They show that banking loans carry a risk premium, which is counter-cyclical due to the higher (lower) expected risks of agency costs in down-turns (up-turns) and is inversely related to the net-worth³⁶ of the their borrowers.

Based on earlier work by Townsend, their model adopts the costly state verification (CSV) approach, which assumes that the auditing (monitoring) costs are imposed on the loan lender if the lender wants to inspect the financial development of the borrower.

Analysing Impulse-response functions (IRFs) of interest rate shocks applied on models of a variety of industrialised countries Goodhart and Hoffman (2004) show that interest rate shocks had a significant negative effect on asset prices whilst, contrary to expectations, bank lending was less affected by those shocks. The authors argue that the agents' sentiments had a stronger non-linear effect on business cycles than the monetary policy appears to have, the highest effect being at the times of sentiment changes, possibly even accelerating such cycles. Using graph analysis they also show that credit growth is highly correlated with asset prices, and, though less so, also correlated with inflation for most of the countries (leading the CPI by several quarters). Their analysis shows that in recent years in the UK, correlation between credit and house prices has increased whilst credit's correlation to equity prices has decreased. They also refer to a number of other studies that show a causality relationship from housing prices to levels of credit. Those authors' VAR based IRF simulation studies show that property prices have significant effect on lending while effect of credit shocks on equity prices show less significant effects.

The authors emphasise that the two most famous economic disasters and the resulting deflations - the 1929 Great Depression in US and 1990 crisis in Japan - have both been caused by their respective central banks trying to prick market bubbles. In the US it was the assets bubble and the real-estate one in Japan. These are just the most prominent

³⁵ the costs associated with the lenders assessing and monitoring performance of their borrowers

³⁶ They defined net-worth as difference between the sum of liquid and the collateral value of illiquid assets, less outstanding obligations.

examples of non-linear effects that interest rate shocks can have on asset prices.

2.3.2 Credit and Imperfect Information

According to Stiglitz and Weiss (1981), Stiglitz and Blinder (1983), due to imperfect information, banks ration credit by nearly-randomly rejecting loans to potentially good borrowers even in (or near) the economy's equilibrium. This is because the optimum return interest rate for banks may be too low to clear demand for loans but lending at a higher rate is likely to increase rate of default among otherwise good borrowers and decrease the banks' returns. In addition, in a credit-rationing situation, the reduced amount of loanable funds results in reduced economic activity, away from its optimal level.

Stiglitz and Greenwald (2003) then take further the ideas on the financial accelerator expressed by Bernanke et al. (1999) and in their opinion “... *general equilibrium credit linkages may be every bit as important in determining the behaviour of the economy as the linkage in goods and factor markets emphasised in traditional general equilibrium models*. However the general equilibrium credit linkages are only partially mediated through the price system (i.e. adjustments in interest rates).” (Ditto pp 140)

“ ... if there is a common belief that that the economy may well go into trouble, interest rates will be high, many firms will go bankrupt and the expectation may be self-fulfilling. “ (Ditto pp 143).

They then assert that corrective actions by central banks, such as changing interest rates and targeting inflation, may not be as effective as it is widely believed (and that sometimes they are only efficient due to the central banks' undue credibility, thus, leading the economy by the means of “placebo pills” and self-fulfilling prophecies).

In times of economic changes (e.g. a recession) risk averse retail and business banks may not drop their high-street interest rates in line with the central banks reductions.

They mainly fear adverse selection and moral hazard due to incomplete information. This thus causes a gap (a spread) to occur and dampens down the corrective effect of reduced base rates intended by government institutions and central banks.

A recession may be then deepened despite a reduction in the central bank's short-term rates. This is because the optimal, loan portfolio driven, interest rate that many risk-averse retail banks charge, may not change, at least, not proportionally. This occurs to reduce any probability of adverse selection of taking up bankruptcy prone borrowers.

They claim that complex networks of companies, both, borrowing and lending from each other, may absorb (i.e. "hedge") a small shock to the profits but not substantial (systemic) ones. Their position may be seen as rather prophetic in the view of the recent 2007 credit crunch crisis.

2.3.3 Money and Credit

According to Stiglitz and Greenwald (2003, pp295), although money and credit are closely related and created, for most of the time simultaneously, by banks, there are differences. Credit however can be created by non-bank channels too, and therefore, the interest rate monetary policy does not affect the credit supply at the same level as it does bank loans and money supply.

The level of credit offered to a potential borrower is a combined quantitative and qualitative assessment of the level of credit-worthiness³⁷ of that potential borrower. In fact, this is true, to an extent, of any economic agent who may even simultaneously act as a borrower, an investor and a lender. The resulting credit worthiness is usually a private, proprietary information set, based on a combination of standard and proprietary assessment methods and judgement of asymmetric and partial information. As such it is often specific to the assessment agency (usually the lending bank or a specialised

³⁷ Credit worthiness is related to the borrower's credit value and in turn related to, but different from, the financial Net-Worth as defined by Bernanke et al. 1999.

organisation), and may vary from agency to agency and itself tradable on the credit assessment markets.

For example, using a heterogeneous agent model, Beaudry and Lahiri (2009) argue that small variations in information across heterogeneous agents and, thus, a resulting (small) amount of asymmetric information, can create a high volatility in expectations of the investors and in the aggregate supply of risk capital available on the market influenced by investor sentiment and the pro-cyclical behaviour of the risk averse investors.

For the above reasons, S&G03 claim credit-worthiness is heterogeneous (and asymmetric) and an aggregate assessment can be misleading since the surplus of funds in one bank is not a substitute for the lack of funds in another, the client's usual lender. This is in part because a bank that has sufficient funds may not be accessible to a borrower for various reasons such as logistic access. Another reason is such a bank may not have sufficient credit information on the client and may either refuse the loan all together or charge too high interest rate. The higher interest rate resulting from both the increased risk premium and the increased agency costs.³⁸

Due to information and the resulting credit asymmetry, S&G03 claim that credit allocation is not Pareto efficient and its effects are highly non-linear - a bankruptcy resulting from increased interest rates cannot be undone by decreasing interest rates after the bankruptcy.

Whilst Stiglitz and Blinder (1983) argue that the credit (e.g. loan) rationing prevents demand clearing at the equilibrium interest rate, Bernanke and Blinder (1988) abandon both the perfect substitutability of money loans and bonds, and, also, the credit rationing, and focus on a simplified (idealised) model with the clearing of loan demand and supply at a certain (equilibrium) interest rate i :

³⁸ The agency cost is what Bernanke et al. (1999) perceive as one of the main mechanisms behind the financing positive feedback mechanism exacerbating business cycles they termed "financial accelerator"

$$L^d = L(\rho, i, y) = \lambda(\rho, i)D(1-\tau) = L^s \quad (2.3.3.1)$$

where ρ, i and y are loan and bond interest rates and output respectively, and $\lambda(\rho, i)$ the return on deposits D .

Kiyotaki and Moore (1997) build their model of the collateral asset value credit constrained agent based upon the earlier work of Bernanke and Gertler (1989) and Greenwald and Stiglitz. After applying a variant model of game-of-life where the predator (the credit-unconstrained) in an analogy plays versus the prey (i.e., the credit-constrained firm), they found that credit constraints in down-turns spirals down credit worth of firms and their collateral asset prices which, in turn further reduces their creditworthiness. They also found that the marginal productivity of a constrained firm is higher than that of unconstrained ones. This, on other hand, has an accelerating effect on output in business cycles when output of (and employment by) a constrained firm is more affected by asset value fluctuations in business cycles.

2.4 Asset market targeting

2.4.1 Background

Asset targeting has been raised as a potential alternative or as an additional control mechanism to inflation and growth targeting used since 1980s. The positions of Bernanke and Gertler (1999/2000) and Bernanke and Gertler (2001) (and, similarly also Lansing (2008) and Gwilym (2009)), is that asset targeting is not an optimal tool in stabilising an economy and favour of using asset price movements just as indicators of future inflation changes. This is however taken by the authors with one exception of bubble build-up when price fluctuations are driven by non-fundamental movements which can then have wider implications on economy (e.g. due to mere regulatory changes liberalising access to asset markets, or the so called “rational bubbles” due to imperfect rationality and herd behaviour of investors). Otherwise, as the main argument against asset targeting, they note that there is not much empirical support in spending

being directly affected by asset price fluctuations affecting the wealth of consumer.

In opposition are few: Cecchetti et al. (2000), Cecchetti (2006), DeGrauwe (2007) and Farmer (2009b), all claim that, in addition to inflation targeting, central banks should adhere to asset market targeting too. In particular, the Central Banks should target and control the rise of rational bubbles and misalignment between the market and the econometric, fundamental prices and aim to prevent the market crashes too. As the Great Depression of 1929, the recent 1997, 2002 and the most recent, 2007-2009 financial crises show, the asset market crashes can have very significant repercussions on the banking sector and on the overall economy by creating a recessionary push through the channels and the mechanisms discussed later in this text.

A similar stance was taken by Batini and Nelson (2000) in relation to foreign exchange rates and related assets. It appears that targeting exchange rates and related currency asset prices is of similar importance as those of bonds and interest rate assets for their wider importance and implications on the economy as whole. This is however not the case with individual equity related assets or even equity related indices.

Farmer (2009b) argues that wealth rather than the wage level is the determining factor for level of aggregate demand³⁹. He then develops further his argument that demand is the main determining factor in the levels of employment and so the central banks should target inflation through interest rates and target the (un-) employment levels through asset price index targeting.

As a follow-up to Keynes' emphasis on the importance of psychology in the functioning of asset markets, Farmer insists that asset values depend on, and are highly correlated to the levels of confidence. To target asset prices but avoid political issues of public ownership in private companies and the direct purchase of shares in companies, Farmer (2009b) suggests the creation of an asset index managed by private fund

³⁹ This may be the case more and more as a large community of (mainly US) households are increasingly also market asset holders whilst the wage share of income is in decline.

managers. Central banks would purchase units from these managers as the bank committee agreed and publicly announced its price - the purchase would be then funded by short-term debt issue (e.g. treasury bonds).⁴⁰

2.4.2. Discussion

Farmer's (2009b) above-discussed method of both, setting and then targeting asset market index is rather complicated and potentially costly to implement and maintain, requiring central banks to invest in the market. In addition, it is still to be determined if the increasing numbers of households are mainly shareholders or bondholders and how effective share asset-targeting may be in controlling unemployment, separately from controlling the interest rates. On another hand, it is also likely to be a form of “helicoptering the money” that will help mainly those who already hold the crisis depleted shares, to offload them at higher than current market prices to the index-fund managers in the first instance but, indirectly, to the central banks at the current or the future tax-payers’ expense. If however it may be profitable, e.g. buying at low and selling at high price as is the case with many of central banks current open market money operations aimed at controlling currency rates, than large commercial banks would probably do that themselves.

In addition, there is nothing to prevent the market reversing the prices (and the market confidence in the companies and banks) below the targets once the term of the offer expires, that is, unless central banks (CBs) keep and maintain their price promise continuously. On the other hand, if central banks control the index price level, it remains a question: what happens if the market price exceeds the bank’s target. That may create an arbitrage opportunity to buy from the CBs at their target rate and sell on the market at the higher rate. An alternative is for the CBs to sell at the higher market rate at a profit but cause a reduction of the market prices.

⁴⁰ There maybe no need to form a separate, new index fund but just to use one of the existing market indices such as Dow Jones or S&P500, and for the central banks to offer to buy that index at a set rate. However, the private index managers will gain extra powers and will require additional regulatory control imposed on them to minimise potential abuse of such increased power.

This will however not financially help the companies (and banks) directly other than by increasing their credibility. The traded shares are from the secondary market and do not bring value to the companies but only to the previous shareholders. It may also lead to the creation of a new asset market bubble that may burst once the CBs cannot maintain their offer at the over-the-market price if public borrowing costs (e.g. yields on treasury bonds) exceed the expected return on the fund index. In that case, maintaining the index at higher than market value could be rather costly and may come at a taxpayer expense.

Instead, this research will argue that asset prices are to be considered a part of the package of an extended price index and that they constitute an additional factor in overall inflation targeting. Thus, the Taylor rule may need to be extended with an additional factor, π_{am} , or a single, aggregated price inflation index should include the asset prices index too. In either case, it could be accounted for through a weighted combination of either the standard or a newly created asset price index mechanisms. Moreover, although asset prices do not directly reflect the cost of current living, they affect the real cost of saving and, thus, the future time living in their retirement. Any forward-looking agents seeking balanced spending in the future then must increase their current saving/spending ratio and so reduce their current purchasing power. In turn, it would be wrong to account for asset prices without a relation to changes in the cost of living components. This creates new dynamics for price index calculation.

In addition, asset prices are counter-cyclically affected by interest rate fluctuations – the rate rise will have a triple effect on the asset prices reduction:

1. the growth rate will be reduced and, with it, the average share price rise will have to be adjusted downwards too
2. the resulting increased discount rate will reduce the value of future dividends
3. the rate increase reduces cash borrowing as well as the amount of free cash liquidity, and, consequently, reduces demand for shares and so the price of those assets too.

Accounting for house prices in the weighted target inflation index will also prevent over-heated housing booms to occur on the margins of (incorrectly accounted) low inflation and the resulting low interest rates. On the other hand, the weighting proportion of different assets in the extended inflation index may vary selectively so that variances and values of some assets may be allowed to rise or, oppositely, their rise may be suppressed more than that of the other assets. This, in turn will create a very price flexible and variable component to of the standard CPI.

A moral and wider economic issue however rises from the RE hypothesis and the central bank's need and capability to forecast moves of the asset markets that may, in turn, affect the markets. Bernanke and Gertler (2001) argue that such interference may have dangerous effects on the market psychology. A similar argument applies however to any centralised control including the standard (CPI) inflation targeting. On the other hand, Bernanke and Gertler state there are some underlying benefits of bubbles being contained, in their role in increasing consumer's wealth and as a result increasing aggregate demand resulting from the increased value of the assets and the related levels of financial credit. An additional mechanism for central banks' control of the commercial banking sector and its overall exposure to risk in particular, as argued before, could be to impose pro-cyclically varied levels of economic capital of those banks.

Also there may be a few explanations for the inelasticity of consumption raised by Bernanke and Gertler (1999/2000): **lifestyle rigidity**⁴¹ (or habit) may not be affected and changed by the relatively insecure income from assets, and so consumption does not increase in response to rise in asset prices as the rise itself may be resulting from higher demand, this resulting from an increased saving through asset investment. The income wage/investment share has shifted in recent years towards the investment

⁴¹ This research identifies difference between habit and **what is this research introduces and refers to as lifestyle rigidity**. Though they sometimes may be used interchangeably, the latter is wider in its connotation and fits the economic theory better. Whilst habit implies an in-reflexive automatism (autopilot) in consumption behaviour, lifestyle rigidity assumes an active intentionality to utilise all means of maintaining lifestyle when it is threatened, such as seeking loan or other means of extra income if the primary become insufficient.

income but that presupposes higher savings and it is unlikely to maintain current lifestyle and lead to the same or similar levels of consumption as before.

2.5 Sovereign Debt Crisis and Default Risk Today

2.5.1 Solvency Criteria and Debt Targeting Rules

In the wake of the Great Depression, few European countries such as Britain and France defaulted on their debt, mainly to protect their domestic markets. In recent years, Argentina and Russia defaulted on their debt and a few other countries such as Mexico and Greece escaped such a measure with a combination of IMF intervention, external pressure and EU countries' solidarity support in the case of the latter. Manasse and Roubini (2005) define some basic criteria for sovereign solvency⁴².

In a (large) closed economy, government debt rise followed by small fiscal adjustments and tax smoothing, may be a suitable solution to tax revenue affecting shocks as found by several authors (e.g., Hawkesby and Wright (1997)). However, Bi (2010) finds a different situation in a RBC model of (small) open economies where governments are facing debt-to-GDP ratio rated interest risk premia on their debt and where a more rapid consumption tax adjustment is found to be optimal. On the other hand, Mitchel et al. (2006) argue that there is a point in level of debt when sovereign debt targeting fiscal rules - triggered corrective measures along three main fiscal instruments (Gov. spending, taxes and transfers) - cannot provide for the sustainability of the debt any more whilst Ferrero (2008) explores and finds advantages of flexible debt targeting rules.

⁴² "A sovereign is solvent, if the discounted value of future primary balances is greater or equal to the current net public debt stock. Likewise, a country is solvent, if the discounted value of future trade balances exceeds the current stock of net external debt... Willingness to pay depends on the relative costs of defaulting or continuing to service the debt. The main costs of defaulting are loss of access to international capital markets and the potential output and trade costs of default. Low output growth does not only affect the ability to pay but also the willingness to pay. When growth is low, being cut off from capital markets is less costly. A debt crisis can also occur if a country is illiquid rather than insolvent. Hence, liquidity measures, such as short-term debt over reserves or M2 over reserves, are included in many recent models of currency and financial crisis that stress the risk of a liquidity run." (Manasse and Roubini 2005)

Also, Bi (2010) and, Bi and Leeper (2010) analysed the Swedish model of consistent counter-cyclical fiscal activity and find that in estimating effects of sovereign debt it matters very much whether an economic model takes in fiscal policy exogenously, as most models do, or endogenously. Likewise, a credible government's commitment to it is a necessary precondition for a sustainable economy.

2.5.2 Discussion

All those authors concentrate on fiscal rules as methods for controlling sovereign debt. This work however believes that the sovereign debt control problem in RBC smoothing models is just one part of a larger picture of public debt and that it may be targeted by means of a Taylor type interest rate rule (or its extension) that will take into account the public debt/GDP term factor. Simply, increased combined public debt - a weighted household, corporate and government debt, each having a separate coefficient driven factor – over GDP will, in different proportions affect rate increases and drive borrowing down.

In addition to reducing household and corporate borrowing, higher interest rates are also likely to lead to a reduction in sovereign borrowing due to the higher costs of borrowing and reduced demand for bonds. Alternatively, the sovereign debt linked rate rise may be triggered by rules similar or same as those described by Bi (2010). Bi and Leeper (2010) also find that the endogeneity of debt-target driven taxation is a pre-requisite for equilibrium to exist.

NOTE: In relation to this is an endogenous government spending and unemployment targeting rule introduced later in this text, where this research work will explain and provide both an empirical analysis and model comparison for a different, novel, Taylor-like, endogenised, counter-cyclical fiscal spending policy rule within a DSGE model using unemployment as its control and target variable as in Perendia and Tsoukis (2012).

2.6 Elections and politico-economic cycles

2.6.1 Background

Alesina et al. (1992) find substantial evidence across developing and OECD countries that governments regularly pursue both monetary and fiscal expansions in election years whilst inflation jumps in post-electoral years as a result of those policies. Frenze (1999 and 2001) goes further and, on similar lines rejects the classic, benevolent, welfare-loss minimisation rational expectation monetary policy in favour of a more realistic and empirically observed rational-strategic one, a monetary policy that will take into account partisan manipulation of the budget both in the pre- and post-election periods as well as possible other political distortions.

Santiso (2013) analysed Latin American countries and states that the Investment Banks' recommendations changes around elections. This occurs mainly in the pre-election periods and they tend to downgrade markets even more if the new candidates are strong and not committed to preserving financial sustainability and the stability of the government budget, thus seeking a higher "democratic premium" on investments. The author then argues two fold, that emerging democratic countries that have governments separated from financial markets and without direct influence on the banking sector have more chance to reduce electoral volatility and maintain a stable financial market in times around and immediately post elections, whilst, at the same time, he concludes that the governments and their agencies such as central banks need to monitor financial market recommendations and pro-actively adjust their policies to avoid financial market turmoil in the pre and post-election periods.

On those lines, Breuss (2008) states that there are two schools of thought. One, where governments generate an "opportunistic" politico-economic cycle to facilitate their re-election, and the other, where so-called, "partisan" cycles are created with the aim to follow the party's own ideology. The two may, however, coincide but Breuss concludes that asynchronous elections in the Eurozone, which is economically lagging the more

synchronously elected US indicate that an asynchronous approach is not optimal. Only in such a synchronised model can common monetary policy be optimal and facilitate faster GDP growth and unemployment reduction.

2.6.2 Discussion

Whilst in countries such as the US, where elections take place on regular, four year periods and the policy manipulation may take place in regular periods too, in some other countries such as UK, the election time may be flexibly chosen (within limits), by the government so to match any more advantageous state of business cycle and the popularity swings. Consequently, whilst such beneficial situation may reduce need for altering the policies just ahead of election, any governments' pro-cyclical actions on behalf of the pre-election distortions is therefore in those countries likely to create an additional acceleration effects triggering a substantial volatility in their business cycles but more detailed analysis of this issue is beyond the scope of this research. It appears that it may also be expected that a synchronisation of European elections would result in higher swings of the joint, synchronised business cycles despite that the elections may bring disparate political outcomes in different states. There may be other, additional reasons why the European economy lags the US such as lack of labour mobility (e.g. due to language differences) or any common fiscal policy.

One could argue that, to achieve economic stability and avoid use of political cycles, in larger countries or markets, they should not run their regional elections at the same as those run for the central control (authority), and also, that the regional elections should not be run for all regions at the same time but spread across the cycle life-span and regional space.

However, a conclusion from the above discussion would be that macro-economic models assessing business cycles would need to have a model-mechanism that can accommodate and measure effect of the election cycles, e.g. as a form of long-term (regular or not) seasonality so that:

1. pure real business cycles can be filtered out and measured free of distortionary effects of the political ones,
2. better overall forecast can be made by modulating pure RBCs with political ones, and,
3. political distortions can be measured and possible socio-political or institutional controls and checks put in place to prevent them if so deemed prudential.

However, to achieve this statistical identification, substantially longer, probably 4-7 times longer time-series data-sets would need to be measured to be able to identify, measure and filter-out effect of usually 4-7 years long election cycles in modern democracies, especially in smaller and more isolated economies or where international or confederation-like market unions run their elections in an synchronised unison like what EU is considering putting in place as discussed above. In addition, usually applied detrending techniques such as HP filters, can be filtering out those effects, by them, as too slow to be included in the data set used for estimations. See also Farmer (2012) who is also raising the issue of detrending using Hodrick-Preston (HP), or any similar filters because they take long-term movements out of the resulting data and out of the economist's picture. One of these that he points out to the long-term correlation between wealth and unemployment he is focusing on in his paper, and refers to several other authors (e.g. Ludvigson) who raised similar concerns.

An outstanding question for research is, are political cycles very different from RBC or they constitute their integral part and was one of the success of independent central bank inflation targeting in controlling inflation and RBCs rooted in them taking control of monetary policy from the government and reducing its ability to impose them as well as RBCs.

3. Overview of Literature: Issues with DSGE Economic Modelling and their Computational Methodology

This section is a short survey of the background literature on DSGE modelling methodology and forecasting methods for macro-economic models used by many central banks and monetary policy research institutions. It also contains many of the recent critiques of (mainly DSGE) and the follow-up discussions on dynamic macro-economic modelling and estimation methods.

3.1 A Brief Introduction to DSGE Models Used in this Research

3.1.1. Introduction to the Methodology Used in Research

Dynamic Stochastic General Equilibrium (DSGE or SDGE) models were developed initially in 1980s and have been used ever since to associate shocks and the economic system's responses to these shocks. Initially used for analysis of the real business cycles (RBCs), they now combine RBC with several Keynesian elements, notably inflation and the essentials of price and wage stickiness.

The forecasting of rational agents' behaviour has become an integral part of forecasts of economic dynamics as a step in resolving the Lucas critique issues of dynamic changes in agents' forward looking rational expectations and in situations of incomplete information caused by either spatial or vertical segmentation and isolation ("island story"). This was paralleled by Lucas' "research programme" (Lucas 1975) aimed at the endogenisation of the agent's (rational) expectations and their pre-emptive reactions to monetary and policy shocks⁴³. The turning point in the history of the DSGE modelling was when Blanchard and Kahn (1980) provided the first general solution for a linear model under the rational expectations (RE) in the state space form during the 1980s to open path in addressing Lucas's critique using DSGE models. These models

⁴³ It is now questionable whether their expectations are truly rational in the sense of REH or they are actually adaptive rational expectations in sense of integration of AEH and REH -> AREH.

were augmented by introduction of Kalman filtering state space systems' methods within economics (Aoki 1987, Harvey 1989).

DSGE research has later shifted its focus towards issues of inflation targeting and measuring the effects of the potential disturbances (including those caused by the Governments' fiscal and Central Banks' monetary policies) and improving the economic system's resilience to such disturbances (see in Levine et al. (2006), Woodford 2003, and, Batini, Justiniano, Levine and Pearlman 2006). This work concentrates on such models and explains them in more detail.

The main computational and methodological toolkit, both used and particularly adapted for this research, has been Dynare software package⁴⁴ for solving, estimating and simulating DSGE models, developed initially in Matlab by M. Juillard and maintained by a team of developers at CEPREMAP (Adjemian et al. 2011). Dynare software also provided a starting model for the design and development of the new BoE's core DSGE modelling and estimation toolkit and the related COMPASS suite of models (Burgess et al. 2013). This new DSGE model, in the recent BoE move amid post-2007 crisis criticism, is planned to replace their Monetary Policy Committee's earlier, BoE's quarterly structural macroeconomic model (BEQM, Harrison et al. 2005) as an even better mid-term forecasting toolkit⁴⁵.

DSGE models used in this research implements a set of Taylor type inflation targeting rules in the monetary policy reaction equation and is closely based on the models developed and described in the work of Batini et al. (2005a and 2005b) but similar to those used in Smets and Wouters (2002), (2003) and (2007) (SW02, SW03 and SW07 henceforth).

⁴⁴ Dynare is free to use but it requires either Matlab, which is not free software kit, or the free Octave package which emulates Matlab environment and programming language syntax but which is rather slower than Matlab (<http://www.gnu.org/software/octave/download.html>).

⁴⁵ The BoE Quarterly Model (BEQM) replaced (or complemented) their earlier Medium Term Macro Model (MTMM) in 2005 whilst providing stronger theoretical grounds based on forward looking and limited, rather than infinite, lifetime agents.

3.1.2 Bayesian Estimation in DSGE Tools

For parameters estimation, modern DSGE methods enhance Kalman filtering based Bayesian VAR state space model with optimising, stochastic simulations and posterior density sampling algorithms to provide the optimised estimates of the values of the model parameters' posterior density distributions.

There are various methods that can be used for estimating DSGE models' posterior likelihoods such as General method of moments (GMM) (e.g. Clarida, Gali, and Gertler 1998), Method of Simulated Moments (MSM) or Maximum Likelihood Estimation (MLE) together with Kalman filter (Sargent, T. 1989). However, the most frequently used is the so-called strong interpretation (see Smets and Wouters 2002) - a combination of Bayesian inference, Markov-Chain Monte-Carlo (MCMC) stochastic simulation and MLE methods with Kalman filter (For further information see Appendices 1 and 3 or Geweke 1998). Most MCMC algorithms used for DSGE estimation, use either the Gibbs or Metropolis-Hastings algorithm for sampling the posterior distribution and evaluation of marginal likelihood of the estimation (Batini et al. (2005 a and b), Boivin and Giannoni 2005 and Levine et al. (2006).

It has been shown that DSGE estimates are generally superior to the VAR or BVAR methods' estimates (Smets and Wouters (2002) and (2003)). This is especially true for longer-term predictive estimation, and in data-rich conditions such as facto augmented VAR (FAVAR) and MCMCML conceptualised, defined and used in Bernanke and Boivin⁴⁶ (2003), Jacquier et al. (2004) and, Boivin and Giannoni (2005) (BG05) respectively.

Note: This research continues the previous work (Pearlman and Perendia 2006 and Perendia 2006) and, in its early stages, in Levine, Pearlman and Perendia (2007) and Perendia (2008)), it also enhanced the PCL86 DSGE methods by using the data rich

⁴⁶ For example, Bernanke & Boivin 2003 build upon the work of Stock & Watson (1999) who conclude that "the best-performing forecast for inflation is an augmented Phillips curve forecast that uses a new composite index of aggregate activity comprised of the 168 individual activity measures".

FAVAR-alike DSGE model implemented through another enhancement of the solution for the partial information rational expectation model for estimating and forecasting optimising micro-structure agents developed in PCL86.

3.2 Recent Developments in DSGE Modelling and Contributions

Since writing the most of the thesis, popularity and then following critiques of DSGE models produced a substantial number of works providing comprehensive introduction and overview of such models in detail so that a part of work initially provided here is now surpassed by those and hence replaced by a brief guide through those references.

Christiano, Lawrence, R. Motto, M. Rostagno (2014) provide an in-depth methodology of DSGE Bayesian econometrics whilst Caporale et al. (2016) provide a comprehensive overview of central banks macro modelling and policies.

Taylor (2016) provides a brief history of macroeconomic modelling while Wieland et al. (2016) provide both another view of the history of mainly DSGE models as well as of the methods for their comparison. Taylor (2016) elaborated that the early, historical, backward looking “path-space” analysis based models were paradigmatically superseded by “rule-space” models in mid-1970s after Lucas critique providing more stable monetary policies since 1980s to the more recent departures from those models from early 2000s bringing more instability, e.g. by Alan Greenspan -led low US Federal reserve policy rate held far below what (Taylor) rule would otherwise prescribe.

On the other hand, Kocherlakota (2016) criticizes strict adherence to Taylor type rules and argues that, alike in the 1930s when the US Federal Reserve prudishly followed the pre-crisis rules and frameworks and henceforth slowing down the Great Depression recovery, so was the case with the US Fed policy following too closely rules (e.g. such as Taylor type rules) based policy and slowing down recovery after the 2007/08 crisis. He therefore argues that a more discretionary policy of a central bank rather than one based on the laws of the rules would be more efficient and beneficial in times of crisis.

The author's argument is not new however and it just adds to a long standing discussion between discretion and transparent rule based policies for central banks (e.g. see Taylor 2016) but adds another argument that in time of crisis and policy rate already near zero, the FED should have pursued policy based on publicising forward guidance for its future plans but rather more aggressive ones than ones driven just by following the (close to-) normal state framework or one based on asset purchase pursued by the US FED.

Wieland et al. (2016) are providing a comprehensive presentation of the semi-automated model comparison method developed for the Macroeconomic Models Data Base (MMB) maintained by the team around Volker Wieland and also, a large set of comparative results obtained by application of its methodology based toolset on a large sample of the models in the database. For this research, it is important to highlight some of their findings. Comparing the impulse response functions (IRFs) to the monetary policy tightening shock on the NK models with financial accelerators (e.g. BGG99 and DG08 (De Graeve (2008))) and those without (e.g. SW07), Wieland et al. (2016) show that the responses are much more affected in the models with the accelerators which is what would be expected. They also find that the financial accelerator models with investment adjustment costs (e.g. DG08) responses of GDP decline are more hump-shaped and persistent, and thus closer to the real observations, than in models with capital adjustment costs (e.g. BGG99) indicating that entrepreneurs are more likely to adjust their mid-term future investments to the new conditions rather than the already installed, productive and past investments.

In addition, Lindé, Smets and Wouters (2016) provide a partial survey of macro-models focusing on central bank models and thus complement the work of Wieland et al. (2016).

3.3 Modelling Issues and Failures

“The 2008 economic crash led to remarkable shifts of opinion among world leaders. Does this crisis create favourable conditions for the reform and revitalisation of economics itself—from a subject dominated by mathematical techniques to a discipline more oriented to understanding real-world institutions and actors?”, Geoffrey M. Hodgson (2009)

In this section this work assesses the main issues with the variety of economic models amidst questions such as: Could economists have modelled the butterfly effect of the sub-prime crisis triggering the much larger, but closely related burst of the CDO market bubble, not envisaged by the FED models before they started increasing the policy rates⁴⁷? Will extending the Taylor rule with the private and Government public debt terms, or a separate bank-leverage targeting/control help?

Though this chapter focuses on bringing-up the DSGE specific issues, it as well brings those more general issues related to various types of economic models as long as they are also applicable to DSGE models.

3.3.1 Insufficiency of pure R.E. theory: Animal Spirits and Herd Behaviour

It was even in the aftermath of the Great Depression that a few authors (e.g. Keynes 1936), pointed out that one of the main causes for the crash was irrational panic, herding, and “Animal Spirit” instincts that greatly contributed to the market crash and its spread throughout the economy. Some other authors also pointed out the similar herding behaviour being observed in the wake of the 2007 crisis and blamed it for the acceleration of the crisis (Akerlof and. Shiller 2009). It is difficult to assess to which

⁴⁷ In a recent speech at the Thirteenth Annual International Banking Conference, on 23rd September 2010, P. Volcker said “he found it inconceivable that complex financial products were developed over the last few years without any updated oversight. He mentioned a subprime mortgage market exceeding \$1 trillion and \$60 trillion in credit default swaps.” Thus, the CDSs market exceeded 60 times the value of value of the sub-prime mortgages and contributed consequently more to the crisis than the sub-primes..

extent and whether the Animal (herd) spirit was a cause or just an accelerator for those crises. It is also likely that the crises may not have become crises and could have stayed minor recessions if there was no such herd behaviour widespread among the agents that was accelerating the downturn. I therefore dedicate a separate chapter to Analysis of Rationality and the Critiques of the Pure Rational Expectations theory, Animal spirits and herd behaviour (see further below).

3.3.2 Beyond the Single Representative Agent: Heterogeneous Agents Models

One of the main issues with the classic macro-economic models is that they assume that a single representative agent may be used to model macro-economic behaviour at the aggregate level.

3.3.2.1 A Brief Introduction to Heterogeneous Agents Models (HAMs):

Heterogeneous agents simulation models such as EURACE (der Hoog, et al. 2009) integrate and combine a variety of traditional micro and macro models and use Monte-Carlo simulation of economic agents segmented by various criteria such as geographic position and economic role whilst integrating a large variety of traditional micro and macro-economic models. The HAMs are departing from the representative rational agent models into an area of modelling and the behavioural aspects of a range of non-rational and rational expectations of aggregate groups (segments) of agents.

First examples of modern heterogeneous agent models date from the mid-1990s: Krusell and Smith (1998) analyse an equilibrium with boundedly rational agents whose forecasting converges with learning over time to a near-rational one. Whilst early algorithms relied mainly on pure simulation procedures, a variety of new algorithms based on perturbation around fixed point (e.g. static or dynamic steady state), or, global solution based on projection combined with simulation and either polynomials or splines of moments point are better suited to solving larger models (Algan et al. 2010).

For example, more recently, Lansing (2011) includes asset prices in a macro-economic model to address the equity-risk premium puzzle. He examines the effect of a concentration of assets in a small Ricardian-type subset of heterogeneous household agents on an increasing of the equity-risk premium that he finds to be related to the higher volatility of their consumption, itself dependant on asset returns significantly more than is the case with generalised representative agent's consumption.

The HA models' accuracy is usually measured through the R^2 or standard error of regression but more potent measures are suggested (Den Haan, Judd, Juillard 2010, Algan et al. 2010). Authors focus their models on different behavioural aspects and types of heterogeneous agents e.g.:

- The more and less (bounded) rational entrepreneur macro agents (e.g. see Levine, Pearlman Perendia and Yang 2009-2012). (An overview of the literature and an exploration of issues of rationality, rational inattention and bounded rationality will be given in more detail later in the text).
- Parallel "Ricardian" saving and "Keynesian" cash-strapped households (Batini et al. 2008 and Iacoviello 2005).
- Weighted averages of the expectations of the fundamentalists and the chartists' investment predictions (Westerhoff 2009 and Gwilym 2009).

3.3.2.2. Estimating Heterogeneous Agent Models

On the other hand, the main problems with the pure traditional HA simulation models (HAMs) is the estimation of the initial parameters from the historical data series (Hommes, 2005). However, as few recent papers prove (e.g. Haan and Ocaktan 2009, Batini et al. (2008), Curdia and Woodford (2009), De Negri et al. (2009), Furceri and Mourougane (2009) and Levine, Pearlman Perendia and Yang 2009-2012) DSGE and Kalman filters may be used for estimating and simulation of simpler HA models too.

Aiming to test and overcome the potential shortcomings of the single representative agent models and the issues with estimation of the HAM, Hommes (2009) applies a

Sorger-Hommes model of consistent expectation equilibrium for asset price market. He concludes that the models with two-type heterogeneous investor agents, one with a variety of sophisticated forecasting on one end, and a naïve expectation, $p_t = p_{t-1}$ on the other, generate negative autocorrelation on prices. Though they will converge to RE models of asset market prices in stable conditions, they will diverge into unstable, highly volatile systems in less stable conditions. The author also suggests that simple, naïve expectation agents may need to be replaced or complemented by a third type of adaptive expectation ones, which seems a direction worth pursuing in future research.

Few others (e.g. Kirman 2009 and Gabaix 2016) conclude that, due to the inherent complexity of markets, a model that includes the interactive dynamics of heterogeneous agents provides a better basis for the modelling of market aggregate behaviour than a model of single representative agent.

On similar lines, Gwilym (2009) and Westerhoff (2009) also points to the importance of the interaction of heterogeneous agents in forming of the asset market dynamic. The author analyses the volatility of exchange rate markets and its agents' heterogeneity. He identifies two types of traders: the fundamentalists as those who are bringing the stabilising, negative (the long-run converging) feedback effect that is opposed to the actions of the other group consisting of technical, chartist, traders who follow (whatever) the current trend is and bring the destabilising, positive feedback effect to the asset markets dynamics.

Note: A more detailed discussion of the heterogeneous agent models is provided later in the text.

3.3.3 Complexity in Economic Systems

A few other authors, such as Chen (2010), go a step further and argue for the use of heterogeneous agents models based on the evolutionary and stochastic, physical chaos-type models in economics.

Chen (2010) identifies two main strands of Real Business Cycle (RBC) theories; the exogenous shock driven cycles based on Frisch's work and endogenous ones based on Samuelson. He also sees two main versions of optimisation-equilibrium business cycles. Whilst the New Classical school lead by Lucas focuses on the effects of monetary shocks, he claims that the RBC mainly studies the effects of technological shocks as the main source of external shocks. Whilst Lucas uses many agents on isolated islands and models estimated using Log-Likelihood (LL), RBC uses representative agent on HP filtered data.

Chen claims that both models however omit to take into account the law of large numbers and central limit theorem states that a system with N independent uncorrelated elements has standard deviation in the order of $N^{-1/2}$ (pp 252). He then takes the stance of Classic economists and concludes that micro-fluctuations in large economies with a large number of agents N cannot result in macroeconomic fluctuations of such a large order as business cycles and micro-foundation models cannot explain the persistency of macroeconomic business cycles. (However, Chen is admitting that relative deviation of perfectly co-ordinated N events will be of same order as of its elements σ).

Chen then observes that a relative small deviation in the US real economy, compared to the financial economy, implies that the real economy is driven by monopolistically behaved large corporations⁴⁸. He states the fluctuations in the financial markets may be influencing the business cycles more than it would be possible for the real producer and labour market to influence the cycles together.

⁴⁸ I.e. driving the price fluctuations followed by the majority of smaller companies, the price-takers

Chen states that the representative agent-based RBC model has $N=1$ and behaves as a perfectly co-ordinated set of N agents. On the other hand, Lucas' many-agent model of overlapping generations behaves in similar fashion because it is solved as a representative agent model. He identifies three main potential sources of business cycles:

1. non-linear macro-economic dynamics,
2. structure and the interaction dynamics of financial and real economies
3. macro foundations of the micro-economy

In Chen's view, Muth (1961) and Lucas (1972) had opposing views of rationality, the former saw it as way to overcome price fluctuations through arbitrage, the latter as a way to amplify price fluctuation through enforcing common, simultaneous beliefs and their resulting behaviour (self-fulfilling prophecies).

It appears from Chen's discussion that the more agents believe in natural rate equilibrium, the more they can take an arbitrage opportunity over the minority of those driven by fluctuations and the more they then can take advantage of driving the economy towards the rationally expected "natural" equilibrium through self-fulfilling prophecy. However, the opposite is true too: the more agents believe in an incoming disequilibrium (or a new equilibrium target) the more it is likely to materialise and then arbitraging around the old equilibrium may show to be disadvantageous. Chen thus refers to rational expectation as a self-defeating prophecy.

Aoki and his colleagues argue on similar lines (Aoki 2005, Aoki 2006, Aoki and Yoshikawa 2008 and Aoki and Yoshikawa 2011) and claim that the representative agent based micro-foundational macro models such as the NK DSGE must be superseded by the stochastic physics based models of behaviour of random clusters of numerous heterogeneous agents, each following its own Markov-Chain distribution. Consequently the new stochastic models, with two-parameter Poisson-Dirichlet distribution of innovations are non-self-averaging and hence are not automatically converging to the

single steady state equilibrium but diverging to at least two and potentially to an infinite continuum of sunspot equilibria. He explains the ongoing problem with stagnation in the Japanese economy by the occurrence of uncertainty trap, a phenomenon that parallels liquidity trap and questions the matching model of the labour market derived by Mortensen and Pissarides (1994).

More precisely, whilst the most of the current macroeconomics theorists assume that processes are IID (independently and identically distributed), and hence result in self-averaging outcomes, the multiplicative variables and the likelihood of correlated shocks may result in exponential probability distributions leading to non-self-averaging systems. The earlier mentioned uncertainty trap pertains to the agent's uncertainty about the future benefits of some decision and it is measured by entropy, the Shannon (1948)'s relative information level measure of making the decision midst uncertainty.

Therefore, Aoki and Yoshikawa claim that it is not realistic to have a micro-foundation where all agents, regardless of their size and position face the same micro-founded shock, a position which could then be more aligned to Chen's earlier mentioned critique that shocks mainly have macro, not micro foundations.

3.3.3.1 Comments on Aoki and Chen

One may argue that such stochastic modelling of agent behaviour, based on stochastic physics, however omits to account for the endogeneity and mass (herd) behaviour of heterogeneous agents. In addition, they are trying to impose a model more akin to those that govern a more normative, the so-called efficient market based costing models used in the finance area.

On the other hand, the notion and the model of the uncertainty trap may be rewritten in a different, more economically inherent manner. The classical economist's view that the representative agent is a plausible base for modelling macroeconomic dynamics

because actions of one set of agents that is shifting economy off-its equilibrium in one direction is fully offset and neutralised by another, equally weighted and important set of agents acting on the opposite end of equilibrium, seems invalid and ungrounded. In the state of higher uncertainty and large number of agents, as raised by Aoki, economic systems will have a larger number of agents making decisions that are sub-optimal at an absolute level that is not offset by other agents acting sub-optimally but their common actions are additive, leading the whole economy to act further away from the optimal equilibrium, thus, acting in a higher order (level) disequilibria. In other words, the potential uncertainty trap Nash (the “2nd best”) equilibrium that the economy will operate-in during the times of high uncertainty will therefore be further away from the welfare maximising or the Pareto optimal one and it may not be self-averaging (converging) either.

To illustrate this, let us assume a multi-dimensional bell-shaped, concave hill-surface, which defines the possible limiting outcomes for the economy’s portfolio’s efficient frontier and the optimal equilibrium representing by its maximum point. However, instead of the economy’s states/movements being limited to the surface, let us assume that the surface only limits the efficient frontier and that its position can be anywhere within the volume that that surface delimits. If all agents are acting close to the maximising equilibrium the economy as a whole will be there (“close to the green hill-top”) too. If however many of them, in time of uncertainty act away from it, in their own sub-optimal positions with the high standard deviation from the optimal one, the economy as a whole will be in a state of lingering somewhere in the inner space below the efficient frontier boundary and below the best of the welfare maximising optimum Nash equilibria (“meandering buried within the caves and the mines below the green hill-top”).

3.3.3.2 Spatial and Hierarchical DSGE

Despite EU unification, its countries retain substantial economic and geographic differences. Such heterogeneous, complex organisation is suitable for the application of

geographic and spatial economic analysis methods such as those suggested by Krugman (1997/2002), and Krugman et al. (2001) and for their integration into DSGE the macro-modelling suite.

An adoption and integration of the hierarchical state-space models (Aoki 1996, pp 29-40) or its derivative seems also suitable for the above data-rich models and spatially oriented estimation. Its application is well suited to projects aimed at modelling economic space or markets segmentations such as models in deWalque, Smets and Wouters (2005).

3.3.4 Dynamic Economic Pricing

One of the most common product pricing approaches in NK DSGE modelling is to use Cournot's equilibrium pricing based price convergence towards the marginal cost due to diminishing margins with the number of participating competitive firms within a monopolistic competition framework. This equilibrium is, however, dependent on the economy operating within a non-increasing (e.g. constant or even diminishing) return to scale technology environment and within an increasingly competitive, large market with many participants (see e.g. Vives (2001), pp110). However, this equilibrium fails if the economy is either monopolistic, oligarchic and either small or operating within increasing returns to scale technology, all of what is nowadays widely accepted within the new international trade economics paradigm.

In uncertain demand conditions, the pricing of any durable but even more so, of those non-durable, perishable, non-renewable, non-transportable or time limited goods (e.g. food produce and services including transport or event tickets) has been made dynamic to follow so called "economic" dynamic pricing approaches such as revenue management or yield management. These are based on computational automation and electronic points of sale such as internet (Bitran and Caldentey 2003 and Courty 2003).

The new technologies such as internet allow for more dynamic price changes. It is,

however also worth investigating further and possibly confirming whether if technological developments and related practices in recent years, such as internet shopping, market monitoring and electronic pricing, has led to substantially lower price rigidities and consequently the lower Calvo type probability of keeping prices in a (quarter) period fixed, i.e. a measure of price rigidity, ξ_p , identified in this research.

The introduction of electronic sales mechanisms such as internet sales means that prices may be adjusted not only once within a year quarter but automatically, possibly even as frequently as several times within each trading day (which may also last 24 hours). This means that the Calvo index of price rigidity has gone through a substantial structural change in the last ten years since online and dynamic pricing started to be introduced. However, whilst reducing price stickiness, those technological advances and dynamic pricing methods are likely to introduce an increased level of volatility and complexity in price levels as well as in the market values of companies' shares.

3.3.5 Modelling Methodology Issues: Determinacy and Sunspots

3.3.5.1 Demand Constrained Equilibria

In a series of preceding articles and in his latest book, Roger A. E Farmer claims that Keynesian animal spirits and self-fulfilling prophecies can lead to numerous inefficient equilibria with different, market confidence dependent, ("natural") levels of employment (Benhabib and Farmer 1999, Bennett and Farmer 2000 and, Farmer 2009a and 2010). He is criticising the would-be-saviour attitude among the world politicians rushing to implement Keynesian strategies in the 2007 Great Recession affected countries. However, politicians can only use what is available, and, in independent central bank regimes, they are restricted to the fiscal intervention tools only.

Farmer (2009a) distinguishes between rational classic economy investors who value shares on basis of fundamentals and dividend returns and the Keynesian economy investors who trade on asymmetric information and hope that in future shares will be

valued by other investors higher or lower than their current price are:

“When households remain pessimistic for a long period of time, they undervalue the stock market. If this pessimism persists, it will cause some households to reduce their purchases of consumption goods. ... Firms will be unable to sell all of the goods they produce and will lay off workers. Dividends, profits and investment will all fall and the initial pessimistic view of the future will become self-fulfilling.”(ibid.)

Farmer (2009a) then introduces Demand Constrained Equilibria as an alternative to RBC theory and claims that there is one such equilibrium for each state of long-term expectations, each related to the self-fulfilling prophecies of different relevant confidence levels (“Animal Spirits”). Following upon their earlier work in Benhabib and Farmer (1999), Farmer, Khramov and Giovanni (2015) provide a different solution to a standard DSGE model which also points to existence of multiple, so called to sun-spot equilibria in a NK model but without significantly large modifications to a standard (Dynare) DSGE package and without use of asymmetric imperfect information as used in Lubik, Matthes and Mertens (2016, see par. 5.8) and shows equivalence of his solution with one of their earlier works on the same subject.

3.3.5.2 Financial Equilibrium

Farmer and Geanakoplos (2008) develop a model of an alternative, financial equilibrium as opposed to general one. They state that only economic models in which at least some agents act in rational manner are the equilibrium model candidates. In Arrow and Debreu’s general equilibrium, the allocation is Pareto efficient. The financial market equilibrium is also Pareto efficient if the market is complete and has payable securities for all of its possible states. However, *“When markets are incomplete, a benevolent and wise dictator can almost always make everyone better off simply by taxing and subsidizing the existing security trades “* (ibid, pp14). Because

allocation efficiency in modern financial economies cannot be shown to be sustainable, economists adopted informational efficiency as a measure of an efficient financial market where prices are expected to be martingales leaving no player with a sustained informational advantage. Because it does not rely on agent's utility function, which is difficult to estimate, the authors claim that such an arbitrage (free) efficient state of economy is a better-fixed point for financial economy than a (general) equilibrium.

In an early analysis of the incoming recession of 2007 (in the first version of the article) the authors pointed that rational expectations based on fear of future defaults and foreclosures was likely to drive the banks to seek larger deposits and so to drive the existing sub-prime borrowers out of the re-mortgage market for new loans. In turn, this was, causing further defaults and further drop in the housing prices and thus foreclosures, concluding that equilibrium models do not stand the scrutiny of historical and psychological facts and recommend alternative, dis-equilibrium based models of the economy based on natural models such as gas-physics, biological or genetic ones.

The authors however, do not seem to take into account that those natural models do not suffer from (and hence do not model adequately) the non-linear effects of rational expectations which may be providing positive feedback towards extreme non-linear fluctuations rather than driving the economy by means of a stabilising, negative feedback. Nevertheless, their observation is still valid considering that a non-linear dynamic of agent's psychology based in rational expectations may create much larger fluctuations than that assumed by any of the commonly used economic models including the recent DSGE ones.

3.4 Credit Issues and 2007-08 Crisis

In this section, we revisit and discuss credit-modelling issues from perspective of recent developments and 2007/8 crisis.

As pointed earlier, in his well-known PhD thesis and the related publications, Bernanke

(1983) and (1995), the author explains causes of the Great depression as the loss of confidence in the banking system and debtor insolvency (in part caused by the doubling of debt service cost/GDP ratio from 1929 to 1933). Bernanke sees roots of the Great Depression's prolonged effect in increased (agency) costs of financial intermediation in the post-crash economy, in contractionary policy that triggered it, and in negative credit supply shock effected through increased interest rates. This is, he claims, in line with the monetarist views of Freedman and Schwartz that banking difficulties created a money shortage leading to an aggregate output downturn and caused the financial crash.

In addition, the milestone joint paper, Bernanke and Gertler (1989) introduced the notion of a financial accelerator as a non-linear, pro-cyclical market fluctuation in response to, and accelerating the effects of the fluctuations in corporate borrowers' net-worth and the lender's agency cost channel due to asymmetric information. However, their financial accelerator model is not sufficient to explain and capture the non-linear dynamics in highly indebted markets affected by credit rationing and the recessionary debt accelerators, a novel type of accelerator introduced and explained later in this research work⁴⁹.

BGG (1999) however pay little attention to models of households' debt and the effects of the financial accelerator on consumption of any long-term loan or mortgage constrained households or businesses midst increased interest rate conditions. Their model of consumption therefore may not fully reflect the effect of the financial accelerator since in their model the accelerator affect was applied only to entrepreneurs and not households.

In addition, most macroeconomic models consider only the borrowings of entrepreneurs and exclude households (e.g. financial accelerator of BGG (1996)) and, for simplicity, assume one-period loans only. They assume that a high interest rate only

⁴⁹ As also mentioned earlier, it may be however that the effect of B&G financial accelerator is over-estimated as the other accelerators are not being modelled and their effects estimated.

deters from further borrowing. They do not consider the effect of the interest rate increase in conjunction with longer term loans, taken by either entrepreneurs or households locked in illiquid assets (e.g. real estate) that cannot be easily liquidated and how this will become an additional burden on operational or house-expenditure cashflow (as similarly raised by e.g. Cecchetti et al. (2000) and Cecchetti (2006)). This is an additional loan rate rise triggered financial accelerator (decelerator) which this research work introduces and refers to as the recessionary debt accelerator (see later explanation and relation to Fisher's debt deflator).

This effect on firms holding longer-term loans has been reflected upon in the earlier version of their paper BGG(1996) Also, most of household models assume bond holdings but not loan holdings, assuming possibly that loan holdings can be modelled by negative bond holding but interest rates on loans tend to be higher and differ even more from the deposit or bond rates in recessions accelerating interest rate effect on the household consumption even more.

The BGG's financial accelerator functional model is based on increased agency costs in recessions, despite author's attempt to give it power to explain many of the non-linear cyclical fluctuations⁵⁰. Its functional explanation is also a restricted simplification in comparison to the wider notion of credit rationing models by Greenfield and Stiglitz:

Hence, the model simplifications made by BGG are that employment is fixed and that the household is infinitely living and it uses only one-term loans. The model is, therefore, unaffected by the effect of long term, (overhung) loans that trigger debt-accelerator and recessionary trend in conditions of interest rate increase. They hence wrongly assume that the inflation targeting driven increase of interest rates exceeding inflation will simply reduce the demand for (new) loans but they omit to take into account effect of the existing, long-term loans on consumption.

⁵⁰As noted earlier, effect and importance of BGG's financial accelerator may be overestimated and overly generalised because it may aggregate effects of other accelerators, such as debt-accelerator, not being modelled or their effects estimated separately.

3.4.1 Housing Prices and Borrowing Constraints

Whilst Stiglitz and Greenwald (2003) explore in detail effects of credit rationing on businesses, Jilek and Matousek (2010), pp 204-207, complement their work with a comprehensive overview of the effects of interest rate increases on the monetary policy credit channel, modern credit and money creation channel within the banks and the budget constraints of mortgage indebted households (for effects of banks as money creators, see also Jakab and Kumhof 2015).

De la Dehesa (2010) points to twelve main systems' failures leading to the recent financial crisis and the regulatory failures among them. The author also criticises central banks for using DSGE models that do not consider housing and financial asset price bubbles, or unemployment, whilst wrongly assuming market efficiency and agents' full rationality. That observation however applies equally to a range of older, structural models used by central bank. For example, although the Bank of England's MPC structural Quarterly model (Harrison et al. (2005)) considers the **inflation of mortgage interest payments** (eq. B.47) as a proxy and as a weighted component of RPI index and housing rent as a weighted component of CPI, the mortgage levels versus total GDP are not considered. Whilst the model with mortgage and housing rental prices included in inflation indices handles well the influence of inflation on future housing moves and decisions, the problem is that it does not handle well, if at all, the rigidity fixed spending for the already existing mortgages and long-term rentals, the credit card and other bank loans. Those will persist at least for a while after falls, affecting the indebted household's other consumption disproportionately. Even worse, households with negative mortgage equity may not be able to part with their increased obligations for much longer, facing, and sometimes even entertaining, bankruptcy option as the only ones remaining.

The roots of the problem are:

1. there is no model for financial intermediaries such as banks in the model,
2. the model uses a single representative agent's household which has various,

including government and corporate debt assets but, consequently to (a), no household bank loans or mortgage debts figure in the model. Only the government and corporate debt explicitly figure in the model:

“Financial intermediaries are not modelled explicitly in BEQM, so households are assumed to hold financial assets directly, including those which in practice are held on their behalf by pension funds and other financial companies. We also use a narrow definition of money, so households’ holdings of deposits with monetary financial institutions and household sector debt are not separately identified.” (ibid, pg. 95)

However, the illiquid pension fund savings, consisting of government and corporate bonds in reality could not be disposed of in exchange for liquid funds by households when needed. Consequently, the effect of changes in the bank interest rate (e.g. its increase) on indebted household’s consumption and its consequent effect on aggregate consumption could not have been forecasted by the model properly.

Iacoviello (2005) is one of the first authors to extend the complete BGG financial friction macro-economic DSGE models with a model of the pro-cyclical effects of housing prices and overhung loans on households’ credit and resulting consumption. He is using three heterogeneous categories of consumers, two of which are two types of households: the savings (i.e. patient) ones and the non-savings, impatient ones whose future discounting factor β^i is much larger than that of the patient ones β^s and who tend to borrow money to conduct spending ($\beta^i > r > \beta^s$). The latter face a borrowing constraint, which is a function of the collateralizable fraction of the expected value of their housing investment. However, the impatient group generally includes the cash-constrained households that are not in a position to save and tend to spend their income. Housing boom and rising price periods then allow liquidity constrained households to increase their consumption beyond their usual income constraints using their house as collateral for consumption loans. The simulated model shows that there is a consumption increase following a housing price shock but likewise a substantial reduction in consumption as a result of an interest rate rise.

Iacoviello (2005) also introduces and augments his model with another type of accelerator – a demand shock driven effect of asset and interest rate rises allowing for higher collateralised loans and even more demand (and the opposite, supply shock “decelerator”). This demand shock accelerator is however different from and is eventually dampened by the recessionary “debt accelerator” (decelerator) introduced and explained in this research. This shock results from a rise in loan interest rates in an already highly indebted economy (see earlier explanation).

Similar to Levine et al. (2008-2012), only one, the former group, is the only group that follows the rational consumption model (in log-linearised form):

$$\log C_{1,t} = \log C_{1,t+1} - r_t \quad (3.4.1.1)$$

However, similar to the findings of Bernanke and Gertler (2001), Iacoviello also shows that there is no significant benefit in adding housing asset prices to the monetary policy Taylor type rule for the stabilisation of output.

Note: Later in the text this research work will return to Iacoviello’s model to reproduce some of original IRF simulations and analyse his work in more detail.

The importance of targeting, or at least considering, housing assets in macroeconomic models has been emphasised by Cecchetti (2006). He points out that policymakers must distinguish between equity and housing assets for several reasons; the efficient markets hypothesis may not be as applicable to housing as to equity markets; that housing represents assets in the hands of a wider population than equity assets, which are restricted to high income recipients only and finally housing has much more leveraged so its value fluctuations may be potentially affecting economy as whole.

Philippon and Midrigan (2011) use a cash in advance (CIA) model to show how a decline in house equity borrowing contributed to the acceleration of the recent recession and explain regional correlation between the housing debt leverage and the

unemployment.

Figure 3.4.1.1 Reproduced from Philipon and Midrigan (2011) showing regional (i.e. individual US states) correlation between the housing debt leverage and the unemployment increase in those regions (US states).



Cobham (2012) provides an overview of the literature on the relation of central banks and house prices in the run-up to the crisis. He argues, in conclusion, they neglected the issue of house asset prices and that they should have used an additional mechanism to target those assets. He, however, does not provide an analytical model or any proof of the beneficial effect of such policy.

3.5 Responses to the recent criticisms of DSGE

“A modern economy is not globally stable. Theories that assume that the economy is a stable general equilibrium system, albeit beset with some frictions and imperfections, do not hold true in general. The instabilities that such theories ignore are precisely those problems that should be the particular responsibility of macroeconomists.”, from Leijonhufvud (2009)

On the other side of the camp, Hendry and Mizon (2014), and Hendry, (2016) strongly criticize DSGE models and outline fundamental econometric arguments to explain why they inevitably fail in time of crises such as 2007/8. The main cause they find is that the models fail when distribution shifts in context of regime change (also in Muellbauer

(2016)). However, Dynare DSGE package already has Markov regime switching mechanisms incorporated and the recent work by Maih (2015) even further improves efficiency of the perturbation methods for solving regime-switching (and distribution changing) DSGE models and their ability to fit the major structural changes.

Muellbauer (2016) (and Duca and Muellbauer (2013)) parallels some of the already discussed criticisms of DSGE models, particularly that of its inability to cope with regime switching or their use of single, rational representative agent. Another aspect the author is focusing the criticisms is the REPIH (or Rational Expected Permanent Income hypothesis) assumed by very frequently used Euler equation of consumption and that it, or its augmented versions, do not reflect the real life empirical findings. This is specially the case with the cash-constrained or heavily indebted households that may face liquidity and bank-credit shortage problems once their main collateral asset, their real estate, depletes in value. His additional comments that NK-DSGE do not have debt, credit, money or liquidity constraints are also along the lines of this and other related and referred research that has already shown great importance of those issues in analysis of the 2007/8 crises and has been partially addressed by other authors (e.g. Iacoviello and Neri (2010)). The author then suggests an extension of the usual Euler based consumption equation in DSSGE by adding missing values: “*an indicator of income uncertainty, ... liquid assets minus debt,illiquid financial assets and gross housing wealth.*” as well as four time-varying parameters derived as functions of credit conditions: the secured housing liquidity index (HLI) and the unsecured credit condition index (CCI). This extension represents a remarkable improvement in modelling of unsecured credit and housing collateral driven consumption rise between 1990s and 2005.

3.5.1 Responses to Romer Critique

Another, more recent critique in Paul Romer (2016) lecture and the follow-up article which are sharply criticising economic models, particularly DSGE and those which ignore simple facts that a monetary tightening can cause recession and shows that on example of two recessions triggered in early 1980s and I shall refer to this henceforth as “Romer critique”. Whilst this research agrees and also argues that such monetary tightening can cause crisis and shows that for the case of 2007-8, I also agree that he quite rightly states that too many observations have been left out of the DSGE models, (which is what this research also argues in case of household debt and its effect on liquidity of the households midst the US Fed rate rise leading to 2007 crisis), or that the effect of the real policy rate rise has been side-lined even by the New Keynesian authors such as Smets and Wouters (e.g. in their 2007 paper,). Whilst that sidelining of effects of monetary tightening is also something this research already points to, it however appears that Romer misses some of the points, namely the point of the Smets and Wouters (2007) model. For example, he states that there are only 7 variable and equations. - there are in fact 14 endogenous variables and equations but only seven are observed whilst the other seven are unobserved (and, in addition, there are seven shocks).

Nevertheless, Romer raises other important questions in relation to DSGE models such as role of (un-observed) technology shocks as well as other shocks, which have been brought-in in numerical identification role rather than being realistic and measurable shocks.⁵¹

Another recent article, that of Olivier Blanchard (2016) on DSGE modelling is less confrontational and more compromising, and so, more similar to the approach of this research. E.g. whilst criticising some aspects of DSGE, he is also stating that they have future after a number of adjustments and a better integration into the rest of the economic theory and modelling. His argument that the models should be based more on

⁵¹Romer mentions reading Dynare user guide but does not quote it as a literature reference.

realistic consumer behaviour has partially been already addressed by the extensions to DSGE modelling pursued throughout this research, e.g. as part of heterogeneous adaptive and rational agents in Levine, Pearlman, Perendia and Yang (2009-2012), saving (patient) and borrowing (in-patient) agents in Iacoviello (2005) and Iacoviello & Neri (2010), borrowing and saving in Curdia and Woodford (2009), Furceri and Mourougane (2009), De Negri et al. (2009), multi-country-agent - Hann, Judd and Juillard (2010) and others. His final conclusion does not seem to be new either: his suggestion that DSGE models should be used in conjunction, as complements rather than as substitute to their models, as already stated and identified in this research work, has been already a practice commonly used in larger central bank institutions (e.g. BoE).

Taylor (2016) claims that there was probably a new form of accelerator acting during 2007-2007 crisis and refers to Christiano, Motto and Rostagno (2014) (CMR14) work on “Risk Shocks where authors introduce risk shock accelerator akin to the agency cost accelerator defined in Bernanke, Gertler and Gilchrist (1999, BGG) where idiosyncratic capital investment uncertainties are referred to as risks whose fluctuations coincide with real business cycles and rising shocks coincide with recessions. They keep referring to that measure as uncertainty though the theory of risk and uncertainty strictly distinguishes risk as measurable and estimable whilst uncertainty as unmeasurable one, and, to be consistent, this capital investment risk referred to as uncertainty remains unobservable in their model. I would agree that this effect can be an additional bi-directional financial accelerator, either into, or out of, a recession.

Whilst it would primarily influence economy through its effects on investment decisions, and consequently but secondarily, through increased (reduced) required risk premium and agent monitoring costs, and, reduced (increased) value of base collateral assets (along the lines of BGG financial accelerator), the risk shocks do not come on their own right but as symptoms or results of observations of news of major exogenous or endogenous movements. Also, risk shock is not so mechanically binding and restricting as e.g. a liquidity constraint imposed by a shock of an increased (or

decreased) cost of both, existing and new borrowings and the resulting consumption liquidity constraints. However, once an uncertainty is increased by, e.g. increased cost of the borrowings and liquidity shortage, this uncertainty/risk accelerator brought in by CMR14 can act as an additional accelerator working through the investment side of the economy.

Though the authors claim that the risk shocks are a major driving factor for real business cycles, they admit that risk shock model cannot explain initial phase of the 2007 recession but only its later development after the crash news:

“ The initial phase of that [2007} recession seems to have been driven by factors other than the risk shock. However, according to the results the accelerated collapse in economic activity that occurred in late 2008 was largely due to an increase in risk at that time “ (ibid)

Their comment is very much in line with the outcome of analysis of the causes of the 2007 crisis developed and outlined as part of this research that the crisis started as endogenous liquidity shortage and recessionary trend that triggered the financial crash and the world market contagion.

One explanation and a possible factor in the failure of the economic models to predict the 2007 crisis are likely to be the relatively slow growths of both, household debt and house prices. The most of central bank economic models, here including DSGE, utilise de-trended data and focus on relatively short to mid-term, one to four quarter deviations from equilibrium whilst the relatively stable and slow growth trends of both, household debt did not contribute significant information to those models due to their low frequency of changes and variations and their relatively long trend. Such trends may have been ignored by the detrending models for that very reason too (see also Farmer (2012) who is raising the issue of detrending using HP or any similar filters because they take long-term movements out of the resulting data and out of the economist's picture though on a different issue). The issue of detrended data sets as well as that of the estimated models which are then “myopic” for longer trend cycles such as political

cycles (as raised in that section of this research), or rise of private or sovereign debt, house prices, or slow but steady reduction of real wages, each spread over longer period or any other longer business cycles. However, according to Brayton, Davis and Tulip (2000), in the US FED macro model, based on a different methodology, that of Polynomial Adjustment Costs, the trends are also estimated and forecasted and hence, the trends of those slow moving variables, if included, would have been also deemed significant.

Analysis of the Great Recession crisis outlined in this research however concludes that some key factors for its potential modelling are missing in their, still closed country model: private household debt, model of banks in their effectively new role in creation and destruction of credit and money rather than acting just as pure intermediaries (see e.g. Jakab and Kumhof.(2015)) , or in channelling money in and out of the country for foreign investment. Some other factors and indicators potentially contributing to a model of real economy in a such crisis but missing in their model would be bankruptcies of both, large and those numerous small companies or households as a major sources of economic frictions (and “sinks” of monetary value).

“Yet [NK] micro-founded models, the only models deemed acceptable in top journals for both theoretical and empirical analysis, are normally rather selective about the data they focus on. Both micro and macro evidence is either ignored because it is inconvenient, or put on a to do list for further research. This is an inevitable result of making internal consistency an admissibility criteria for publishable work.” (Simon Wren-Lewis (2016) in his comments on Paul Romer (2016) criticism of macroeconomics , pub. on e-axes)

In a summary, the most of academic models failed to see crisis coming or to model its long term effects mainly for two reasons: they tend to be smaller in size and number of variables and observables being taken into account and thus, suffering from a form of boundedly rational inattention, that is, rationally ignoring available information due to

extensive costs (in time, money and intellectual resources) needed to include and process them too or, due to under-estimating of their value and importance. Another part-reason of this under-estimation of their importance and their consequent ignorance may be that such information is not perceived or even measured as beneficial, or assessed as significant, in normal times of economy close to some ideal equilibrium, therefore, researchers optimising their work around more parsimonious models.

Such parsimony is particularly prevalent in DSGE models which, among the rest, require as many exogenous shocks as observables, thus, complicating dimensionality and estimation of DSGE models as well as explanatory value of, and for, the large number of different, uncorrelated shocks needed. It may be then in turn raising their not-completely-undeserved criticism for being “out of touch with reality” including those by some prominent economists (e.g. see Romer (2016)).

One may argue that such models cannot be considered rational expectation models as they do not utilise all relevant information available at time $t-1$ and thus have incomplete information not only about the shocks but also about the relevant variables. Usual explanation that that models already assume that the agents modelled do have all information but the modelling econometricians do not. Such systemic explanation may

Another issue with the most of New-Keynesian (NK) micro-founded models, frequently used in DSGE models is that the role of government and its spending is most of the time sporadic, modelled as an external, almost accidental shock, hence, another useful source of unexpected and uncorrelated shocks needed to balance-off the observables in DSGE models, and thus, not at all endogenised. Thus, role of such spending is not sufficient to model a government intervening in a counter-cyclical manner and possibly accelerating regressed economy, and thus, acting in a Keynesian manner. In the course of this research, an augmented endogenised government spending DSGE model with the spending rule driven by increase in unemployment and news-shocks in addition to the “standard” NK features is also analysed and its advantages presented.

Benchimol and Fourcans (2016) compare nine variations of monetary policy rules applied as variations to Smets and Wouters (2007) model and conclude that instead inflation and real growth gap based rules, ones based on Nominal GDP (NGDP) growth perform better but that economic stability pursued by the central bank (US Fed) policy loss function does not necessarily translate in higher well-being for households.

3.5.2 Discussion: Was the crisis of 2007 caused by failure of DSGE models?

Whilst numerous authors see the recent crisis as a complete failure of modern, Neo-Keynesian economics and the DSGE methodology (e.g. Gordon (2009)), this research argues that the causes lie elsewhere.

Firstly, most of the central banks do not rely only on the NK DSGE models but use a weighted sum of results of a set of small and large systems of equations, VAR and only some of them, in conjunction with these other models, also use DSGE models. Therefore, it may have been the effect of the more standard or traditional methods on the weighted sum and decision that led to the failure and it is after the 2008 crash that some of the main central banks decided to increase their reliance on DSGE models instead (e.g. the Bank of England's (BoE) decision to develop a large DSGE model COMPASS - Burgess et al.(2013))⁵²).

Secondly, more general and complete DSGE models may have been more adequate to prevent the recent crisis. For example, there have been numerous discussions for a long time whether oil, energy and house/ Real Estate prices should be included in the index used for inflation targeting. If housing and possibly some other asset or commodity prices were included as a part of the inflation target package, it is possible that the target rates would have been increased earlier, thus, preventing (or reducing) the

⁵² The Bank of England's forecasting platform: COMPASS, MAPS, EASE and the suite of models

housing market bubble so that its bursting would have had milder consequences. However, the overall growth experienced in 2003-2007 may have been then disadvantaged by the resulting lower levels of borrowing and lending by many economic agents (including the governments themselves).

Also, there may have been a model misspecification by the central banks who have been assuming rational expectations (RE) were the main driving factor for behaviour of the agents rather than some of the other, less rational motivations, for example, households may be more driven by, what is this research refers to as **lifestyle rigidity** (though more often referred to as **habit**). A research should then test if a balance between the lifestyle rigidity (habit) and some sort of adaptive adjustment behaviour is better in describing household behaviour than the rational expectations. Along those lines, one should assume also that the consumer sales oriented firms themselves form their (partially) adaptive behaviour and inflation expectation on basis of so expected consumer behaviour as has been, for example, shown by Levine, Pearlman, Perendia and Yang (2009-2012, explained in more detail later in this work).

There is however an additional factor to be considered. DSGE and other economic models which are estimated and calibrated on long term data series assume a near linear inverse relation between interest rates and consumption, which is affected by a habit, lifestyle rigidity factor. . However, the sudden rise in interest rates did not only reduce commercial borrowing , employability and consumption by detracting from borrowing. It further reduced both the spending power of households with existing loans due to increased interest payable and hence the demand for goods, thus accelerating unemployment.

Whilst many authors (e.g. Brender and Pisani (2010), p.164) blame the indecisive policy of the US FRB after its restructuring and change of Chairman in 2005 and the slow reduction of base rate in the wake of 2007 crisis, this work argues that the relatively sharp and high rise in the base rate in the 2004-2006 period towards long term rate was the main trigger for the bubble bursting and the 2007 dual economic and

financial crisis through two main channels:

1. the resulting sudden reduction in the purchasing power of an average household with mortgage obligations leading towards economic recession, and,
2. a simultaneous, significant burst of sub-prime (and, to a smaller extent, prime) mortgage defaults resulting from rise in unemployment and housing assets deflation, both in turn resulting from the recessionary trend in (a). (this is elaborated in more detail later in this work and in Perendia (2015)).

It therefore appears that:

1. a too-loose Fed rate policy under Greenspan (and that of Bank of England (BoE) in 2001-2004 led to the creation of the combined market asset price and mortgage bubbles⁵³,
2. an overly prudish rise of the Fed policy rate under the new leadership in the 2004-2006 period, relative to its long-term levels, may have then contributed to the bubble bursting.
3. the maintenance of the high rate for too long time, despite the output and inflation reductions in 2006-2007, would have had then further reduced the Fed's ability to contain the market bubble that eventually burst.

This work then also argues that if the impact of such a rate rise on the consumption of the households with high mortgages was taken due care within the Fed's future interest rate setting assessment, then the rise and the resulting reduction in spending power may not have been so large and sharp, and may not have led to the crisis of such proportions.

⁵³ E.g. Though Bank of England considers **Inflation of mortgage interest payments** (BoEQM eq. B.47), it is considered only as a proxy and as a weighted component of RPI index and housing rent as a weighted component of CPI, mortgage levels and their interest rates are not considered, i.e. only $rpix$ RPI excluding mortgage interest payments, $rpix$ =Retail price index. excluding mortgage interest payments and council tax, and , for Inflation the **Retail Prices Index (RPI) excluding various housing factors** (council tax, housing depreciation and mortgage interest payments), Source: BoE Quarterly Model, February 2005.

3.6 Conclusion

The primary focus of this chapter have been issues in macroeconomic modelling, particularly in Dynamic Stochastic General Equilibrium (DSGE) models used by macroeconomic planning bodies such as central banks. Whilst many of the critics have been responded to as being out-dated since DSGE models evolved in their capabilities, surpassing many of the older limitations that have been raised in many of the critics.

One of the criticisms that is still very valid is that they are complex to implement and difficult to use and require much more preparation and skills than e.g. VAR or panel data models. Another is that they tend to require more time and computational power to run even small, parsimonious models used by academics but these remarks are not disqualifying DSGE models for their power of predicting and optimising economy.

Most of other valid remarks are generic for economic modelling in general and not specific to DSGE so that they cannot be directly blamed for the 2007/8 crisis. One of most controversial such issues being the existence of multiple possible equilibria rather than single one.

Part 2: Rationality and Partial Information

4 Theories of Rationality in Economics and Neuroeconomics

4.1 Introduction

As this research is concerned with modelling aspects of decision making in incomplete information condition and measuring balance between traditional rational expectation and the adaptive behaviour in economics, in this part of the text I would like to introduce the issue of rationality and rational expectation agent in economy, outline some of important and more recent developments in area of rationality of economic agents since introduction of Von Neumann–Morgenstern (VNM) expected utility rational choice decision theory and also, introduce some aspects not so far discussed in economic literature but deemed important for a better future economic modelling of heterogeneous economic agents.

To address issues of rational agent, it was deemed important to address in depth nature of rationality and rational thinking with limited information, either by its in-availability (bounded rationality), or by rational optimisation of its use (rational inattention), dwell into the realms of animal spirits and neuropsychology driving our decisions through developments of neuroeconomics. One of additional aims and results of this apparent diversion was to identify if there are reasons for the duality of two models of rationality in economics, that of the so-called rational choice theory and the other, the rational expectations (RE) decision.

Some of the work developed here was, in meantime, in part, superseded by the publication of Daniel Kahneman's work Kahneman (2011)⁵⁴ but, this research complements and takes issue further to point-out the likely reasons why our own empirical analysis results can be correct when showing that only a minority of

⁵⁴ “Thinking Fast and Slow”

economic agents act on basis of rational expectations using full available information at the time.

4.1.1 What is rationality?

Rational:

“... Opposed to irrational.more generally, a commitment to reason as opposed to faith, prejudice, habit, or any other source of conviction considered to be irrational.”
(DoPh (1979))

As can be seen from the above dictionary quotation, it may be difficult to define what is that being **rational** in general and I here present a systematic, step-by-step definition. For the start, **rational** usually refers to a division of a large unit or an entity into, usually a natural number (an integer)⁵⁵, of smaller ones. A **rationalisation** for a conclusion or a decision can be regarded as a form of “Offering rational explanations in an attempt to justify attitudes, beliefs, or behaviour that may otherwise be unacceptable.” ((Kaplan (1998), pp.221) . and can be observed from several aspects:

1. Traditionally it is seen as reasoning by dividing the thinking, the reasoning, process, from its starting point to its conclusion into smaller units (e.g. steps or thought-ratios) and establishing relations between those steps with an aim to progress through the path step-by-step, from the starting premise to the conclusion (or just to justify and explain such progress) in a causal sequence. This step-wise concluding process is usually expected to follow its reasoning steps according to the rules of logic in which case it is referred to as logical rationalisation.
2. An alternative approach, introduced by Von Neumann–Morgenstern (VNM) expected utility rational choice decision theory, it is a process of dividing a

⁵⁵ Rational numbers are, for example, by definition and their ontology, defined as ones obtained by division of one quantity defined by integer (nominator) by another, non-zero integer number of pieces (denominator), e.g.: $\frac{2}{3}$, $\frac{1475794875}{2837456598393746}$

choice utility into its quantitatively proportional, (rationalised) goal constituents, e.g. value/goal dimensions in a vector hyper-space (some of which may be “rational” and some “irrational”), assigning them certain desire/demand satisfying weight factors, and constructing the complex utility/goal hyper-plane as a product of the two vectors, $D'=[d1, d2, \dots dn]$ and the value V ($V'=[v1, v2, \dots vn]$).

$$U = D' \times V$$

4.2 Distributed parallel processing, neural networks and stochastic rationing

Here I would like to provide some shorthand highlights of modern psychology which may both, corroborate but also challenge classic economic notions of rationality.

Developments in the 1990s in cognitive sciences led to the development of models of parallel distributed processing and the neural network (connectionist) simulation. Whilst the former claims that the stages of the staged (e.g. decision tree) type of reasoning can be processed by the human brain in parallel rather than sequentially, the latter allowed modelling or reasoning and choice assessment that closely resembles a multi-staged network of nodes, each actually acting similarly to a Von Neumann–Morgenstern (VNM) expected utility rational choice decision value unit (see Stillings et al. (1987), pg. 300 and Beltratti, Margarita and Terna (1996). The two models can be considered as closely related and overlapping and further extended by the mathematical model of **probabilistic threshold** for decision making (so called Fuzzy-Logic). They are both descriptive of human cognitive processing, and prescriptive (i.e. normative) as models for development of automated methods of cognitive processing in areas of computational artificial intelligence (AI). As such, they are used for the commercial and the academic R&D applications (e.g. in character pattern recognition, robotics or medical research, e.g. see Anderson, G., Collinson, M. and Pym, D. (2013)).

4.3. Damasio and the role of the prefrontal lobe

In his 1995 book, "Descartes' Error", (and also, in Bechara, Damasio, et al. (1994)), neural-psychologist Antonio Damasio draws upon the model of distributed parallel processing and empirically analyses the effects of the pre-frontal brain lesions that may be very difficult to diagnose otherwise.

Such damage, the author claims, can permanently impair one's ability to make fully rational, good decisions even if they possess brilliant knowledge, education or intelligence. His main point is that psycho-somatosensory processes and our emotional learning largely influence our logical-rational thinking even when the brain is not damaged or impaired. This represents a departure from the classic, logical rationality towards complex, emotionally factored, weighted and driven reasoning even when-if it may be conducted in a "rational" - step-by-step wise fashion, (a non-logical rationality), not unlike the effect of the subconscious in our decision-making defined initially by theoretical psychologist Sigmund Freud.

Thus, one often reaches an answer before putting all the steps into a logical sequence and the sequential logical form is frequently just a rationalisation of parallel (concurrent) cognitive processing (Popper (1935) refers to a cognitive rationalisation as "rational reconstruction").⁵⁶

As Levi-Strauss (1962) pointed out, primitives do not lack rationality in development of their "primitive science of the concrete": though, they may lack contemporary, western, scientific knowledge of the correct casual premises, years of observation, trials and errors, may nevertheless still equip a tribal medicine men to identify and use statistically most adequate cure for an illness in spite of not knowing its actual causes.

⁵⁶ E.g. a medical student may have to backtrack step-by-step in the means-end problem solving heuristics to assess symptoms of illness before diagnosis. However, once the student mastered his subject and became an expert, he would be able to recognise a pattern of the attributes and identify illness in a leap of apparently irrational, non-deductive reasoning based on the recognition of the set of symptoms [Stillings et al. (1987), pp.93-101].

Roots of early mathematical thinking can be traced to pre-historic cultures, preceding ancient civilisations but, according to more recent findings, the earliest written documents found are related to business accounting and stock recording: numerous notches engraved in various bones date 10,000s of years BC across Africa and Europe⁵⁷.

The early trading civilisations and their scientists had therefore to develop commonly acceptable notations and further develop rules of measurement and division on those grounds of this universal logic⁵⁸. It is therefore not that surprising that the first documents found among ruins of the early Middle-Eastern civilisations dating about 2500-2000BC are of a similar, related nature too:

“Egypt and Iraq had a broadly similar priestly bureaucratic structure, and evolved both writing and mathematics very early to serve (among other things) bureaucratic ends. Indeed, as far as our evidence goes, ‘mathematics’ precedes writing, in that the earliest documents are inventories of goods. The development of counting-symbols seems to take place at a time when the things counted ... are described by pictures rather than any phonetic system of writing. The bureaucracy needed accountancy before it needed literature” Hodgkin (2005, pg. 16)

⁵⁷ A piece of baboon fibula with 29 notches was carbon dated to 35,000BC

⁵⁸ The roots of modern mathematics can be traced to early urban civilisations of Mesopotamia: Sumer and Babylon where the earliest written texts can traced to about 2500-2000BC too. Modern geometry was however invented a few hundreds years later, in Ancient Egypt, and Thales of Miletus brought it to Greece and Asia-Minor after visiting Egypt and seeing it applied there in land delimitation and irrigation.

4.4 Rationality in modern economic theory: Background of RE theory

Among the many authors, even Keynes (1936) pointed out that one of the main causes for the Great crash was irrational panic and the herding “Animal Spirit”⁵⁹ instincts that greatly contributed to the bank runs and to the market crash and its spread throughout the world economy.

As a follow-up to Keynes’s emphasis on importance of psychology in functioning of asset markets, Farmer(2010) insists that asset values depend on, and are highly correlated to levels of confidence.

4.4.1 Decision Theory and the General Theory of Rationality

A formal, mathematical model for rationality has been developed within a discipline called Decision Theory (e.g. see French (1986)). This model has been initially developed to provide a scientific model for general rational decision-making, primarily for military operations research, but it found its way into modern classical economic theory. It contains all of the main axioms and theorems for a generalised utility maximisation under certainty and the expected, multi-attribute utility under uncertainty with sample applications to both economic and non-economic domains (e.g. student marking or holiday choice).⁶⁰

⁵⁹ Animal Spirit will be discussed in more detail later in this text.

⁶⁰ As Simon French (1986) pointed out, the similarity between weak preference ordering (\succsim) and numeric ordering \Rightarrow “can not have passed unnoticed” and is, however, quite clear that one can associate some numeric values to the preferences a and b ($a \succsim b$) and add their ordering to a more meaningful mathematical model. French provides a solution in the form of ordinal numeric Value Functions $v \rightarrow R$ {s.t. $v(a) \geq v(b) \Leftrightarrow a \succsim b$ }. Such mapping, French claims, reduces the size and conceptual complexity of the model. However, such function is only suitable for ordering preferences in the ordinary meaningful way. To give the cardinal quantitative meaningfulness to the numeric values he introduces the value difference measurement method (ibid, pp. 82-89).

We usually make choices on a number of different factors rather than just one (e.g. marking an essay takes into account a number of criteria or factors, see also the above rationalisation, case 2). To develop a model of multi-attribute (multi-criteria) decision-making, French also structures the alternatives as vectors of specific levels of achievement against a number of factors q where $a=(a_1, a_2, \dots, a_q)$ and A is q -dimensional cross-product $A=A_1 \times A_2 \times \dots \times A_q$ where A_i is the set of possible levels of

Such a mathematical model of rationality developed within the Decision Theory has both a descriptive and a prescriptive role. It describes a scientific model of human rational thinking as a close approximation as it is computationally and scientifically possible.

It is also prescribe a model of decision-making that may be expected to be followed by individuals or teams in formal environments, such as corporate or military operations or in scientific research, again, as much as it was computationally possible or reasonable, or in the development of automated methods reasoning in areas of computational artificial intelligence (AI) and Decision Support Systems (DSS).

4.4.2 Rationality in Economics and Utility Maximisation

One can thus argue that the modern, economic “Rational Utility Maximisation” model is close, if not almost identical to a general, scientific, model of rational decision-making. However, as French(1996) points out, such a model is not identical to the observations performed by psychologists. And such model is, however, just one of the few models of rationality developed by different disciplines including philosophy, linguistics, modern psychological theory which abandons the over-loaded term “rational thinking” in favour of the more specialist term “cognitive process”, and the relatively new scientific domain of cognitive science (Stillings et al. (1987)) which developed out of the merger of cognitive psychology with computer sciences.

4.4.2.1 Rational Utility Maximisation in Economics

The meaning of Rational Utility Maximisation needs to be ascertained before we can embark on further analysis of its relation to the general theory of rationality.

Campbell (1986), references to Richard Dawkins’ theory of the Selfish Gene, arguing achievement against factor i.

that rational utility maximisation is still valid if we extend the utility to include apparently irrational altruistic behaviour and choice rationally aimed to benefit the close and wider family and its current and any future offspring, at the cost of one's own "Selfish" pleasure utility.

On the other hand, there are numerous examples of non-optimal irrationalities in economic decision-making within what he calls face-to-face groups, whose members want to show solidarity with the rest of the group.

A similar phenomena of apparently irrational behaviour can also be observed in so-called "peer-groups" or "peer-pressure groups" whose, either adult or teenage members (or would-be members), need to conform to some codes of dressing. This code can include obligation to wearing expensive, branded clothes that is irrational from the standpoint of budgetary rationality, or to be branded in some other way (e.g. tattooing). But such, apparently irrational behaviour, serves another, a symbolic utility, one of the group acceptance and belonging conformism. In general semiotics this is often referred to as emphatic function. However, the more irrational such symbolic behaviour is, the stronger the intra-group bonding and the reciprocal, inter-(or extra)-group separation it may drive.⁶¹

Thus, the Utility may serve either some other rational or irrational goals, but what classic economics is concerned with, is behavioural consistency with one's utility regardless of one's inner rationality or irrationality of the factors forming that utility function.

Sen argues that "...This approach of definitional egoism sometimes goes under the name of rational choice and involves nothing more than ...consistency" i.e. "with the revealed preference definition" (Sen (1979), pp. 92) That is, we cannot infer from their consistent behaviour whether their choice was consistent with the rational utility

⁶¹Such behaviour, however, is not common only to the teenage but a few religious and also, some other, "rational" adult groups adhering to a particular etiquette too, and may aim to fulfil some particular socio-emotional utility.

maximisation or whether it is just a consistent, (e.g. a habitual) error. He then argues that resolution of the famous Prisoners' Dilemma leads to a sub-optimal strategy for the two (i.e. for the group).

On the other hand, Damasio (1995) argues that even one's apparently altruistic commitment to a social group may be ultimately serving some egoistic utility, e.g. a commitment to one's (or even a remote) community's welfare may ultimately benefit one's "Selfish Gene".

Also, a random, or a consistently changing choice, may serve a set of other, higher utilities than the function/price efficiency. Pursuing such choice policy, e.g. buying apples from different countries, may provide for a healthier variety of vitamins and other substances.

Along the lines of Habermas (1983/96), Arrow(1987) also claims that rationality is not a feature of an individual but of the social environment. Arrow then states that rationality is not required for an economic system to function and that plausible economic theories can be built upon criteria different from rationality of the individual participants.

Following Habermas, it can be therefore argued that rationality does not need to play a very important role in decision-making of an individual actor in economics (and utility maximisation) but in a few situations:

1. In any process of negotiation when a purchase decision is being made, between (or among) the parties involved in the negotiation (e.g. over the price, the quantity or the choice of the item), a rational argumentation as a means of collective decision-making is usually being used a priori to the decision.
2. When a decision needs to be achieved by a collective actor (e.g. a family, group, association or a business unit consisting of individuals) and individuals need to

assert their positions and recommendations in the decision-making process. This is in line with the Schumpeterian argument of the non-individualistic economy gradually prevailing over the individualistic one.

3. Not unsimilar to the above situation, when one is asked to rationalise, i.e. explain the reasoning behind a decision that was made (i.e. as a form of a posteriori rationalisation). Because decisions may be made intuitively, randomly or habitually computationally quicker than on the basis of a rational assessment of all known information and the consecutive deduction, for everyday shopping choice, or when decisions need to be made quickly, the rational decision process may be abandoned. However, to make one's decision understandable and/or acceptable to his own super-ego or to their social group, one may retract to the development of a rationale for the decision that was made a priori (Popper (1935/2002)) refers to this as "rational reconstruction").

Here, the Rational Utility Maximisation model acts as a normative and as communication model for explaining or rationalising our decisions reached in alternative, intuitive ways. This then can lead to the model of so-called "communicative rationality" developed by Jürgen Habermas (1983/96) that also uses the notion of rational reconstruction as its base.

However, Tversky and Kahneman (1987) argue that decision models are mainly normative and not sufficiently accurate to be also descriptive of human decision-making and that decision errors are too systematic to cancel each other out. "The four principles underlying expected utility theory can be ordered by their normative appeal: Invariance and dominance seem essential, transitivity could be questioned, and cancellation has been rejected by many authors" (Tversky and Kahneman (1987))⁶².

⁶² It may also be argued that the independence axiom is not an axiom in the first place and is not a required condition for rational expected utility maximisation but mainly an application of the rule of transitivity.

It is their opinion that the criterion of invariance of choice presentation does not stand in many cases, as a decision is driven by non-linear, (intuitive) loss aversion and an accompanying incomplete (rational) decomposition of the given presentation into its invariant “canonical representation” (Chomsky 1967).

In my opinion, the two issues, one of non-linear systematic loss-aversion and the other of random incomplete reconstruction of invariant canonical presentation, should be separated. The loss-aversion affects both the invariant canonical (rational) presentation as well as the incomplete one that circumvents the invariance, but the latter more so. The loss aversion can be statistically measured and modelled using non-linear weights (e.g. prospect weights or similar, wealth-related weights) and such a model can be used to create a loss-aversion extended invariant rational utility maximisation decision model suitable for both the normative and descriptive purposes.

On the other hand, invariance circumvention due to incomplete (rational) analysis of choice presentation would invalidate the rationality of the utility maximisation decision, regardless of whether it is normative or descriptive. This is mainly because the criterion of invariance is implied by the criterion of independence where a variance in the presentation can be regarded as a special case of an irrelevant alternative. Such circumvention of invariance would invalidate the cardinality of utility function and the expected utility assessment.

4.4.3 Rational Utility Optimisation, Decision Cost and Risk of Error

Macroeconomics takes into consideration the labour offer based on one’s choice between consumption capability and leisure time. Having taken into consideration Simon’s and other remarks, it transpires that in real life situations, participants are more likely to make decisions that allow them to reach an optimum level of utility midst social pressures, information and time available, rather than to go through the whole process of information acquisition and its computation.

Information acquisition, and processing it using declarative memory, may both be costly. The actor may need to do a search and find the other party and then analyse and compare quality and then negotiate or assess the price of the items (goods or services) being exchanged (search, observation and negotiation costs respectively as in Gravelle and Rees (2004) pp317). The high costs of the decision process may deter otherwise profitable exchanges or purchases to be pursued and completed.

We believe that the amount of information acquisition (depth of knowledge) and computation used, is an individual's function of the relative cost of the choice, and with it, the associated cost and risk of possible error. If we were to spend the whole evening after work going around different supermarkets and comparing prices and value-characteristics of different cereals for tomorrow's breakfast, we would have been considered mentally or emotionally unusual to say the least, unless price-spotting became a social or family quality-time activity.

However, such rational optimisation of a choice of one of bundles can be considered a constituent part of the maximisation of an overall utility vector, or the overall expected utility over a range of bundles, where the optimisation of the costs of the choice and the associated error for each bundle are constituent parts of the overall utility maximisation.

4.4.3.1 Dual nature of utility function

If the earlier findings by Brocas and Carrillo (2011) are taken into account, and our conclusion of non-linearity of decision naming, we need to assume that even the utility function may not be linear in a similar sense if a sufficient information shock may shift one's thinking from procedural to the costly declarative domain.

4.5 Modelling Rational Agent

Giocoli (2003) claims that the importance of Nash's Equilibrium for classicist rational utilisation based economics was recognised very late. He draws a line between two visions of the economic systems, the first as a System of Forces (SoF) and the second, as a System of Relations (SoR), both around equilibria. He also makes a distinction between two types of rationality in those economies: the more recent one based around consistency of behaviour and transitivity of choice of perfectly logical agents, the approach aimed to take any psychologism of the agents out of the economics theory, and, the more traditional, "marginalist" approach, around the utility maximisation approach of real agents. It is the consistency of an economic agent's approach that was paralleled by the empirical behaviourist reorientation in psychological theory, which prevailed and provided grounds for the vision of economics as a System of Relations leading to economic equilibria.

In Giocoli's view, it was Max Weber's abstract, strictly rational approach to human behaviour based around a non-existent ideal of rational *homo-economicus*, devoid of any psychological empiricism, that provided some of the seeds for the newer, rationalist view of consistent rational agents and for the economy as system of relations (SoR).

Giocoli (2003) refers to 1935 work by Morgenstern when he already attacked Hayek and other supporters of the perfect foresight hypothesis (PFH) theory of equilibrium and argued that the intellectual capabilities of agents are over-estimated and that it is more applicable to modelled economic agents as boundedly rational individuals with imperfect knowledge. Giocoli (2003) states that von Newman-Morgenstern (1953) (vNM) theory is rooted in a socio-cooperative approach, prevailing in the culture of Central Europe, whilst Nash's equilibrium is a result of typical American non-co-operative culture.

4.5.1 Bayesian Rationality

"Thoughts without content are empty, intuitions [i.e. observations] without [prior] concepts are blind." Kant (1781)

The Bayesian inference model is paralleled by Kantian epistemology that states that our understanding of the objective world is based not only on experience, but on both the experience and the a-priori knowledge. Hence, Bayesian estimation posterior depends on both the likelihood of observed data and the prior distributions, both taken in the calculation of the posterior distribution.

Whilst the mathematics of inferring data likelihood has been well established and accepted in the wider scientific community (though still open to alternative interpretations), one of the main issues in Bayesian inference is choice of the parameters' prior beliefs' probability distributions.

Though in depth discussion on their choice is beyond the scope of this research, I just wanted to provide some of the highlights of the controversies relevant for his research. Flat, non-informative (Laplacean) priors are often used when no other, either intuitive (subjective) or rational informative beliefs can be used. Sometimes, so-called Minnesota priors are used as an alternative, as a first proxy for the flat priors. A few authors, so-called strict subjectivists, argue that intuitive (subjective) prior beliefs should be used, whilst others argue that empirical priors – priors based on some empirical evidence - should be used instead. Others argue that the non-informative priors should be replaced by the objective ones consistent with the whole, (i.e. prior) background knowledge but non-committal, maximum entropy ones, thus, near to the non-informative (Williamson (2010)).

Gilboa et al. (2004-2008a) and Gilboa et al. (2008b) analyse this issue in detail and argue that Bayesian theory ignores belief formation and prior beliefs may or may not be founded on objectively rational grounds. E.g. Gilboa et al. (2004-2008a) argues that a

delusional agent (or a delusional economic scientist) may satisfy all of Savage's axioms (originally in Savage (1954)) and the Bayesian axiom of updates, but remain on the wrong track because his priors and the resulting posteriors may not prove him wrong in his objectively irrational (though rationally internally consistent) prior belief that he is e.g. a genius.

4.6 Critiques of Pure Rational Expectations theory

The main stream of the critiques of the traditional rational expectations theory focuses on its shortcomings rooted in the “abstraction” of the real price-setting agents and an implicit assumption of an external Walrasian auctioneer (Lyons (2001)). Another traditional assumption and shortcoming of RE is that of complete information and the related ability of the agent to process the complete information set in a timely manner. Therefore, a few alternative models have been put forward.

4.6.1 Animal Spirit and Herd Behaviour

Even in the aftermath of the Great Depression, few authors (e.g. Keynes), pointed out that one of the main causes for the crash was irrational panic, herding, and “Animal Spirit” instincts that greatly contributed to the market crash and its spread throughout the economy. Some other authors pointed to the similar herding behaviour being observed in the wake of the 2007 crisis and blamed it for the acceleration of the crisis (Akerlof and Shiller (2009)). It is difficult to assess to what extent and whether the Animal (herd) spirit was a cause or just an accelerator for those crises. It is also likely that the crises may not have had become crises and could have stayed only minor recessions if there was no such herd behaviour widespread among the agents that was accelerating the downturn. The original passage by Keynes (1936) reads:

"Even apart from the instability due to speculation, there is the instability due to the characteristic of human nature that a large proportion of our positive activities depend on spontaneous optimism rather than mathematical expectations, whether moral or hedonistic or economic. Most, probably, of our decisions to do something positive, the full consequences of which will be drawn out over many days to come, can only be

taken as the result of animal spirits - a spontaneous urge to action rather than inaction, and not as the outcome of a weighted average of quantitative benefits multiplied by quantitative probabilities."
Keynes (1936)

One should make some distinction between agents' deliberate ignorance of a rational, informed decision-making process associated with following herd behaviour (regressing to analogue, imitative behaviour) on one hand from acting within the constraints of the bounded-rationality and incomplete information resulting from inability to gather and to process the complete information. Categorising what probably accounts for the majority of economic agents to act within the constraints of incomplete information driven bounded-rationality as "animal spirits" may be therefore perceived as being rather limiting and inaccurate if not even arrogantly condescending.

As mentioned above, Loewenstein and O'Donoghue (2004) define the cognitive optimum and develop a very simple economic agent decision model as a weighted balance between the cognitive and affective dominance.

Rotheli (2007) argues that heterogeneous agents affect the economics of the equilibria in different ways. For example, he refers to psychological research that concluded that people are biased more often towards over-estimating their abilities and potentials and, as a consequence, they tend to be more often optimistic in general and in their productivity estimates than that of ideally rational agents would (pp21).

Using also a rather simple model, Rotheli (2007) then shows how any type of homogeneity among the agents, whether being dominantly rational or dominantly biased towards either optimism or pessimism, is more beneficial for the overall economic output and welfare, regardless of the level of the bias and expectation error, than is a nearly equally spread of those heterogeneous agents between the two main bias-groups of optimists and pessimists. In more recent research, Harrison and Weder (2010) use a limited supply of one asset (land) as the collateral constrained borrowing limit in a relatively simple model based on Kiyotaki and Moore (1997). They then show that in credit friction marred markets, there can be an in-determinacy of equilibria, driven by agents' self-fulfilling optimistic or pessimistic prophecies.

In a remarkable break-through paper, De Grauwe (2009) and later, De Grauwe and Ji (2016), explore along the similar lines the non-linear effects of human behaviour and the pertaining balance between optimism/pessimism biases on self-fulfilling prophecies. The author compares several behavioural models with the biases against a simple rational, linear DSGE model and shows that the behavioural model is better at forecasting and creating business cycles. He argues that, though the more complex rational DSGE models are better at predicting business cycles than the simple ones used in his experiment, the behavioural ones can do that without the complexity being involved. And also, that the behavioural models can be extended similarly with the additional auto-regression and financial accelerators to achieve even better fit with the observed persistency and cyclical behaviour.

For simplicity he assumes pragmatically in the first part of the research, that both the optimistic and pessimistic agents forecast inflation along the lines of the central bank target forecast, that is, 0, though that position is relaxed in a later stage of the experiment and a 2nd heterogeneity between the central bank target believers (rational?) and the sceptics (adaptive forecasters?) introduced.

He finds that the impulse responses to the shocks in the behavioural model are not consistent across the trials. Though the parameters are consistent, the diversity of outcomes comes from the variation in the waves of optimism and pessimism that prevail in the individual IRFs, something not present in the consistent rational models. This creates an interesting model of non-linearity in agent behaviour and that of the economy as a whole.

De Grauwe (2009) then distinguishes between exogenous (systemic, transmission) inertia present in the auto-correlation in the rational DSGE models, and what he calls endogenous inertia, caused by the agents' mood-wave oriented behaviour evident in his behavioural models. He also claims the inertia to be informational, as agents do not instantly understand the transmission of the observed shock and, consequently, its

effects.

To this argument, however, it may be better to say that they do not observe the mood of others sufficiently to model that into their forecasts. It can be said that the rather technical term “transmission delay” encompasses to a great extent the above informational inertia due to the lifestyle rigidity (i.e. habitual behaviour) as well as lack of information and of understanding of the consequences when that agent has to rely on the emotional aspect of his/her psychological mood. However, the optimistic or pessimistic auto-correlation wave, as presented in the De Grauwe's (2009) model, does represent the innovative contribution that allows for the cyclic behaviour to be modelled. It is however, also auto-correlative and adaptive as the biased agents do measure and weight previous prediction errors and may correct their choice and the level of their optimistic or pessimistic bias.

It is another issue how we can measure or observe such “mood waves”. Consumer (and investor) confidence measures are a starting point, and using those B&G, as we have shown already, can improve DSGE forecasting.

Consequently, using a more comprehensive model and methods, De Grauwe (2009) explores non-linear feedback of optimism and pessimism and contradicts Rotheli (2007) by showing that optimistic bias is more beneficial for the output and welfare whilst the pessimistic position could be rather detrimental.

However, one shortcoming I see with De Grauwe's (2009) work is that the model of optimism and pessimism is not providing for measure and effect of either a time variant or culturally-variant ratio between the biased (either optimist and/or pessimist) positions on one and the rational approach within the same model on the other side. And, although the time-variant asymmetry between optimism and pessimism is achieved by time-variant but exclusive probabilities that agents are either optimistic or pessimistic or driven endogenously in De Grauwe and Yi (2016) where endogenous changes take place, it is not leaving an option of sufficient probability for the

heterogeneous agents to be somewhere rational, within the same model.

This latter option has been explored in part by Rotheli (2007) later on when he developed an integrated heterogeneous agent model using additional weighting between the heuristic (adaptive-historical) and the rational decision-making models for the economic agent, though within a very simple, non-DSGE model. Such an extension may be the way to integrate the two (or more), the behavioural and the rational (and possibly the heuristic) heterogeneous decision models under a DSGE model of partial information.

Herd behaviour may be in part rooted in the psychology of adopting and following collective behaviour. However, information and rationality may still play an important role in adoption of the so-called herd behaviour. Firstly, a rational expectation of herd behaviour becomes a self-fulfilling prophecy and it may be rationally optimal to follow the mass behaviour at least in the short term. Secondly, another rationality working behind the scene may be referred to as “communicative rationality” (or “rationality of communicative action”) introduced by Habermas (1981/84). While Habermas argued that communication facilitates more objective rationality, reverting irrational outliers by means of negative feedback towards the common, higher levels of rationality, in times of irrational fear or exuberance, the same communication may instead provide a so-called positive feedback, an actual acceleration of the irrational (e.g. herd) arguments and resulting behaviour by leading the behaviour of those who use others’ supporting responses to strengthen their opinion and actions along the common, self-fulfilling, disequilibrium path (that is, unless they are the contrarians in either of the above cases) and I would refer to this as an “accelerated communicative irrationality”.

Along the lines of the above discussion, Barton, Berns and Brooks (2012) find relation between market earnings, returns news, investment decisions and functioning of the human inner-brain, whilst Levine, Pearlman, Perendia and Yang (2008-2012) are estimating a model with two sets of heterogeneous agents, one set being fully rational and the other set behaving in an adaptive manner. These estimations were performed

within both perfect and imperfect information assumptions and show significant data fit improvements with such diversification of rational and adaptive agents⁶³.

4.6.2 Academic moral hazard

Colander et al. (2009) accuse mainstream economics for holding on to standard models of the economic systems hovering within the limits of an inherently stable general equilibrium state whilst ignoring warnings of a pending major crisis from a minority of academics, and then switching to the common sense measures in a rush to provide exceptional measures for exceptional times. The authors in essence seek agreement on a model that can be used to warn of pending exceptional circumstances and help in developing policies that can either prevent or manage those exceptional circumstances using scientifically approved methods. The authors also claim that it was unlikely that all researchers were unaware of the fragility and limitations of their financial economic models. The most likely explanation is what they refer to as “academic moral hazard”: that the researchers did not think it was their responsibility to provide, and the authors argue for assertion of ethical responsibility of economists to warn of their model limitations.

Such apparent academic behaviour in being overly cautious in disclosing results indicating a pending crisis, may be rational in essence because they may want to understate the seriousness of a possible crisis in the hope that maintaining an optimistic mood may help avoid the crisis.

In addition, in essence, as (Perendia and Tsoukis (2012)) research shows, good news can have a beneficial effect on positive fiscal multipliers, but, reciprocally, bad news can have a very negative one. Widespread publications of pending crisis warning signals may lead to a crisis on the basis of a self-fulfilling prophecy, even if such crisis would not have happened, or not to the same extent, if the bad news were not made public, and established economists rarely want to risk the burden of such consequences.

⁶³ This model, its solution and results will be presented in more detail later in this work

The authors (Colander et al. (2009)) however, also point to the usual limitations of standard macroeconomic models such as a single representative agent following a rational expectation behaviour model and ignoring imperfect information and adaptive behaviour based on bounded rationality and heuristic decision-making that is observed in reality and is in line with the wider psychological research. They then argue for the development of imperfect information heterogeneous agent models where agents are connected in networks through which contagion spreads and that provide an additional dimension for macro-micro economic analysis.⁶⁴

⁶⁴ In response to such and similar criticism, Levine, Pearlman, Perendia and Yang (2009-2012) research develops such extension and shows clear benefits of models with imperfect information and heterogeneous, rational and adaptive behaviour. This model is described in more detail later in this research.

4.7 An Introduction to Neuroeconomics

Neuroeconomics is a relatively new multi-disciplinary area of research, in part derived from behavioural-economics that combines economics with neuropsychology based on distributed parallel processing theory and augmented by recent developments in live brain MR scanning which allows identification of the relevant centres in the brain that are involved in information perception, synthesis and decision-making. Neuroeconomics has two sides: one is applying economics, mainly microeconomics paradigm on analysis of the brain and neural system working and its optimisation. For example, Brocas and Carrillo (2012) analyse inner-brain neurology and mechanisms and apply economic methodology on optimal management of memory retrieval.

On the other hand, neuropsychological findings are applied to better understanding or modelling of both micro- and macro-economic agents. These two apparently distinct and separate fields are however interconnected. There is an overlap or a kind of a mutual correlation of those two aspects: the neuro-microeconomics of the brain workings influences the way the brain makes decisions and its understanding augments the understanding of how economic agents optimise their decision-making and their market choices.

We then need to ask what is an economic model, i.e., if not other than an aggregate model of human economic agents' decision- making mechanism – the brains working within the constraints of their neurological and physical environment, the budgets and time, but on an aggregate level. This works then vice versa too: the macroeconomic and microeconomic decisions can be measured statistically, as statistical averages of the whole or of a segment of the human population, and on these assumptions, analysed, and the information used to understand better the human behaviour and to model decision-making from both, the economic agent and the neurological science perspectives. Brocas and Carrillo (2008a) emphasise that neuroeconomics offers the advantages of scientific rigour in modelling bounded rationality and better understanding of the inner workings of one's time preference and future discounting.

4.7.1 Economic Brain

Another research publication by Brocas and Carrillo (2008b) takes this further and extends their theory of the economics of information on optimisation of inner conflicts within the brain structure that leads to decision-making: the asymmetric information, the inter-temporal horizon, and the incentive salience.

Extending the works of Damasio (1995) and Bechara (2005), they derive a model based on two distinct areas of the brain, the prefrontal that is reflexive and good at assessing long-term future related decisions, contrasted with the ventral striatum and amygdala centres associated with immediate gratification, short-term rewards and impulsive reactions. One can say that an individual's future discounting depends on the strength of the influences of the two areas of brain relative to each other, whilst damage in one or another leads to extreme reactions respective to which part is functionally remaining. This model is shown to support the theory of hyperbolic discounting.

Their model is very much based on the micro-economic model of a firm, where heterogeneous agents and principals act in asymmetric information and different incentive and time discounting fashion. Whilst it may be beneficial for understanding the decisions an individual makes through application of the economic optimisation within budget and the above informational constraints, it is unlikely to contribute greatly to the broader, micro or even less, macro-economic dynamics.

Their more recent work (Brocas and Carrillo (2011)) has probably the most profound implications in that it shows how humans may be using their more precise declarative memory only for important and high-level information shocks, but tend to use their less precise but “cheaper”, easier and quicker to use procedural memory and its associated thinking in other, less critical situations. In decision-making, a brain will engage in retrieval of the more costly but more precise “declarative” memory only when information impulses are high, exceeding averages by a substantial amount, otherwise it will use the less expensive but less precise, “procedural” memory.

This may be one of the possible explanations and factors contributing to habitual behaviour or lifestyle rigidity, since the everyday decisions, from supermarket shopping to experienced traders' security trading in usual circumstances, may not call-in the expensive declarative but only the cheap procedural memory, resulting in near-habitual behaviour. Respective brain damage in different areas of the brain will then bring about quite distinctly different behavioural patterns: from extreme habitual, sticky preferences for the known and learned options, to an extreme divergence and inconsistencies in the agents' consumption choices.

This finding parallels an earlier work of Loewenstein and O'Donoghue (2004) who present a comprehensive overview of the psychological background of human agents' decision-making process. They divide decision-making between the deliberative (cognitive, rational) and the affective (emotional, instinctive) and introduce the emotional cost of rational decision-making in the form of the scaling factor $h(W, \sigma)$:

“i.e., the higher is $h(W, \sigma)$, the larger is the cognitive effort required to induce a given deviation from the affective optimum (we assume $h(W, \sigma) > 0$ for all W and σ). This cost of willpower will depend on the person's current willpower strength, which we denote by W , and on other factors that undermine or bolster the deliberative system, which we denote by σ If the affective system alone were completely in charge of behaviour, and if the current vector of affective states were a , the affective system would “choose” $x^A = \arg\max_x M(x, a)$, which we refer to as the affective optimum.”

They then define the cognitive optimum and develop a very simple economic agent decision model as a weighted balance between the cognitive and affective dominance. It can be said that the former reflects declarative, and the latter, procedural memory retrieval and decision processing.

4.7.2 Neuroeconomics and Animal spirits

It may be a tempting and an undue simplification to conclude that the new theory of

Neuroeconomic, neural science based model, is consistent with the Animal Spirit theory outlined above in that the rational behaviour relates to higher, declarative thinking whilst the animal herd behaviour stems from use of the procedural thinking. It seems however that the neuroeconomics theory is more consistent with that of Damasio (2005), Kahneman (2011) and Loewenstein and O'Donoghue (2004) work distinguishing between fast but intuitive and emotional, and the slower, cognitive, rational thinking. However, further cross-mapping may be beneficial for drawing parallels and establishing the cross-consistency of the theories by accepting that the near-automatic, procedural thinking may be more affected by the subliminal, emotional and intuitive processes than the higher cognitive and rational one.

Camerer (2011) conducts experimental research and points out (what many restaurant owners, who let smells of their cuisine out onto the street, have known for centuries) that the sense of proximity of food (or other desired goods) can invoke a Pavlovian reaction and lead agents to accept a higher price for those goods than in its absence. This however, may also be less of an instinct, and in fact, subliminal rationalisation of the extra financial (but also, the emotional) cost(s) of obtaining cheaper goods further away in space/time, combined with a sensory reminder of its existence and our desire for it. The author points out that presentation of an already-signed cheque may lead the other party in a financial argument to neutralise their negotiation strategy armament and settle for a lower deal than otherwise. Also, sadness cued agents tended to sell for lower and buy for higher prices, indicating that similar behaviour may be expected in times of economic depression.

Another experimental behavioural economist, Dan Ariely (2008) points to a variety of experimentally proven irrational decisions people make that may affect and potentially harm their well-being. Standard economics based on rational agents will assume that they will not be tricked into free lunches, and that agents are saving for retirement exactly according to their preferences for life in retirement. Behavioural economics, as Ariely points out, is however assuming irrational agents and can explain that they irrationally can forego the value of their time for apparently “free-lunch” deals, and,

more importantly, often underestimate and suppress rational knowledge of difficulties of a long retirement without sufficient income, all for the sake of short-term pleasure from high expenditure today.

4.7.3 Discussion

4.7.3.1 Two (or three) models of economic rationalities

In terms of Neuroeconomics, lack of information about the shocks, and consequently, a lack of a sufficiently large information shock that can act as a trigger for declarative, cognitive processing, the thinking then may remain within the emotions, imitations and habits-influenced area of procedural thinking.

This trigger-driven switching between spheres of mind where processing is performed and memories are utilised, represents another form of non-linearity in human decision-making but it is however very difficult to model any non-linear behaviour, and the modern economic theory seems to be only in its very early stages of modelling non-linearities. To our knowledge, no such models have been used in practice by central banks. However, one can possibly argue that the modern economics theory has already recognised and catered for the two spheres and two kinds of rational thinking.

Whilst the revealed preference rational choice model, mainly applicable to every-day consumption and short to mid-term purchases performed mainly by household consumers requires less information and cerebral engagement and may most likely be processed and decided using the cheaper, emotional (procedural) rationalisation, the more important, mid-to-long term professional decisions such as wage or other contract negotiations and larger investments, or any major informational shocks to everyday life, would require assembly and processing of “full information” available (i.e. reasonably available and feasibly operational information, see below chapters on rational inattention) which will require discussion the more “expensive” (declarative) brain processing, could probably be associated with the other type of economic rationality,

that of fully informed Rational Expectation (RE) and similar sets of models.

However, despite requiring and relying on the more “expensive”, declarative centres, the mode of declarative thinking in one's mind is still not fully free from priming and other emotional influences. To be more objective, the decision process therefore needs to get engaged into a team, collective discussion when making important decisions and hence, utilise a form of a communicative rationalisation defined e.g. by Habermas (1983/96). One can therefore argue that closest to the fully rational agents in economy can be found only in medium-to-larger institutions, whether private or public, where sufficient information can be afforded to be collected and processed and where either large advisory teams or collectives, such as boards of directors, are engaged in collective, communicative rationalisation prior to the final decision-making on major moves. However, even such collective rational decision may be sub-optimal when individuals taking part in it may find it fully rationally-opportune and optimal from their own separate, individual standpoints.

4.7.3.2 Subliminal information affecting fast thinking

As we now know, the fast thinking which is not based in declarative memory and does not invoke slow logical derivation of conclusions, but which instead integrates our emotional priors and efficiently derives decisions, may be affected by a number of factors. Factors such as emotional state (Damasio (1995)) and our emotional and cognitive history and many of memories would be processed in parallel, thus without direct control of the consciousness and may therefore bring about the effect of subliminal information into decision making without passing the threshold of human conscious recognition. We may then be affected in our decision-making by a number of subliminal cues, from information arriving from the side of our visual perception, or imprinted in one of 24/25 frames of a film or a television programme (despite such techniques being banned), or registered by our auditory or smell senses, however, still below the threshold needed to trigger conscious registration.

Further discussion on this subject is beyond the main scope of this research.

4.8 Imperfect information, Neuroeconomics and “Animal Spirit” effects

One of the main issues raised by the New (Information) Paradigm movement, led by Greenwald and Stiglitz (Stiglitz (2009)) on information in economics, is the issue of effectiveness of the competitive market economy which, they claim, cannot reach the real Nash optimum equilibrium due to imperfect information (Stiglitz (2009)).

Kirman (2011) analyses the impact of human interaction networks (other than those formed purely by economic market mechanisms) and their stochastically formed topologies on economic and financial markets. He lists several possible reasons for herd behaviour in economic and financial markets and also points to various other interpretations of herd behaviour. In some cases, such as informational cascade, when actors abandon their own (rational) information and adopt to follow the prevailing behaviour accepting that as the more correct information, they may still remain rational and still follow herd behaviour. (I.e. in a way that can be seen as a form of rational asset market behaviour where the price reflects the true knowledge of its value.). He also refers to the 1992 research work of Banerjee who, in turn, shows that the Bayesian Nash equilibrium may be chosen differently by agents acting fully rationally, each resulting in a stable equilibrium, however, an inefficient one from the welfare point of view, but each of which may be derived depending on the starting movements and on the dynamics of the players in the game.

Kirman states that a belief that a macroeconomic policy works may itself provide for a stable economy, based on the self-fulfilling belief, valid for the time being only, until agents change their belief.

4.8.1 Role of historical data in RE models

Paul Krugman (1991) shows that in economies that are moving relatively slowly and where adjustment costs are high, it is their historical paths that are prevailing in determination of their optimal equilibrium, dominant over the alternative, rational

expectation-based “self-fulfilling” paths to several of possible alternative equilibria.

Those conditions seem to reflect the situation in larger, highly invested and more developed economies where adjustment costs would be prohibitively high in comparison to the benefits of moving to an alternative, economically possible equilibrium.

The opposite could however be true for economies with low or no adjustment costs, e.g. under-invested and under-developed economies in their prime development stages, where a co-ordinated political effort in converging rational expectations of the investors may help develop an economy towards the one, politically most desirable out of several plausible, attainable equilibria (Krugman 1991).

However, similar may apply to the so-called post-industrial service-oriented (e.g. financial services) economies where adjustment costs and time-scales are highly reduced in comparison with the “old-style” heavy-invested industrial-oriented economies.

Similarly, though assuming a different perspective, Woodford (2000) argues that pure forward-looking monetary policy may result in indeterminacy of equilibrium, and concludes that historical data analysis is necessary in derivation of an optimal policy because it allows for estimation and projection of the market agents’ responses to inflationary and other economic factors based on their past information and expectations (i.e. the “forecasting the forecasts of others”).

In addition, Svensson and Woodford (2005) state that it is optimal to take into account historical paths even when future development paths are not dependent on them solely because it is assumed by the players that the future paths are dependent on the history and so takes part in forecasts by other players.⁶⁵

⁶⁵ Although acceptable as plausible, such situation may be falsified since there is no adequate measure of statistical importance of such false belief.

In an article, Krugman (2009) criticises contemporary economists (mainly the so-called Fresh-water Neoclassical purists) for relying too much on mathematically attractive, “neat, plausible and wrong”, rational agents and efficient markets models. According to him, they are omitting to account for the effects of agents’ irrationality and market inefficiencies, both of which largely contributed to, and accelerated the downfall through the recent (2008-09) economic and financial crisis as they did in many other similar crises. He also points out that despite Keynes’ emphasis on agents’ irrationality (e.g. in his notions of Animal Spirits and the ‘beauty contest’ applied in financial economics), even most of the Neo-Keynesians, whilst accepting a certain level of market frictions and inefficiencies, have nevertheless accepted the Neoclassical models of rational representative economic agents.

4.8.2 Forecasting the forecasts of others

This area has been augmented by “forecasting the forecasts of others”, i.e. modelling of an infinite, explosive, iterative process of deriving one’s expectations on the basis of estimation of expectation and pricing decision-making of other rational agents such as policymakers and micro-economic agents (Townsend 1983 and Sargent 1991). More recent approaches use frequency-domain (Kasa 2000) or a combination of recursive methods, Kalman filter and sub-space methods in the time domain (PCL 1986 and, Pearlman and Sargent 2002) to deal with situations of asymmetric or incomplete information.

4.8.3 Bounded Rationality and Rational Inattention

The issues of rational expectations in a partial information framework has also raised an additional epistemological question and resulted in further expansion of the already extensive discussion on the rationality of economic utility maximisation, and the expectations and the psychology of the subsequent decision-making amidst constraints of incomplete (partial) information and bounded rationality (e.g. Campbell (1986),

Simon (1986) and (1979), Arrow (1987), Tversky and Kahneman(1987), and, Gigerenzer and Todd(1999)). It also became questionable whether the agents' expectations are truly rational in the sense of REH or they actually are adaptive rational expectations in the sense of integration of AEH and REH, or their convergence to AREH.

4.8.3.1 Simple Heuristics that makes us smart

Gigerenzer and Todd (1999) (GIG99) are bringing back to our attention Simon's (1957)⁶⁶ original idea of Bounded Rationality and are differentiating it from optimisation under constraints. The idea of simple but effective heuristics based on one (or a small number of) reason(s). In short, to make computationally and time-efficient decisions, living organisms, including humans, usually search for clues, and at the first sign of a positive clue give up further searching and go for the solution that is not fully optimal (maximal) but is satisfying for less important decisions, or use so-called "Fast and Frugal Heuristics" (FFH) for multi-factor decisions. However, both of them are possible, but not necessary to differentiate from decision-making optimised for the computational time and the incomplete information constraints.

On the other hand, such heuristics depends on satisfying a goal or the (optimal) number of "reasonable", most important factors and cues that can be identified for the FFH. When the goal is reached, or the reasonable number of cues for a decision is identified, the search for better solutions or further cues stops.

However, such satisfying (Satisficing) or FFH (bounded) single cause rationality may be also just a simplified explanation used as an a posteriori rationalisation for a rather complex, intuitive, or distributed decision-making process. In any case, its goal, though constrained, is the (bounded) rational maximisation of utility.

⁶⁶ Originally in Simon, H.A., (1957), *Models of Man*, New York, Wiley & Sons

4.8.3.2 Rational Inattention and Informational Limitations

Rational Inattention (RI) is characterised by agents' deliberate inattention to some available information since they consider attendance to that information sub-optimal and prefer to make decisions in ignorance of that information. For example, the cost of adjustment to information at hand may be prohibitive when if it needs to be done in short, or in real time, i.e. as soon as the information becomes available. The production life-cycle may not even allow for such adjustment in short time, and so, the strategic or tactical plans may need to be followed-up on the basis of the previous period(s) predictions (expectations) of the current state rather than on the basis of the accurate information that just arrived.

4.8.3.3 Entropy and Rational Inattention

The notion of Rational Inattention and use of entropy in Rational Inattention theory has been introduced in a ground-breaking paper by C. Sims (2002). Few other authors accepted this information theory approach to the Rational Inattention theory and use entropy, signal/noise ratio and impose restrictions on information channel flow.

Although entropy of a series of events X with probability of $p(X)$ is defined as:

$$H(X) = - \sum p(X) \log_2 (p(x)) \quad (4.8.3.3.1)$$

Entropy is usually expressed using a logarithm with base 2 for the convenience of measuring capacity in the binary base in *bits*. However, other logarithmic bases may be used instead and when base e is used, the capacity is measured in *nats*. In addition, as per Sims (2002), for a Gaussian process $G \sim N(\mu, \sigma^2)$ of dimension n it may be shown that entropy is

$$H(G) = - \frac{1}{2} \log_2(|\sigma|) - \frac{1}{2} n \log_2(2\pi e) \quad (4.8.3.3.2)$$

Following Sims (2002), Luo and Young (2009) and Martins and Sinigaglia (2009) impose a time in-variant information channel capacity κ constraint on the difference between the posterior and the prior values of entropies, both conditional on the information set available.

Whilst Luo and Young (2009) impose entropy difference for only one state variable – capital k_t , Martins and Sinigaglia (2009) use the full set of state variables respectively.

Thus, the difference between the posterior and the prior values of entropies has to be limited to the available and used information channel capacity κ , i.e.:

$$H(k_{t+1}|I_t) - H(k_{t+1}|I_{t+1}) \leq \kappa \quad (4.8.3.3)$$

Or, for Gaussian variables,

$$\log_2 |\Psi_t| - \log_2 |\Sigma_{t+1}| \leq 2\kappa \quad (4.8.3.4)$$

where $|\Psi_t|$ and $|\Sigma_{t+1}|$ are prior and posterior variances of the state vector. The change in entropy and reduction in uncertainty need not be positive in all cases and a higher uncertainty may be introduced with a posterior information set.

4.8.3.4 Some other approaches to use of Entropy in Economics

Gomes (2006) and Gomes (2009) deal with entropy and diminishing returns of agents' communication, learning and their memory depreciation, and argue that a rapid knowledge rise can result in entropy of knowledge and that may become a source of endogenous business cycles. Human capital, the knowledge, and the organisational capital can suffer similar depreciation as the physical one. What is more, an entropy based knowledge accumulation difference equation may lead to unstable bifurcation

leading the economy into different directions unless it satisfies stability criteria. Gomes (2009) introduces a model of divided cognitive resources when agents have to choose between introspective analyses of historical data or adhere to communicative inference methods.

Similarly, to Sims (2002), Chen (2002) and Chen (2004) analyse subject cognitive capabilities or behaviour in relation to the theory of entropy and to Shannon (1948)'s formulation of mutual information one can receive based on conditional entropy $H(x|y)$,

$$R = H(x) - H(x|y) \quad (4.8.3.4.1)$$

where higher levels of information can be transferred between correlated agents than uncorrelated ones, as the uncorrelated groups would not have been able to understand each other and decipher information from the other group (e.g. as if they are not sharing same languages). Chen (2002) introduces entropy reduction as a measure not only of information along the lines of Shannon (1948) but also of socio-economic value, a measure of the laborious effort required to reduce (or reverse the trend towards) entropy (chaos) within the human socio-natural environment. Chen (2004) uses $H_y(x) - H(x|y)$ as a measure of information asymmetry, and states that new information is difficult to comprehend and a (usually slow) learning process is required to increase mutual correlation and so improve understanding between two groups. For uncorrelated (i.e. statistically "orthogonal" groups of) agents, $H(x|y) = H(x)$ and hence,

$$R = H(x) - H(x|y) = 0 \quad (4.8.3.4.2)$$

One can then recall and relate this model to the concepts of communicative (i.e. collective) rationality as in Habermas (1983/96) or Arrow (1987) concept of rationality as a social phenomenon.

4.8.3.5 Discussion on RI and Partial information

Despite their nominal difference, Partial Information as defined in PCL86, or, as redefined as Imperfect Information in the later works, e.g. Levine et al (2008-2012) are conceptually similar, analogue to both, Bounded Rationality and Rational Inattention in that, for a variety of different reasons, incomplete information is used in decisions. This in turn, delays effects of the phenomena, e.g. shocks, as both, the real world and the model of the economy adjust slower to new information and the respective model simulation IRFs show more realistic, humped, delayed responses.

For example, Maćkowiak and Wiederholt (2009) model the economy with restricted information channel and observe the effect of imperfect information inattention on the firms' sluggish (sticky) price-change decision-making: *"Firms adjust prices every period and yet impulse responses of prices to shocks are sticky — dampened and delayed relative to the impulse responses under perfect information..."*

The main difference between Sims (2002b) model and that of PCL86, is that Sims uses information entropy to model RI whilst PCL86 assumes that the new, current, shocks are not observed in real time but with delay but the overall effects are similar. There is however, a large number of alternative, non-entropy based, models of partial/imperfect information and rational inattention and they are discussed in more detail later, in Ch. 5 and 6 of this work.

4.9 Discussion:

4.9.1 Habit and lifestyle rigidity as R.I. driven utility maximiser

Contrary to the earlier definition of rationality (e.g. one from the dictionary of philosophy), habitual behaviour can be seen as a mean of maximising one's utility rationally. I.e., instead of acquiring and analysing all necessary information about the variety of the substitutes of the products we intend to buy every time we go to a supermarket, one can rely on repeating the same behaviour learned from rational

optimisation performed over a longer period of time. Such habitual behaviour, thus, minimises information acquisition and its processing costs (in terms of both the time and financial costs) a trip to a supermarket would entail if one was to take the fully analytical, rational approach. As such, habit may be considered to represent a form of rational inattention.

However, as already mentioned in this work, a number of cues, some even subliminal, or an optimisation based, e.g., on local supply and avoiding of a much longer and more expensive journey needed to obtain the first favourite, can make a consumer purchase a less favoured (second-best, or a lower ranking) substitute, which may then be observed, however wrongly, as a purchase of the favoured variant.

Though it is unlikely that families would be discussing inflation and all other publicly available economic data whilst optimising their next week's regular purchases over Sunday family lunches, however, a certain element of consumer behaviour optimisation may be resulting from the communicative rationality and irregular revising of the market news over family events, evening tea or beer drinking sessions of the relevant households' purchases decision-makers and their peers.

I would therefore argue that, having been most likely rooted in an early-established set of revealed preferences, habitual behaviour used in daily purchases is most likely based on the procedural (emotional) thinking as discussed earlier, and that is what is enabling consumers to quickly work-out their short term purchases on a semi-automatic pilot.

Such, emotional, thus not RE-rooted, combination of habit and lifestyle rigidity would affect market stability at a more strategic level, when such agents are trying to maintain their life-style and their perceived social position midst income loss. Aiming either to “keep-up with the Joneses” or just to maintain their own family and social strata lifestyle continuum irrespective of the rational expectations of their future, lower, income, they may resort to spending any of their precautionary savings or to borrowing, when that desire is met by over-optimistic credit facilities.

4.9.2 A Hypothetical Mid-level Model of Rationality and Knowledge

I would like here to postulate a hypothetical development based on traditional distributed cognitive processing and Neuroeconomic theories, which are, of course, the underlying ground for this model but overly too detailed for explaining macro-economic agent knowledge based decision making in socio-economic context.

4.9.2.1 Distributed Parallel Processing Utility Maximization

What this intuitively may mean is that our brain does not cognitively process information in a “logical” sequence but divides (rationalises) the process into parallel, concurrent processes. At the top of the hierarchy, each rationalised process is a stage of what we traditionally perceive as a step in logical processing and may be assessed concurrently before their results are “projected” into the sequential, pre-dominantly left hemisphere for its presentation in the sequentially-logical, form that is easily translatable into word-sequential spoken language form. Thus, cutting the lapse time from the start to the end of processing allows more factors to be evaluated within the same short time comparable with a heuristic process.

Thus, one often reaches an answer before putting all steps into a logical sequence and the sequential logical form is frequently just a rationalisation of parallel (concurrent) cognitive processing (Popper (1935) refers to a cognitive rationalisation as “rational reconstruction”). A person making a decision has then a choice of how to present this rationalised cognitive process in the logical and the phonetic forms of a sequential natural language (possibly based on Chomsky (1967, 1995)), mainly:

- 1 . Project the most important of those parallel assessments and the overall result in a form of a single-reason heuristic conclusion, or,

2 . Project several of the concurrently processed assessments into a logical sequence or a decision tree and “derive” the same logical conclusion in a sequential logical process.

Let us take an example of a medical student who may have to backtrack, step-by-step, using difference reduction and sub-goals in the means-end problem-solving heuristics to assess all the symptoms and causes of an illness before reaching a diagnosis.

However, once the medical student masters his subject and becomes a practitioner and an expert, he/she will not need to go through the whole process of step-by-step rational assessment of the factors, but will be able to recognise a pattern of a few of the attributes and identify the particular type of flu in a leap of apparently irrational, non-deductive, non-declarative but procedural reasoning based on a recognition of a whole set of factors (see Stillings et al. (1987), pp.93-101).

Thus, the general model of a multi-attribute rational utility maximiser can still stand as the ultimate goal of this alternative model of rationality. A quick intuitive or a heuristic decision may be based on a large number of factors, probably cognitively processed by the distributed neural network of vNM nodes in the right hemisphere before their results are “projected” into a sequential, left hemisphere for a presentation in a logical form. Hence, a heuristic, short decision may be just the tip of a hierarchical “iceberg” of distributed processes taking place in the human brain.

The emotional and other subliminal factors may act as Bayesian priors and this is then why a trained, Bayesian neural network simulator can simulate a “trained” consumer, apply multi-attribute statistical regression, recognise a pattern and act as an expert in solving some problems such as identifying a product with the highest utility, both quicker and more close to real life, than a system based on the first generation of AI systems and the single-dimensional predicative logic.

Rationality has, to a varied but a larger extent become associated with contemporary

economic theory. An economical definition of utility maximising rational choice, on the other hand, allows close econometric mapping of “consumer choice” on the set of rational numbers. The association goes so far that the mere word economical became almost a synonym for rationality, which has probably been part of human thinking from the time before writing, the pre-historic times. The economic theory of rational utility maximisation was however developed in a dialogue between the economic and the decision-making theories developed in WW2, based on maximisation of the effect the military operations achieved under severe constraints of incomplete information and limited time.

4.9.2.2 Communicative Rationality

On the other hand, as part of the increased amount of available information and the information needed to make rational consumer choice, we can observe that consumers more and more opt to acquire both market and product information for facilitation of their rational utility maximisation choice from the pool of technologically advanced and increasingly complex products. This information is increasingly sought from specialised magazines with long articles dedicated to price and feature comparison of groups of products (e.g. Which Car, Mortgage, etc.). As a result, social conversations nowadays increasingly frequently consist of either single, or, sometimes, two sided, elaboration and comparison of features and utility benefits of consumer products, raising the case for Habermas' (1981/84) communicative rationality.

The majority of individual consumers and other agents of the economic system, as many recent psychological researchers argue, do not follow this rather normative model. This paper shows that such unexpected, observed, behaviour is not just simply due to the individual agents behaving in an irrational manner, but it might be better described by some different rules and models of rationality. However, even with the recent developments of the models of rationality, the rational utility maximisation ultimately still applies to both the economic and the non-economic domains of our lives as either a normative or a communication model for explaining and rationalising our

decisions reached in various, alternative ways.

Because decisions made intuitively, concurrently, heuristically, procedurally or habitually are quicker than those made on basis of the full rational cognitive assessment utilising declarative centres, it seems that rationality does not play an (important) role in individual decision-making. Along the lines of Habermas' (1981/84) communicative rationality, Arrow (1987) claims that the rationality is not feature of an individual but of the social environment.⁶⁷ What this may also mean is that the a posteriori rationalisation (“rational reconstruction”) is mainly used just to present and justify the choice to a social group for approval. However, the vNM (bounded) rational expected utility maximisation-like mechanisms are inherently at the core, though sometimes behind the stage, of the many alternative human decision-making processes as well as of the applied normative models⁶⁸. These models, however, need to remain compatible with the findings of neurology and neuroeconomics.

4.9.2.3 Applications of Entropy

On the other hand, following-up on Sims (2002b):

- 1) An economic model, as such, is an approximation, a kind of “bracketing out” and acts as a restricted information channel with its own entropy as its capacity. Different agents have different models and observe different data with different frequencies and with a different precision. (E.g., macroeconomists are trying to model economic behaviour using only a subset of quarterly data. Such data allow modelling and identifying cycles only as short as 0.5 year, whilst those

⁶⁷ Arrow claims that rationality is not required for an economic system to function and that plausible economic theories can be built upon criteria different from rationality of the individual participants: "Among the classical economists rationality had a limited meaning of preferring more to less"

⁶⁸ Thus, the general model of multi-attribute rational utility maximiser can still stand as the ultimate method and the goal of this alternative model of rationality. A quick intuitive or a heuristic decision may be actually based on a large number of evaluated factors, possibly cognitively processed by the distributed neural network of vNM nodes in the right hemisphere before their results are “projected” into a sequential, left hemisphere for a presentation in a logical form. Hence, a heuristic, short decision may be just the tip of a hierarchical “iceberg” of distributed processes taking place in the human brain.

more frequent, shorter, production and price change cycles in the economy cannot be identified.). If a single model is to represent a generic, representative agent, than it is that model's entropy that defines the channel capacity.

- 2) Restricting entropy change to the information channel capacity κ as in Sims (2002b), Luo and Young (2009) and Martins and Sinigaglia (2009) is a convenient abstraction but one which, mainly for the above reasons, has little, if any relevance in reality. Any model has its own entropy and different agents will have different models and capacities, but none will have the ability to perceive the economy in full and will be limited to partial (imperfect) information.
- 3) If the model is that of a representative agent, simulating the agent's information processing, than its entropy represents the representative restriction k . If it is a meta-model trying to represent the entire economy, then its information change cannot be restricted by the representative agent's capacity but only the sub-model of the agent's own perception of the economy can be restricted.

Increasing computational power may enable us in near future to have macro-economic heterogeneous agent model with detailed neuroeconomics simulation models at its core for each agent. Until then, we need some intermediate-complexity models, probably based on entropy as a measure of limits to their informational capacity limits to work with but building such full-scale model is beyond the scope of this research.

4.10 Conclusion

The preceding chapter revisited issue of rationality, a fundamental presumption in at least two of its main models, that of rational preferences and the other, rational expectations and it was shown that there is, one could say, a common underlying and partially, sub-conscious mechanism connecting the two models as analysed within the relatively new domain of neuroeconomics. It was also shown that there are additional, major implication of imperfect, incomplete, limited information and of its limited processing capacity available to individuals or smaller organisations, thus driving heuristics based decision making within bounded rationality or rational inattention conditions and so, explaining why only larger teams or organisations can be considered to have basic conditions to needed for forming fully rational expectations. Saying so, it does not necessarily mean that they follow it and some empirical results in the following chapter confirm the clear segmentation among fundamentally heterogeneous agents driven markets and the surprising ration of agents not following it, thus, indicating a major issue in the traditional and more recent macro-economic modelling theory making assumption of full sufficiency of a single representative agent forming fully rational expectations based on fully set of needed information. There is of course, more work needed to pin-point more precisely the statistical and causality relations between the above theoretical conclusion and segmentation and the ground data that that what has been done in this research work and the next chapter though, it should be mentioned that the above results in a way match the small sample of the author's ground-work professional experiences.

A remark: This research work is, therefore, on its own just an attempt to rationalise a large number of collected facts, bracketed by a rational attention, itself optimised to collect sufficient but not overly too large number of information items that can be put in a rationally logical and communicable sequence so to convey certain scientific discoveries at a level of complexity, quality and quantity expected for a PhD dissertation.

5 Methodology and Application of Partial Information DSGE Economic Models

5.1 Partial Information Rational Expectations DSGE Models

In line with the main aim of this research to address importance of more realistic assumptions of absence of full information (or of the ability to process it) in decision making by economic agents, this section aims to address some of the most frequently voiced criticisms of both classical and NK DSGE models and tools that deemed to be fully justified:

- 1) that economic agents have full information available at their disposal (and, though less explicitly mentioned, are also assumed to be able to process it correctly), and,
- 2) that a single representative aggregate agent may then form fully rational expectations and be sufficient to represent aggregate economic behaviour.

The aim of this chapter is to provide and test some of improvements to DSGE modelling in those two areas of most frequent criticisms of rather unrealistic classical assumptions of the DSGE models discussed and criticised earlier.

I.e., most of both classical and NK DSGE models make a computationally simpler assumptions of asymmetric information, where full information about shocks is available to the economic agents but not to the institutional (e.g. central bank's) econometricians (e.g. in Svensson and Woodford 2002b). According to many the critics (e.g. Romer 2016), such models henceforth fail to take into account that only partial information is available to all the economic agents. The full-information assumption leads to more questionable estimates than those following a more realistic scenario where partial (i.e. imperfect, though symmetric) information assumptions are made when the models are estimated and evaluated.

A partial (imperfect) information approach can be seen as an attempt to provide a

model for rational inattention or bounded rationality information constrained agents within a Rational Expectation DSGE framework solution, when agents make decisions without having full knowledge of all current shocks affecting endogenous, unobserved variables.

5.1.1 Asymmetric Partial Information

Whilst assumption of asymmetric information being available is realistic, it is not realistic to assume that any party has full information (and, to add to that, the ability to process it in reasonable time with the all needed accuracy) to derive fully rational expectations. On the other hand, Svensson and Woodford (2002b) argue that it is logically sound to assume that in case of asymmetric information, where central banks and/or policy makers observe less than private sector economic agents who will have a full common information set of all relevant factors. The elegant logic they postulate is that only the information about target variables, symmetrically known across all private agents is relevant for economic modelling. Whatever else is there that is not known by the agents, although possibly known by others such as policy makers is, in their opinion, nevertheless irrelevant for making decisions by the agent being unknown to them. Such additional information is thus irrelevant for forecasting agents decisions and their behaviour and hence for making policy decisions. (Svensson and Woodford 2002a) also say that authorities, e.g. central banks only have additional information about their own intentions).

However convenient and elegant this pragmatic approach aimed at creating an aggregate and tractable model is, their argument is also rather difficult to accept as being realistic:

Firstly, it would be wrong to assume that private agents commonly shared more information than is available publicly to the authorities and their econometricians too. This is mainly because such situation would be contradictory to both, the rules but also aims of market competition.

Secondly, most of the shocks come from the effects of actions based on private information (or from the inferred conclusions based on the mixture of public and private information and staying private for a while), i.e. private information that drives some organisations in directions not expected or being inferred from the public information.

Also, contradicting the above assumptions Romer and Romer (2000) show that the Federal Reserve's forecasts of inflation (a private information at the time but released several years later) - has much higher statistical regression significance in predicting inflation than any of the commercial forecasts publicly available at the time. Even in the case of forecasting GDP, the Fed's forecasts had a higher significance than those by the commercial forecasters, but the difference was not as high as in the case of inflation. In the authors' opinion this may be indicative that (at least some) planners have more information than the agents do about future state of the economy. The authors suspect that the source of additional information results from the fact that the Fed has more resources and more data collected by the regional offices. This allows them to process more information than any commercial, public forecaster can afford to have⁶⁹. As a result, they expect that market agents suspect that Fed has more information when rising (or lowering) short-term interest rates in relation to the overall inflation process. The market then proportionally adjusts the expected futures and, consequently, the longer term rates (and bond yield curves)⁷⁰ which is in line with the findings of Cook and Han (1989).

And, it is not just that the large pull of heterogeneous data series enables authorities to produce more efficient and accurate forecasts. Examples of types of additional information a financial authority, such as central bank, would have at its disposal as (a temporary) private information useful in planning the future policy are fluctuations in

⁶⁹ Exceptions may be Thomson/Reuters and Bloomberg. (that is, with the addition of the FED itself since it is not strictly speaking purely a public institution).

⁷⁰ From other sources such as Bernanke and Boivin (2003) the researchers know that Fed uses several thousands of data series in their estimation process.

the value of money in circulation and aggregate loan exposures of retail and some of investment banks. This raises a case for models of both, imperfect and asymmetric information being available among heterogeneous agents.

5.1.2 Symmetric Imperfect (Partial) Information

However, as was case in Minford and Peel (1983), in the course of this research, it was deemed that a closer and more accurate approximation of such complex heterogeneous model would be assumption of a set of symmetric (i.e. publicly shared) information, however, assumed to be incomplete (imperfect or partial). This imperfection is either because there is a multitude of different (heterogeneous) agents holding private information (this including the central banks and authorities) or the current period data and shocks are yet un-observed because there is a set of exogenous shocks but publicly yet unknown (i.e. yet unobserved), or data are observed with substantial errors.

Many works in this area: (e.g. Minford and Peel (1983), Sargent and Wallace 1985 or Lungu et al. 2003/2006) concentrate on the so also called Ragged Edge Partial (Imperfect) Information when only some of the contemporary state information is available (i.e. at time t) to the market participants, usually only the interest rate (and, in some models, the exchange rate), and all other information is only available as past data, lagged at least for one period and as previous or current estimates of current period data.

For example, aggregate supply curve in Sargent and Wallace (1985) eq.1:

$$y_t = a_1 k_t + a_2 (p_t - {}_t p^*_{t-1}) + u_t \quad (5.1.2.1)$$

where ${}_t p^*_{t-1}$ is public expectation of the time t (current) value of log of price levels held at time $t-1$ has been a starting point for many imperfect/partial information models. However, more recent examples, like PCL86, instead, provide solutions and estimations for the problem of current, imperfect, estimate of the current values, e.g. $p_{t,t}$ (or, ${}_t p^*_t$ in

Sargent and Wallace (1985) notation). PCL86 solution is first RE DSGE solution for imperfect information using the current estimate of the current values, e.g. $p_{t,t}$, to be provided as an extension to Blanchard and Kahn (1980) RE DSGE solution.

I.e. Blanchard and Kahn (1980) solve linearised model around steady state:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (5.1.2.2a)$$

$$w_t = [K_1 \quad K_2] \begin{bmatrix} z_t \\ x_t \end{bmatrix} + v_t \quad (5.1.2.2b)$$

Where w_t is observation vector and eq. 5.1.2b observation equation. PCL86 extension, using earlier notation, solves the following model:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} z_{t,t} \\ x_{t,t} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (5.1.2.3a)$$

$$w_t = [K_1 \quad K_2] \begin{bmatrix} z_t \\ x_t \end{bmatrix} + [L_1 \quad L_2] \begin{bmatrix} z_{t,t} \\ x_{t,t} \end{bmatrix} + v_t \quad (5.1.2.3b)$$

Other research works that provide similar solutions to PCL86 are by Collard, Dellas & Smets (2009), Kormilitsina (2011), and, Neri and Ropele (2011) who quote both PCL86 and an earlier, 2010 version of Levine, Pearlman, Perendia and Yang (2009-2012) that they used as one of models for their solution also based on symmetric partial information. In addition, Adam and Marcet (2011) provide a model of so-called Internal Rationality, which reflects an idea that households behave fully rational but based on only limited information they can obtain and process.

5.1.3 Asymmetric Imperfect Information

More recently, building upon PCL86 and asymmetric partial information model of Svenson and Woodford (2003b), Lubik, Matthes and Mertens (2016) developed a

partial information solver for linear rational expectation equation system (LRE) inspired by, and that of Farmer, Khramov and Giovanni (2015). They emphasize differences between their and the work of PCL86, which they consider as a special, simpler case of their model and which, this research is using as its starting point too. They provide a set of solutions showing how varied imperfect information can lead to different equilibria based on what appears, the lowest common denominator of available information processing (filtering problem) capabilities among the agents and the nature of information. In addition, Feve, Kass-Hanna and Pietrunti (2016) develop another DSGE partial information model for treating imperfect real-time data and Hauk, Lanteri and Marcet (2014, 2016) use another PI DSGE solution to model optimal policy with endogenous and general signal extraction respectively.

In another recent and discussion triggering work, Gabaix (2016) raised a controversy analysing a NK model with “myopic”, not fully rational but boundedly-rational agents, ignorant of unusual events and unable to perfectly anticipate future, distorting general equilibria. He does not provide partial information solution but instead, simulates different agent's information asymmetry by means of weights of their “myopia”. He then claims that his model with myopic agents allows even for a passive monetary policy, thus, not just active one, to gain determinate equilibrium rather than multiple ones. However, one of his conclusions is that in such framework myopic agents are not Ricardian as they do not fully anticipate future effects of tax cuts so that the fiscal policy becomes much more important and powerful.

Remark: It needs to be said that, those recent finding of Lubik, Matthes and Mertens (2016) that economy converge to different equilibria based on what information is available are similar, if not in line with the much earlier (2008-10) findings of this research based on implementation of PCL86 where different assumptions of various information availability to the agents would create different responses and hence reaction in the economy (see later in this chapter, in 5.6.1).

5.1.4 Forecasting the forecasts of others and Optimal Policy under Partial Information

It is however also a question whether the economies are operating in the Pareto optimum manner, or as either irrational or simply adaptive reactions to disturbances in a competitive and uncooperative environment leading to an under-performing, local, Nash equilibria where one can only fit models to data, assume Bayesian rational expectation and that only a local equilibrium optimisation takes place (Kirman (2011), see earlier reference to Banerjee(1992)).

The above issue has been underlined by the problem of “forecasting the forecasts of others”, i.e. modelling of an infinite, explosive, iterative process of deriving one’s expectations on the basis of an estimation of expectation and pricing decision making of other rational agents such as policymakers and micro-economic agents (Townsend 1983 and Sargent 1991). The later approaches used frequency-domain (Kasa 2000) or, a combination of recursive methods, Kalman filter and sub-space methods in the time domain (PCL 1986, and, Pearlman and Sargent 2002) to deal with situations of asymmetric or incomplete information.

For deriving optimal policy in such complexity and imperfect information, Svensson and Woodford (2003a) state that, under usual linear estimation principles for purely backward-looking models and quadratic (welfare) loss functions, the principle of certainty equivalence applies to the derivation of optimal policy by policy maker whether the state of economy was fully observable or not. However, in case of forward-looking Rational Expectation models the situation is more complicated if for no other reasons than for the problem of forecasting other's forecasts, and optimal policy becomes sub-optimal over time leading to time-inconsistent discretionary (reputational) policy strategy.

The authors however refer to the PCL86 solution saying that it provides rather a complex, partial symmetric information Kalman filter solution⁷¹ that allows for

⁷¹ They provide a partial information solution they claim is more intuitive than that of PCL86

certainty equivalence under non-optimising, time-consistent, regimes, either discretionary or non-discretionary, and that Pearlman (1992) provides a solution for the optimising regimes also showing that certainty equivalence applies in both commitment and discretion models.⁷²

Another important contribution to imperfect information literature was Woodford (2003), who used a model of imperfect competition pricing decisions of the form weighted sum of current estimates of market price levels and output. Woodford then goes to demonstrate how the Townsend's (1983) method of estimating the overall average of others' estimates can be reduced to finite-dimensional form.

5.1.5 Information, price and wage stickiness

Most of contemporary DSGE have NK micro-foundations and models of price and/or wage rigidities (stickiness). The Calvo price contract stickiness parameters (ξ_p) is usually estimated by DSGE models to be well above 0.8 that relates to the probability of contracts being negotiated to less than 0.2 in each observation period and that they are renegotiated in periods exceeding an average of 5 quarters. This, however, does not reflect reality and observations indicate renegotiation periods on an average are just above 4 for European markets and even less for the US.

Some authors link (rational) inattentiveness with information and price stickiness. For example, Reis (2008) introduces asymmetric in-attentiveness as a main cause of the information, and consequently, of the price and wage stickiness at all levels of economic market - among firms, labour and consumer groups, each having potentially different level of attentiveness. Using both Euro and US data Reis (2008) concludes

⁷² Woodford and Swenson also state: "Certainty equivalence means that the estimation of the partially observed state of the economy can be separated from the optimization, the setting of the instrument so as to minimize the intertemporal loss function...(...). In the case of commitment, "certainty equivalence" means that the optimal instrument settings are the same linear function of the current estimate of the predetermined variables describing the state of the economy *and specific Lagrange multipliers* (related to the value that alternative expectations would have had in the previous period's policy problem) as in the case of the corresponding optimal policy problem under certainty."

that US and European firms show similar levels of attentiveness, whilst US labour and Euro consumers show more attentiveness than their respective counterparts across the ocean.

Several research projects concentrating on modelling and taking into account various aspects of partial information however, managed to reduce the estimates of the Calvo contract factor ξ_p closer to the observations. Martinez-Garcia (2007), concentrating on asymmetric information being available to different, heterogeneous agents in the area of foreign exchange, estimates 3-3.5 quarters and works of Levine, Pearlman and Perendia (2008) and Levine, Pearlman, Perendia and Yang (2009-2012) focusing on partial but symmetric information and the US data. The results of their later research are consistent with those of the authors' earlier work and estimate average contract lengths of 4 periods showing advantage of partial information assumptions (and PCL86 PI model solution method) for DSGE parameter estimation.

5.1.6 Volatility and Imperfect Information

Here we explore if incomplete information leads to higher swings in agents' expectations.

For example, Pearlman (1992) states that Minford and Peel (1983) and Currie and Levine (1985) showed in the early 1980s that imperfect, incomplete information of contemporary price levels leads to higher volatility of asset prices, exchange and interest rates⁷³. Similarly, Martinez-Garcia (2007) indicates that imperfect, asymmetric information may be one of the main factors contributing to the observed high volatility on forex markets. He argues that “...*whenever agents are informationally-constrained, their responses are lagged and re-balancing consumption expenditures across countries requires a more volatile exchange rate.*”

Such volatile behaviour is consistent with earlier mentioned mood swings and self-

⁷³ Indicated in Pearlman (1992), but the source materials were not available

fulfilling prophecies resulting from combination of imperfect information and the consequent, prevailing “animal spirits” herd behaviour, and also, from adherence to such majority swings by rational agents and, as Gabaix (2016) recently showed, the so called “myopia” of incomplete, partial asymmetric information being available.

5.1.7 Conclusion

The previous sections presented several models of Imperfect and Partial Information and outlined concepts behind their implementations. It also outlined several advantages of use of imperfect information models such as being more realistic in simulating delayed, hump-shaped responses to shocks as well as many them being better at modelling complexity of forecasting forecasts of others, volatilities caused by so-called “animal spirits”, usually borne from uncertainty and myopia of incomplete, partial, information.

5.2 PCL Method for Solving and Testing Partial Information RE Models

5.2.1 Background of PCL86 Imperfect Partial Information in DSGE Models

As mentioned earlier, most of modern DSGE models and tools (e.g. BayesDSGE and Dynare, prior to their enhancements for PCL86 solver), and for most of the time, use variations of the Blanchard and Kahn (1980) or its generalisations (e.g. by Sims 2002a, or, Collard and Juillard 2001 perturbation based solution for Dynare). They generally provide asymmetric information solution procedures to obtain a closed form solution of the linearised model. Along the line, these solutions assume that not all information is observable by the authorities but is by the private agents.

To correct such unrealistic assumptions, Pearlman et al. (1986) (PCL86) provided a non-optimising - a sub-space and Riccati equation based solution for partial information, forward-looking Rational Expectations DSGE models whilst enhancing the solution given initially by Blanchard and Kahn (1980). PCL86 also provides and

uses a partial-information extended recursive Kalman filter that enables estimation of the extended, partial-information model. As mentioned earlier in Ch. 5.1, PCL86 solution and its version of Kalman Filter are first RE DSGE solution for Bayesian estimation of imperfect information using the current estimate of the current values, e.g. $p_{t,t}$, to be provided as an extension to Blanchard and Kahn (1980) RE DSGE solution. I.e. Blanchard and Kahn (1980) solve linearised model around steady state:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (5.2.1.1a)$$

$$w_t = \begin{bmatrix} K_1 & K_2 \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + v_t \quad (5.2.1.1b)$$

Where w_t is observation vector and eq. 5.1.2b observation equation. PCL86 extension, using earlier notation, solves the following model:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} H_{11} & H_{12} \\ H_{21} & H_{22} \end{bmatrix} \begin{bmatrix} z_{t,t} \\ x_{t,t} \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (5.2.1.2a)$$

$$w_t = \begin{bmatrix} K_1 & K_2 \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} L_1 & L_2 \end{bmatrix} \begin{bmatrix} z_{t,t} \\ x_{t,t} \end{bmatrix} + v_t \quad (5.2.1.2b)$$

NOTE: A reduced version of PCL (1986) solution model adjusted to ByesDSGE system has been described in detail in Appendix 1 to this document.

The model for implementation for Dynare DSGE system required additional modification and adjustment of the original PCL 86 solution. For details on partial information implementation in Dynare, please refer to Pearlman (2009), Perendia (2010d), Levine and Pearlman (2011), and, as well, Dynare users' manual and on-line code.

5.2.2 Use of PCL86 Solution for Partial Information in DSGE Models

A partial (imperfect) information approach can be seen as an attempt to provide a

model for bounded rationality driven agents within a Rational Expectation DSGE framework solution, when agents make decisions without having full knowledge of all current shocks affecting endogenous, unobserved variables. If a model has as many shocks as observables, n (as recommended by the most of DSGE literature) then a partial information solution of a p -variable model will assume position that all n shocks can be derived from an $p \times p$ covariance matrix and equation system of $p-n$ unknown and n known observations. As a result, both the solution and the estimation results will be exactly same as in case of the standard (e.g. Dynare) full, but asymmetric information knowledge model.

However, if the researchers increase the number of shocks (or reduce the number of observables), the partial information solver will assume the position that not all shocks can be derived and both the model solution and the estimation results will differ from those of standard DSGE solutions such as Dynare⁷⁴ perturbation based ones.

NOTE: For more detailed user guidelines of the PCL86 solver and facilities within Dynare, please refer to Perendia (2010d) and, as well, Dynare users' manual.

5.2.3 Evaluation Methodology for PCL Solution and New Enhancements

5.2.3.1 Parameter Estimation and Model Shock Simulation

One of the aims of this research was to apply and test the PCL86 partial information DSGE solution by applying both the old and the enhanced solution method on US macroeconomic datasets under various shocks and then present a comparison of the results. In addition to using variety of known, standard DSGE models, a number of modelling enhancements and extensions to those models have been made in the course of this research so that those specific enhancements can be tested in their own merit

⁷⁴ Dynare also provides for Bayesian VAR estimation on lines of Sims & Zha (1996) and the DSGE-VAR combination for model miss-specification assessment and comparison based on del Negro Scharfheide (2004), del Negro Scharfheide Smets Wouters (2007) and, after adjusting for partial information PCL86 soleution, used in Levine, Pearlman Perendia and Yang (2009-2012)

against the original models using standard DSGE solutions. However, in line with the underlying theme of this research, those new, models enhancements introduced in this research are estimated and simulated also using PCL86 partial information solution to assess what effect and differences the PI approach could have made.

5.2.3.2 Data

With the exception of the first work undertaken during this research study, Levine, Pearlman and Perendia (2007), which uses EU data covering the period 1970Q1 – 2005Q4 obtained from the Area Wide Model database, all other research models were estimated using US data from several sources. This was case mainly because US data and estimation parameters based on them informally represent a de-facto standard economic research benchmark for models and results comparisons. The obtained model parameters scoring the highest likelihood of the fit to data were then used for IRF simulations in most of the cases.

5.2.3.3 Model and Solution Evaluation Methodology

Del Negro and Schorfheide (2006) advance methods for comparing models and ranking their possible, relative miss-specifications whilst recent work of e.g. Wieland et al. (2016) suggests sets of complex methods for model comparisons. However, most of results' comparisons in this research will be between those obtained from Bayesian estimations of similar or the same models being estimated with the same or similar data sets, in few cases with added time series, however, using different solution methods. Considering such relative minor model differences, the main criteria for assessing quality of either the enhancements to the models or to the solution mechanisms will be comparison of the posterior marginal likelihood levels along the suggestions of Geweke (1998).

5.2.3.3.1 Comparing DSGE Models using Posterior and Marginal Densities

For comparative purposes, with the DSGE toolkit, one can estimate model data and evaluate it against other similar models, comparing marginal densities whilst keeping data and priors constant and common. These densities are dependent on

- 1 Model parameter set θ_M and their priors ,
- 2 dataset (Y_T)
- 3 model variations (R_i)

More specifically, the posterior probability density:

$$p(\theta | Y_T, R) = \frac{p(Y_T | X) * p(\theta | \mathfrak{R})}{\int p(Y_T | X) p(\theta | \mathfrak{R}) dv(\theta)}$$

$$= \frac{p(Y_T | \{\theta, \mathfrak{R}\}) * p(\theta | \mathfrak{R})}{p(Y_T | \mathfrak{R})} \sim p(Y_T | \{\theta, \mathfrak{R}\}) * p(\theta | \mathfrak{R}) \quad (5.2.3.3.1.1)$$

Its denominator, referred to as marginal density for e.g. a model R , $p(Y_t|R)$, can be expressed as integral over all model R 's parameter sets can be calculated using full integration or estimated as a discrete sum, of all conditional likelihood nominators for all parameter sets.

Different models are likely to have different probability of single dataset across all of their parameter sets and are therefore, expected to have different marginal density denominator even for common dataset. Among others Smets and Wouters (2003) and Adjemian (2008) test and assert that the marginal density computation can be simplified with use of either Laplace transformation or modified harmonic mean (as suggested by Geweke (1998)) to evaluate marginal density integral over the sample with similar accuracy, instead of computing full integration.

For further details on Kalman filter based Bayesian DSGE estimation, the posterior density for a state space system see Geweke (1998) or, for its Dynare implementation, Appendix 3 or Adjemian (2008).

5.2.3.3.2 Empirical comparison

In addition, we will empirically compare the “proximities” (i.e. inverse of differences or errors) either of the estimated parameter values or of the responses of the IRFs to various shocks in comparison to the empirically observed or theoretically expected values.

This integral denominator of the posterior density equation is constant for a model using same data set so that it can be ignored if only probability of different parameter sets conditional on parameter set needs to be assessed for a single model, and the model parameter estimates can be then compared based on the nominator estimates only.

The nominator is usually expressed in logarithmic form for a state-space Kalman filter based estimation and its right part, probability density of the data sample usually calculated within the Kalman filter, one for each time-step vector y_t in the time sequence Y_T as log likelihood ($\ln L$) of model for given data sample (or probability of data sample for given model):

$$\ln L = -1/2 * [T * n * \log(2 * \pi) + \sum \ln \det(\text{cov}(e_t)) + \sum e_t^T (\text{cov}(e_t))^{-1} e_t] \quad (5.2.3.3.2.1)$$

where T is the length of the data sample and n - the number of observed variables in the sample and e_t - a vector of prediction errors for each time step's. To obtain full measure of the nominator in logarithmic form used for parameter set likelihood comparison, Dynare and other DSGE estimation tools, calculate and add logarithm of the joint prior density $\ln P(\theta) = \sum \ln P(\theta_i)$ (see Adjemian (2008)).

5.2.3.3.3 Expectations

The main theoretical expectation in estimation and simulation of PI models solutions would be that either their parameter value or the simulated IRF (or both) outcomes show more empirically and theoretically realistic, slower, delayed reactions of those

unobserved endogenous variables to the shocks through either the value of their associated parameters or hump-shapes of their IRF curves.

5.2.3.3.5 Extended DSGE-VAR Evaluation Tests

In case of one of the enhancement projects undertaken in this research, encompassing more complex model enhancements to the standard, single representative agent NK DSGE models, the models were also evaluated using DSGE-VAR along the lines of Del Negro and Schorfheide (2004) and their background work. Levine et al (2009-2012) that used DSGE-VAR as an additional, model miss-specification evaluation method for its variety of models of the heterogeneous agent enhancement to standard DSGE, for both of the two solution mechanisms, the standard Dynare asymmetric and the PCL86 PI extension, partial imperfect information too. However, since that project is already explained in detail in a publication, it will not be detailed in this research.

5.2.3.4 DSGE Work-bench Systems Used

Two different DSGE solution, estimation and simulation workbench systems have been enhanced and used to enable solving and estimating models and running their IRF simulation under different, standard asymmetric full and symmetric imperfect informational assumptions using the solution for partial information modelling developed in PCL86.

- 1) BayesDSGE, a small-scale DSGE workbench that was originally developed by A. Justiniano who made it available in the course of a preparatory implementation and evaluation of PCL86 Partial Information sub-system work preceding this project (see next sub-chapter below). This research project, at its start, used it in Levine, Pearlman and Perendia (2007) and Perendia (2008) initial yield curve fitting research work.
- 2) Dynare, a very comprehensive set of DSGE tools, initially developed by M.

Juillard at CEPREMAP and enhanced regularly by a team of researchers and specialised developers. It was enhanced for PCL86 sub-system and used for the most of research work on this project.

NOTE: For more detailed user guidelines of the PCL86 solver and facilities within Dynare, please refer to Perendia (2010d) and, as well, Dynare users' manual.

5.3 Initial Implementation Work and Tests

5.3.1 Initial Implementation

This project continues previous work (Pearlman and Perendia 2006 and Perendia 2006) so that, in its early stages, as in Levine, Pearlman and Perendia (2007) and Perendia (2008)), a modified BayesDSGE system of Matlab routines was used. Comparing to Dynare, BayesDSGE is a simpler, two-stage solution variant of the standard MCMC DSGE tool based on the recursive State-space Kalman Filter MLE and Bayesian MCMC Random-Walk Metropolis-Hastings algorithm methodologies⁷⁵. BayesDSGE was initially developed by A. Justiniano around C. Sims' '**gensys**' and '**csminwel**' algorithms (See Sims 2002a) and also used in e.g. Batini et al. (2005 a and b).

The BayesDSGE system was then extended by implementation of

- 1) two modifications aimed directly for PCL86 solution and estimation: one for modified general solution subsystem, and the other for Kalman filter estimation sub-system with aim to support the partial (but symmetric) information assumption based on the solution provided in PCL86.
- 2) In addition to the direct support for PCL86 enhancement to standard DSGE, this project provides another, the so-called Factor-Augmented VAR (FAVAR) data rich estimation econometric extension. The PCL86 in particular was deemed

⁷⁵ Results from both stages are reported in Appendix 3.

well suited for a further, FAVAR data-rich enhancement to both DSGE in general and PCL86. This PCL86 enhancement was designed upon the model of data-rich estimation model of data as imperfect indicators driving Factor-Augmented VAR (FAVAR), specified and used in Bernanke and Boivin (2003), Jacquier et al. (2004) , Bernanke, Boivin and Elias (2005), and, Boivin and Giannoni (2005)⁷⁶ (see also Appendix 2.a)

NOTE: This version of PCL (1986) solution model adjusted to the BayesDSGE system implementation as well as an outline of the modifications to the BayesDSGE system have been described in detail in Appendix 1 of this document. (The BayesDSGE system technical modification is described in more detail in Appendix 1.6). Also, due to alternations to implementation of PCL86 into Dynare and complexity of Dynare system FAVAR-like extension was not ported and implemented in Dynare system.

5.3.2 The Initial Models

The two NK models estimated in the very early stages of this project were both derived from Smets and Wouters (2002 and 2003) model. The first, used in Levine, Pearlman and Perendia (2007), as noted earlier, was estimated using EU data. The model and its results were in detail described and discussed in the paper available on line and will not be covered here. One of its features, however, the rich data FAVAR-like option extension was not covered in detail there; however, it is explained in Appendix 2a of this work.

The second, used for the early version of yield curve fitting in Perendia (2008), was based on the model used in Pearlman and Perendia (2006), also a small, single and closed country, a subset version of standard New-Keynesian (NK) models as defined in Smets and Wouters (2002 and 2003). It is also closely based on the model used in Batini et al. (2005 a and b), and Levine et al. (2006), however, extended with the wage

⁷⁶ For example, Bernanke & Boivin 2003 build upon the work of Stock & Watson (1999) who conclude that “the best-performing forecast for inflation is an augmented Phillips curve forecast that uses a new composite index of aggregate activity comprised of the 168 individual activity measures”.

equation based on the one used in (Smets and Wouters (2002) and (2003)). Alike the first model above, it also featured data-rich option for estimation FAVAR-like noisy factor data along the lines of BG05, however, here used in yield curve fitting mechanism. It was estimated using US data with the treasury yields obtained from US Fed Reserve database, augmenting the overall data fit log-likelihood. Again, the rich data FAVAR-like option extension used is explained in Appendix 2a of this work. The initial model and its log-linear linearization around the steady state, are described in Appendices A2b and A2c respectively.

In the remainder of this section an explanation of those models is presented and it is closely based on the main source material, namely work of Smets and Wouters (2002) (SW02 henceforth).

Please see Appendix 2b that replicates the model used and described in detail in Perendia (2006) and also, used in Pearlman and Perendia (2006) and Perendia (2008). Appendix 2c outline the model's log-linear linearization around steady state.

5.3.3 Initial Estimation using US data:

That work project then:

1. Reproduced some of the results of DSGE asymmetric-information US macroeconomic parameter estimation and forecasting work by Boivin and Giannoni (2005) (BG05) and Smets and Wouters (2003),
2. Applied the enhanced, partial information method on US macroeconomic datasets to forecast macroeconomic factors under shocks inside sample.

Both the earlier and this work then evaluate differences in the estimation accuracy and the extent to which accuracy of forecasting business cycles using DSGE methods can be improved by the estimation method developed in PCL86. It provided motivation and basis early stage of this research and presentation Perendia (2008).

5.3.4 Additional Discussion on Early Estimation Results

In all early estimations using PCL86 in BayesDSGE one can observe a significant difference between the part and the asymmetric information model estimates and both sets of results from this research and those of some other researchers. The partial information estimates are particularly significantly lower for consumption and wage indexation factors (ξ_c and ξ_w), higher for (differentiated, skilled) wage mark-up: λ_m , and significantly higher for labour disutility Φ (i.e. σ_1) (i.e. lower labour inter-temporal elasticity) (e.g Please see the results in Appendix 4)

Even the authors' asymmetric-information estimates for indexation are lower than the results reported by other studies covering longer data samples (e.g. Boivin and Giannoni (2005) covering 1965-2002 and Smets and Wouters (2003) starting back in 1957).

In de-Walque, Smets and Wouters (2005), the authors pay their attention to the estimates of price and wage “stickiness” factors in their previous (2004) work (i.e. $\xi_p = 0.89$ and $\xi_w = 0.71$). They found those variables were over-estimated in comparison with the observed micro-data, This means that their estimates indicated much longer contracts (e.g. approx. over 10 quarters for prices) than the observed (approx. 4-8 quarters) and they devised a method based on the grouping of firms into “cohorts” by price category by which they were able to show a lowering indexation estimates.

However, this division effectively creates semi-isolated “economic islands”, for groups of firms where information and labour can flow easily within the island but not much so between those islands –not entirely dissimilar to the Lucas’s island. This has a dual effect. First, the creation of economic clusters which are known to increase the fluctuation of labour and the information sharing within them, but has an overall effect that the overall demand elasticity for labour and information share is lower.

Consequently, the second effect is that they also create a situation of information partialisation, i.e. the cohorts have full information within but only limited information outside their “islands”. In this manner, they effectively create a partial information situation and the resulting model does yield lower indexation estimates similar to the PCL model – but their estimates are valid only within the cohorts, not for industry as whole.

The estimates in this research, using both the asymmetric and, even more so, the partial information estimates show values which are substantially lower than their original estimates, without the need for market sub-structuring. It is then, however, possible that both, the estimation on the data window from the last twenty years and the use of higher precision, partial information, estimation model, indicate some of the changes in the economy in recent decades. For example, it may indicate the higher impact of technological developments (e.g. of the internet and information technology) and/or reflect the recent increases in the collection and the assessment of marketing data at micro-agent level and indicate the effect of such changes on lowering price stickiness and increasing frequency of price optimisation⁷⁷. This, however, needs to be clarified by additional research, for example, applying the part-info estimation to the same period as in Smets and Wouters (2003). Similarly, it is also possible that the authors’ estimates of λ_m and η indicate the effects of changes in the recent decades, marked by an increased frequency of short-term contract based employment, and the associated (re-)negotiation of the wage contracts.

In the longer term, it is worth investigating to which extent both of the above micro-agent factors could have contributed to decrease in both inflation and inflation related shocks over the past decades rather than attributing this effect solely to the inflation targeting skills of central bankers⁷⁸.

⁷⁷ For example, the consumer price indexation parameter ξ_c in the part-information model reflects much more realistic estimate of price contract lengths of about 3 months rather in comparison to the contracts estimates of more than a year in some other model estimates (i.e. when $\xi_c \sim 0.8$).

⁷⁸ Justiniano, Kumhoff and Ravena (2006) find that short (one to two quarter) price contract business cycles are still compatible with the observed inflation persistency and that Calvo type price stickiness,

It is also possible that, the higher precision of partial information estimation similarly points to other possible effects of technological developments that have led to the increase in demand for skilled, differentiated labour and the wage mark-up $(1 + \lambda_w)$ and the inversely related lower elasticity of the specialised labour demand $(\eta = (1 + \lambda_w) / \lambda_w)$. Similarly, the rise in marketing methodologies and market analysis technology may have led to the increase in overall role of consumer preferences (and the new-brand release preference shocks) relative the technology shocks. This change is expected to have led to the (relative) increase of the preference shock factor over the technology shock factor, the ρ_{pref} and ρ_{tech} respectively.

Also the increased likelihood of the part-info estimations with a larger number of series and the consistency of their estimation results show the ability of the PCL86 method to cope and take substantial advantage of the additional, noisy indicator data sets in data rich environments.

5.4 Using Partial Information Solution to Fit Yield Curve

This section partially reproduces work Perendia (2008).

5.4.1 Overview (Abstract)

At early stage of this research project, an experiment was done to use multiple Taylor-type equations as extension to the above described large dataset model, one for each different maturity treasury yield. The starting point and motivation was to parallel work by De Graeve, Emiris and Wouters (2007) and (2008) that extends Smets and Wouters' DSGE model with term structure for bond yield along the lines of extensions of structural NK models in research programs conducted by several authors showing advantages of DSGE implementations over structural model implementations.

due to intermediate product price aggregation and their random optimization adjustments occurring at different times. (re Justiniano, Kumhoff and Ravena (2006): **Multi-Sectoral Cascading and Price Dynamics - A Bayesian Econometric Evaluation**, unpublished paper).

However, the Perendia (2008) research work is taking a slightly different approach to Taylor rule and it is estimating yields using the above combined Taylor rule, extended by the Hull and White model of term structure (see Appendix 8), with both, the standard, full (asymmetric) information DSGE model and the PCL extensions to the linear Kalman filter. The results provided a better fit in general than the standard model. This experimental work was partially replicated with similar YC extension to the SW07 model with news and unemployment in the fiscal rule, as in Perendia and Tsoukis (2012), but not in Partial Information mode (see Appendix 7).

Note: An additional discussion related to this project is included later, in context of chapter 6.6 and data in Appendix 7.

5.4.2 Background

An article by De Graeve, Emiris & Wouters (2007) and (2008) extends Smets and Wouters' DSGE model with term structure for bond yield. Their rationale was that the current macroeconomic models are insufficient, leading to inadequate yield prediction and rational expectations, and those authors proposed a more rigorous model of macroeconomy, which allows more rigorous formation of rational expectations of the term structure in DSGE models.

They achieved a substantial explanatory coverage of the yield fluctuations over the past forty years and improvements in out-of-sample predictions of the yield changes, and also, related to that, improvements in predictions of the GDP changes from the interest rate and term spread fluctuations. They also base their model on a variation of Smets and Wouters (2007). However, they extended it with a more rigorous model of inflation targeting; by adding time-varying inflation targets. As a result, they succeeded to match the model to the more realistic observed variations in long- term future interest rates (and, hence, their expectations) than has been achieved in the standard macro-economic models which tend to model them as rather flat.

5.4.3 Fitting Yield Curve in Standard and Partial Information DSGE Models

5.4.3.1 Fitting yield curve using DSGE

It is suggested in DEW07 for the term structure to be modelled with RE and in line with the risk-neutral, “perfect foresight” valuation methodology and Pure Expectation Hypothesis (see also Curtberthson 1996, pp224,226), modelled “as a weighted average of expected future short term interest rates:”

$$R_t^n = 1/N E_t \{ R_t + R_{t+1} + R_{t+2} + \dots + R_{t+N-1} \} \quad (5.4.3.1.1)$$

The authors then extend the state space of the RE DSGE model with forward rates and yields. They consider several possible ways of estimating the yields within the recursive state space model. One approach is to take the risk-neutral assumptions that time t expectation of short rate is “tomorrow’s” (time t+1) forward rate and progress with estimation in forward recursive manner.⁷⁹ The second approach takes into account risk premium and uses a log-linear RE solution with a lognormal approximation of a stochastic discount factor as used, e.g. by Wu (2005).⁸⁰

However, DEW07 selected yet another, the third approach, and simply extend the space state system matrix with an additional set of state variables R_t^N where N is bond maturity in periods (N= 4, 12, 20 and 40 for 1, 3, 5 and 10 years respectively) and extend the observation matrix with four equations in the form of :

$$R_t^{N \text{ obs}} = c^N + R_t^N + \eta_t^N \quad (5.4.3.1.2)$$

⁷⁹ This would probably require running a 40 step forward simulation for each estimation step.

⁸⁰ Wu does not use the traditional linearised DSGE model as he states that the DSGE model first order linearization of Euler equation leads to risk -neutral “certainty equivalence” solution which, in turn, renders all assets’ returns identical and makes such linearization unsuitable for asset pricing research. Instead, he uses a two-step solution strategy: log-linearization of Euler equations as usual for macro models and then, log-normal bond pricing Euler to derive risk compensation terms.

Where

$R_t^{N \text{ obs}}$ is observed expected yield on a zero coupon bond over N periods as of time t,

c^N is a constant aimed to capture mean yield

R_t^N is the current PEH based estimate of the observed (expected) yield rates R_t^N over N periods (where N=4, 12, 20 and 40).

η_t^N is the measurement error and its fluctuations are expected to be closely related to, and capturing, the fluctuations in the term risk premium.

Such an extension, however, does not relate the observed and estimated yields for different periods (other than the one period bank rate) to the system of endogenous variables and equations other than by means of time-variate state-space error var./covar matrix.

The observed current interest rates for different periods, however, are not observations of the factual, measured values of those interest rate/yield curves (those will be known at the end of the lending period), but are observations of the current (rational) expectations of those future interest rate yield curves, in a similar way to the equity prices which are current expectations of future income curves. They are therefore rational expectations of future economic equilibrium behaviour, and the longer the interest rates' periods, the less they are influenced by the current fluctuations⁸¹.

In their budget constraint equation the authors also include an exogenous risk premium ε_t^b on return on holding default-able bonds as opposed to risk-free assets, similar to the model of Goodfriend & McCallum, (2007). Again, however, they do not seem to make that risk premium relate to the above- mentioned yield observation errors (η_t^N) which should reflect the risk premia.

5.4.3.2 Fitting yield curve using Partial Information and FAVAR enhancement

This research is taking a somehow different approach and it is estimating yields using

⁸¹ The currently observed spot prices of goods on the markets are, on the other hand, not measurement of RE of their future demand but of their spot demand.

the combined Taylor-type rule, extended by the Hull and White model of term structure, (See Appendix 8) and via both, the standard, full (asymmetric) information DSGE model and the PCL extensions to the linear Kalman filter. The results provided a better fit in general than the standard model. (Perendia (2008))

The better fit to data is achieved on a few fronts:

- 1) **Provision and use of PCL86 model solution for more correct partial information assumption.** Most economic estimates, including those using DSGE models, are done using contemporary observations, with values from databanks at time t and assuming knowledge of the shocks at time t too.

However, in reality and in so-called real-time situations when decisions are made, not all that assumed information is available, and some observed endogenous data (series) are not available at time t for time t but only as one-period lagged values.

The PCL86 framework allows a solution for the more correct assumptions that some but not all observable information and shocks are only available as one period lagged values (e.g y_{t-1}) rather than at time t .

- 2) **Provision of a framework to use of FAVAR-like data-rich extension,** introduced as an enhancement to PCL86 to augment estimates using a large number of additional data (series) that are available at time t though, as inaccurate and noisy observations.

In addition, the PCL model with extension as defined and used in Pearlman and Perendia (2006) and Levine, Pearlman and Perendia (2007) allows for establishing an even larger variety of functional and estimated relations between the noisy input data and the model's endogenous data. In this current research, longer term Treasury rates are handled as noisy observations and put in relation to the endogenous variables in a form of a Bayesian regression for which parameters may be either pre-calibrated or estimated during the DSGE Bayesian estimation process:

Treating the additional yields via PCL extensions should provide a better fit in general. More specifically, the PCL model with the FAVAR-like Bayesian regression extension (Pearlman and Perendia 2006 and Levine, Pearlman and Perendia 2007) allows for estimation of an even larger variety of relations between the yield rates and the endogenous variables in an extended measurement equation.

5.4.3.3 Measurement equations for yield curve using FAVAR

- 1) related directly to the estimate of one-period rate:

$$\mathbf{R}_t^N = \mathbf{a}^N \mathbf{R}_t + \boldsymbol{\eta}_t^N \quad (5.4.3.3.1)$$

- 2) A very simple but complete Taylor/Hull & White model: spread between the long-term (e.g. 10 year, 40 period) and the one-period rates related to the contemporary output gap $y - y^*$ between the real and the flexible price economies:

$$\mathbf{R}_t^N = \mathbf{a}^N \mathbf{R}_t + \mathbf{b}_y^N (y_t - y_t^*) + \boldsymbol{\eta}_t^N \quad (5.4.3.3.2)$$

- 3) A more complete Taylor / multifactor Hull & White model: the spread between the long-term (e.g. 10 year) and the one-period rates related to both the contemporary output gap $y - y^*$ between the real and the flexible price economies and the inflation gap between current inflation and inflation target.:

$$\mathbf{R}_t^N = \mathbf{a}^N \mathbf{R}_t + \mathbf{b}_y^N (y_t - y_t^*) + \rho_\pi^N (\pi_t - \pi_t^*) + \boldsymbol{\eta}_t^N \quad (5.4.3.3.3)$$

In addition, using the FAVAR-like Bayesian regression extension to the PCL model, the researchers can derive the weighted sum (or average) of error $\boldsymbol{\eta}_t^N$ related to exogenous risk premium ε_t^b :

5.4.3.4 The Model, Data, Priors and Results

The core model used in this project is the same one used in Perendia (2006) and Pearlman and Perendia (2006), extended using above measurement equations for additional, noisy, data representing yield curve of zero-coupon treasury bonds. Again, the rich data FAVAR-like option extension used is explained in Appendix 2a of this work, and, the initial model and its log-linear linearization around the steady state are described in Appendices A2b and A2c respectively.

Main data and priors (mostly taken from SW03) are in Appendix 3 and the additional Treasury bond rates were taken from Datastream. The priors for the output and inflation gaps in the additional YC measurement equations were same as those for the corollary parameters in the Taylor rule equation.

The main estimation results for log-likelihoods and yield curve estimation parameters with yield curve fitted, are presented in Appendix 7.

5.4.4 Discussion:

The estimation results for the above cases 2 and 3 are in Appendix 7.

Whilst relation to the output gap shows a higher level of variance between the observations, the π -gap seems to be less prone to such variations. On the other hand, introduction of inflation gap to long-term yield curve equations increases fit likelihood dramatically, from 174.9 to 268.9 and indicates high explanation power of the inflation gap for the longer-term yield curve.

However, for both the Y_t and π_t gaps, a pattern consistent with the expectations clearly emerges: the longer the maturity is, the higher the spread weight load is, and thus, the higher the spread is between the contemporary spot interest rate and the longer maturity period yield.

NOTE: This work also has implication to analysis of the so-called conundrum of short and long-term interest rates moving in different direction in 2005 but it is deferred to the chapter 7 where it has more relevance.

5.4.5 Conclusion

This work shows that:

There are close relations between macro-economic, Taylor rule based models for deriving interest rate, the financial models for equilibrium forecasting (Vasicek) and the arbitrage-free fitting of yield curve (Hull and White). (see appendix 8).

There are few advantages of the Pearlman, Currie and Levine (1986 - PCL86) partial information model in utilising multitude of available real-life/real-time imperfect data as either contemporary or lagged data, endogenous or as noisy, auxiliary data in the Pearlman and Perendia (2006) Bayesian FAVAR-like data-rich extension to the PCL86 model introduced there and used here.

5.5 Comparative Tests of IRFs Using Dynare

5.5.1 Motivation and Method

The next stage of this research was porting PCL86 method to Dynare package and these tests were the initial comparative tests for differences in the outcomes of the PCL'86 solver to the Dynare DSGE modelling, solving and simulating package. The PCL86 solving an estimating method was integrated as part of a joint EU FP7 funded MonFisPol project⁸², itself aiming to show the benefits of new econometric methods for

⁸² Seventh Framework Programme for Research (FP7) of the European Commission's Socio-economic Sciences and Humanities (SSH) Program from October 2008 to September 2011 under grant agreement SSH-CT-2009-225149.

optimising monetary and fiscal policy models⁸³. Using the PCL'86 solver, PI Kalman Filter estimation and an IRF simulator modules augmented Dynare 4.0.2 software, the researchers run initial, comparative impulse response function (IRF) tests with the model using the common initial values for two different solution and IRF simulation methods:

1. The standard Dynare⁸⁴, with unrealistic assumptions of full information, and,
2. The new Pearlman SVD-based, general purpose, linear model solver tailored for integration and running of the PCL96 partial information estimation Kalman filter and the associated, iterative, IRF and forecasting simulation law-of-motion model within the Dynare system.

The tests were run as comparative proof of accuracy in four groups:

1. Standard Dynare `stoch_simul` IRFs for five variables: π_t c_t y_t r_t
2. the full information version of PCL law of motion IRF for five variables:
3. the partial information version of PCL IRF but with full information assumptions for the same five variables
4. the partial information version of PCL IRF with partial information assumptions:
 - a. only one variable being observed
 - b. several combinations with two variables
 - c. three variables
 - d. four variables
 - e. five variables
 - f. seven variables assumed being observed at the time.

⁸³ One of the aims of the Monfispol consortium project (<http://www.monfispol.eu/>) was to provide a PCL'86 Partial Information solution for estimation and an IRF simulation to Dynare DSGE package (<http://www.dynare.org/>) users, a project the author participated in from 2009-2010. This research is also a background for the resulting joint research report and publication of Levine, Pearlman, Perendia and Yang (2009-2012).

⁸⁴Original Dynare `mjdgg` solver and its IRF using `stoch_simul` manager

5.5.2 Model and Calibration

Model used for these tests is the rational expectation one described in Levine, Pearlman, Prendia and Yung (2010),⁸⁵ The model was first log-linearised assuming that variables are deviations from its linear steady state. It used only three observations, output y_t , inflation π_t and interest rate r_t from a sample of US data Q1:1970- Q4:2004, detrended as deviation from the sample mean. Its Bayesian estimation priors, their distributions and standard errors, and the fixed (pre-) calibrated parameters, were taken from the previous literature including, mostly, Smets and Wouters (2007) (please see the original paper for more details).

The IRFs were run under a subset of shocks present in the model:

Table 5.5.2.1: shocks present in the model used in the tests:

Shock	Description	Std. Error
eps_g	Gov. spending	1.67
eps_a	Technology	0.60
eps_ms	Price Markup Shock	0.50
eps_r	Interest rate	0.10
eps_c	Consumption	0.10

5.5.3 Results

The results from the first three groups were identical, showing that both the PCL solver and its partial information law of motion, IRF generator can comparatively accurately project model behaviour under the same, full information conditions for the same model as the standard Dynare package solver and IRF generator.

The respective results in the fourth group from IRFs, under a partial information assumption however, showed some differences from the other three groups. The results for the IRFs under partial information assumption were same as for those of the full information assumption when the researchers had five or more variables observed and

⁸⁵ This is an earlier version of the paper published in EJ in 2012, presented at the workshop at University of Surrey in 2010, available as "Endogenous Persistence in an Estimated DSGE Model under Imperfect Information," CDMA Working Paper Series 201002, Centre for Dynamic Macroeconomic Analysis. At : <https://repec.som.surrey.ac.uk/2010/DP03-10.pdf>

the same or nearly the same when four were observed. The small, but (in the graphs) visible, differences occurred when three variables were assumed to be observed. The differences were significant when less than three variables were assumed observed, but they also depended on what particular variables were assumed observed. A subset of the comparative graphs obtained, a subset useful for illustrating and assessing the effects of IRF simulation under different partial information assumptions (i.e. only part of the variables being observed, e.g. 2 or 3), is presented in Appendix 5.

Note: These early results are in line with the much later work of Lubik, Matthes and Mertens (2016) who also developed a partial asymmetric information solver for DSGE models, but, as they emphasis, different from the work of PCL86 which they consider as a special, simpler case of their model, and showing how varied imperfect information can lead to different equilibria based on the what appears, the lowest common denominator of available information processing (filtering problem) capabilities among the agents and the nature of information.

5.6 Further applications of the PCL'86 PI model

5.6.1 Persistency in Imperfect Information Models

The later revision of the above research work was included in the Levine, Pearlman, Perendia and Yang (2009-2012) started in 2009 as a part of a joint EU FP7 funded MonFisPol project. In a summary, this research provides a tool for estimating DSGE models by Bayesian maximum-likelihood methods under very general information assumptions. This framework is again applied to a NK model where the researchers compare the standard approach that assumes an informational asymmetry between private agents and the econometricians, with another, mixed rational and behavioural assumption of (all) imperfect informational symmetry.

For the former, private agents observe all state variables including shocks, whereas the econometricians use only data for output, inflation and interest rates. For the latter both

agents have the same imperfect information set and this corresponds to what the researchers term the '*informational consistency principle*'. The researchers first assume that rational expectations drive the agents and then generalise the model to allow some heterogeneous households and firms to form expectations adaptively. The researchers find that in terms of the model's posterior probabilities and on a comparison with the benchmark, the assumption of imperfect informational symmetry by the agents significantly improves the model fit.

The researchers also find qualified empirical support for the heterogeneous expectations / heterogeneous agents model with consumption habits comes out as a more realistic one and also, showing that majority but not all of both, household and corporate agents adhere to the adaptive expectations rather than the rational expectations (see next section in this chapter for detailed discussion on this issue of heterogeneity). Another significant finding, in line with the title, is that impulse response to a variety of shocks is humped, thus, slower to start but staying for longer and showing a higher level of persistency in partial symmetric than in the standard, asymmetric information, mode. **Please refer to the Levine, Pearlman, Perendia and Yang (2009-2012) article(s) for more details on the models, data, results and the additional discussion.**

5.6.2 Partial Information DSGE Models with Heterogeneous Agents

As mentioned earlier, heterogeneous agents' models (HAM) started to receive more research focus after the recent crisis. Most of the HAMs are based around behavioural modelling and the stochastic simulation of several economic agent segments, but the issues of estimation methods of such models are still mainly unresolved. Another issue is the determination of the number, the types and the relative proportions of the different segments of agents.

Levine, Pearlman, Perendia and Yang (2009-2012) make progress related to the estimation of relative proportions of four (two pairs) distinct groups of heterogeneous

agents. They assumed two main types, one being classical economic rational agents, and the other, adaptive-rational learning agents. Both of these groups are being distributed between the sectors of household and the business entrepreneurs/firms' agents.

5.6.2.1 Relevant Results

The results appear a bit surprising if taken from the perspective of modern, RE based economic theory:

- a. There is a higher proportion of agents following adaptive-learning behaviour than those adopting rational expectation consistent behaviour in both sectors.
- b. There is, however, a higher proportion of households than firms that behave in apparently rational expectations consistent manner relative to their adaptive counterparts. I.e. results show that a relative larger proportion of around 30–34% of households compared to only 17 – 25% of firms behave in a rationally consistent manner.

5.6.2.2 Discussion

The finding (a) is in some respect in-line with both, the theoretical position expressed earlier that only very largest institutions can be deemed to base their decisions using full available information in a rational manner (e.g. see discussion section in the previous chapter)⁸⁶. It is also in line with a similar lack of empirical evidence that agents are using or behaving in RE manner expressed in research findings, e.g. by Chow (2007) who shows that adaptive expectation models still have usefulness and dominance in modelling markets.

⁸⁶ It is also with the empirical/experiential observations of this author as an experienced commercial data analyst working at major international industrial organisations that, by majority, utilise more traditional regression or adaptive econometric rather than rational expectation models in their forecasting.

On the other hand, one can then conclude that, as majority of agents use by education or to simulate other assumed adaptive agents using adaptive methods, that the adaptive behaviour becomes a self-fulfilling prophecy and that it is fully rational to behave in the prevalent adaptive manner as it is assumed that others will adopt it too.⁸⁷

In addition, the apparent rational consistency prevailing among households may not be what it appears: as adapting and learning may require regular family weekend coffee table games or discussions to become focused on multivariate time-series analysis and the adaptation of. These activities are rather rare if not unlikely to be habitual family weekend behaviour. The apparent rational consistency may instead simply be a consequence of their adopted life-style rigidities and the intuitive habit formation based on their consumer experience.

This so-called habitual (i.e. procedurally – rational) behaviour may be driving some small and medium businesses too. Along those lines, it is interesting that such macro estimations roughly (though very tentatively) also echo some recent survey findings in the area of business firms' management, which have identified that a rather low proportion of the surveyed business managers base their strategic or tactical decisions on a thorough analysis of historical evidence and data.⁸⁸ Those findings also point out that managers tend to put much higher weight on a combination of their personal experience and forward looking risk, cost-benefit and overall business impact assessments instead.⁸⁹

However, even among firms, mainly among intermediate producers, the consistent rational expectation formation strategy may result from equally experiential reasons

⁸⁷ In a way, this is inspired by and a paraphrase on Akerlof and Shiller who claim that adopting a prevalent herd behaviour in a crisis is fully rational.

⁸⁸ The finding identifies that avoidance of the evidence-based approach is justified mainly by a variety of difficulties and costs rising in obtaining and then processing such data.

⁸⁹ This finding may not be so surprising considering that the most of the management training courses and books shy away from complex numerical rational expectations techniques and focus instead on various heuristic and common-sense, communicative rationality based business management methods whilst, at the same time, emphasizing that “businesses need to adopt new strategies so as to adapt to the ever- changing business environment”.

and a need for maintaining consistent market behaviour for the sake of retaining their long-term business partners, customers or shareholders in the larger firms. (see McClelland et al. (2010))⁹⁰

5.6.3 Some hypotheses for future work

A hypothesis is that, in the modern developed economy society, there would be an increasing proportion of smaller or single families relative to the large ones among those higher income, affluent families, and also, that of the lower income larger families, a trend that adds to both, the increasing inequality and increased saving among affluent ones. Another consequence (H2) would be that those affluent, traditionally Ricardian (as so often denoted in the early heterogeneous agent models, e.g. Levine et al., 2009), small families are increasingly becoming less and less Ricardian. This is not only because they are boundedly rational about the future effects in increasing complexity of the socio-economic system, but more likely so because they are increasingly rationally inattentional, one could say, less concerned about it. This is in part due to the (partially consequential) slow breakdown of intergenerational social contract, which makes even stronger argument for inadequacy of the infinitely - living (intergenerational) household economic models. (Also, the lower income ones remain less able to optimise consumption based on Ricardian principles mainly due to their low income and the resulting lower ability to save.).

5.6.4 IRF Simulation of Housing Prices and Borrowing Constraints with Imperfect Information

Iacoviello's (2005) model is one of the models available in the Macro-Model Database (for reference, see <http://www.macromodelbase.com/> and Wieland et al. (2010)). Here this research wants to pay special attention to this model as it extends the BGG

⁹⁰ A further analysis of this (?) however indicates that the older managers of larger firms tend more to commit to status-quo but is this because they are at that stage of their career becoming more risk-averse or are those characteristics and attitudes required for them to gain the position of a CEO in a larger and more successful firm?

financial friction DSGE models with a model of the effect of housing prices on consumption using three heterogeneous categories of consumers, two of which are two types of households: the saving, patient (Ricardian-type) ones and the cash-constrained, impatient ones. The former group is the only one group that follows the rational consumption model (in linearised form):

$$C_{1,t} = C_{1,t+1} - r_t \quad (5.6.4.1)$$

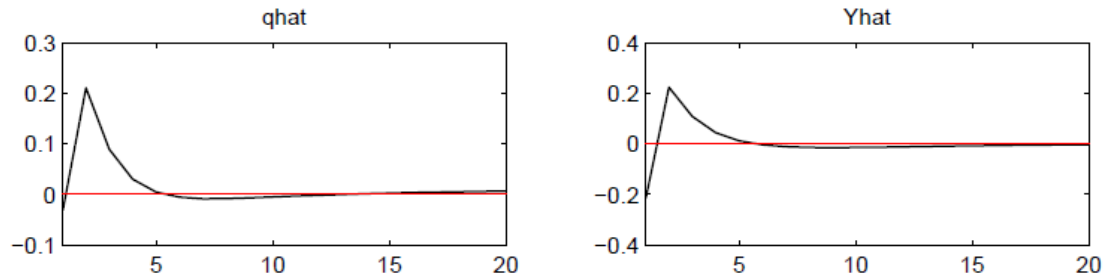
This section reproduces some of the IRF simulations of that model using the US_IAC05 model from the Macro-model Database (Wieland et al, 2009) that reconstructs the Iacoviello 2005 model for DSGE simulation and applying the new PCL partial information solution framework.

The main result that appears is that IRFs behave differently if we apply partial information solution with different observation assumptions. For example, when we do not restrict observation, there is no difference in impulse response IRF graphs from shocks under full and partial information models. However, if only inflation and interest rates (or only the latter) are being observed, there is a significant difference between partial and full information impulse response simulations for some of the variables such as real housing price ‘qhat’ and output ‘Yhat’.

For start, under the technology shock, assumed un-observed in partial information simulation, one can observe significant differences in IRFs for partial information solution in the first row and full information in the second row further below. For example, one can see in the below graphs that PI IRFs to technology shock result in a more realistic:

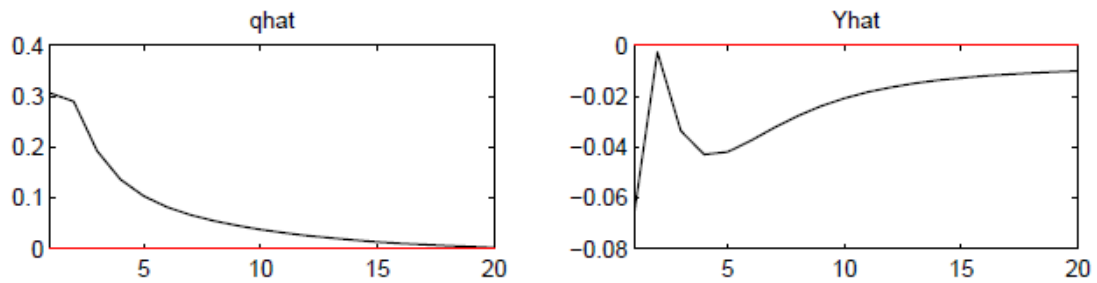
- a) delayed response in housing prices as observed in real data.and,
- b) symmetric response in output to technology shock rather than dominantly negative one resulting from the full-information assumptions.

Figure 5.6.4.1: Partial Information responses,



and

Figure 5.6.4.2: Full information responses to a technology shock



The above IRF simulation responses are comparable to the earlier presented partial information assumption simulation in 5.6 of this chapter and, in particular the case of Figure A5.3: Part information PCL IRFs for ϵ_{ps} a technology shock when only π and y (left) are observed. The response of the partial information Levine et al. model in output is slower, more humped and less sharp than that of Iacoviello for partial information (5.6.4.1, top figure) whilst house prices react completely opposite to the consumption inflation in Levine et al. (2010) model which may not be surprising to observe in the same period of time. A shock in the marginal utility from housing creates different effects on interest rate R , inflation π , housing stock q and output Y :

Figure 5.6.4.3 Partial Information effect of shock in marginal utility from housing:

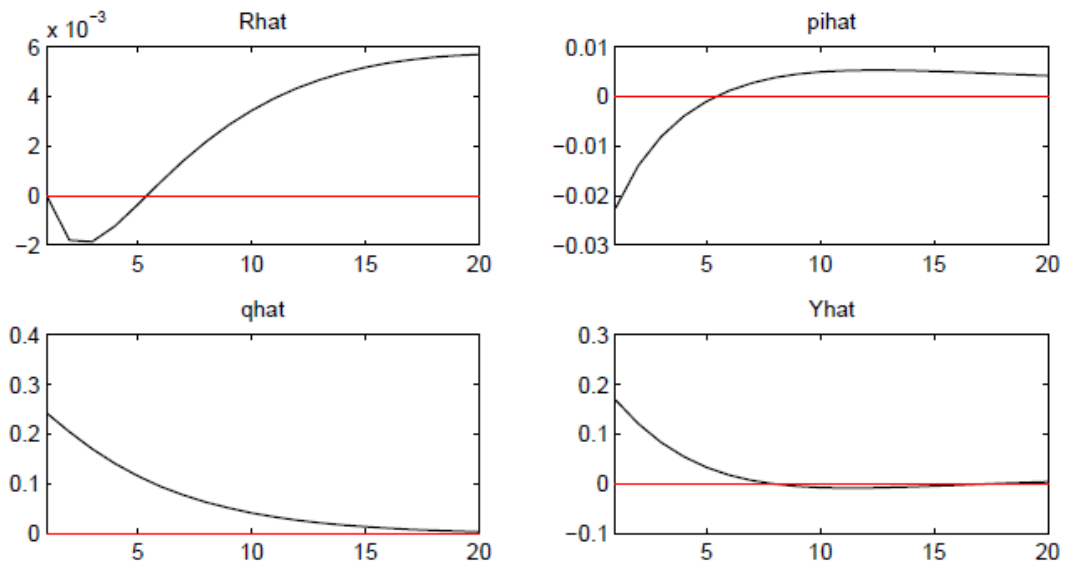
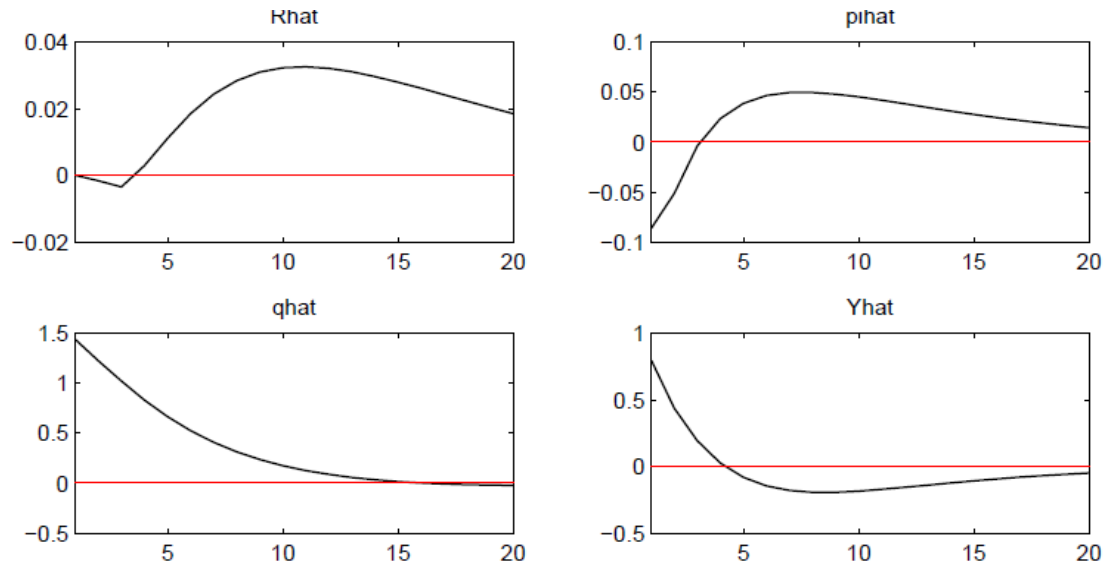


Figure 5.6.4.4: Full information effect of shock in marginal utility from housing



Similarly, an inflation shock creates a significantly smaller effect on the system under the more realistic partial information assumption:

Figure 5.6.4.5: Partial Information effect of inflation shock:

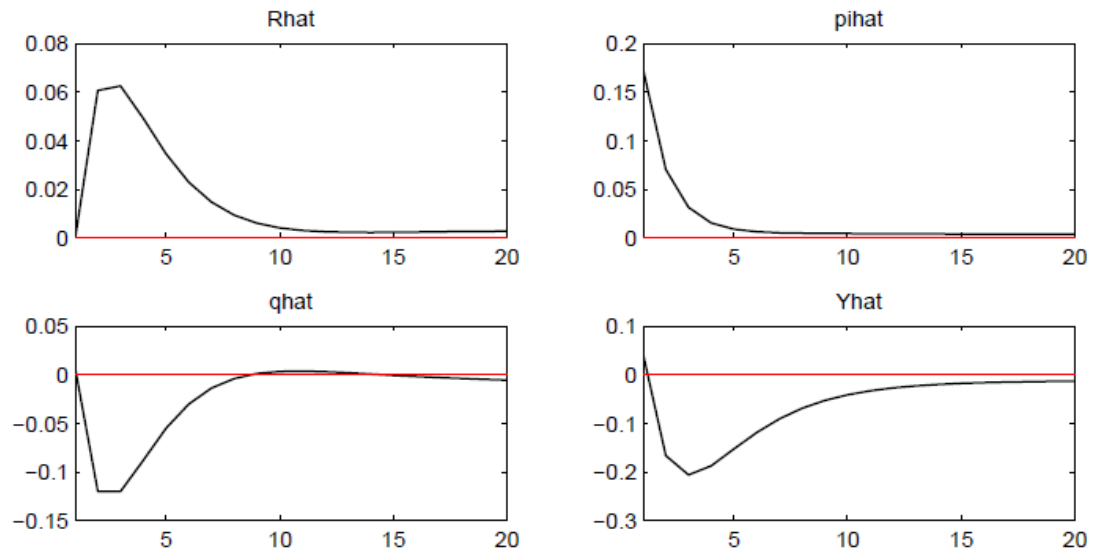
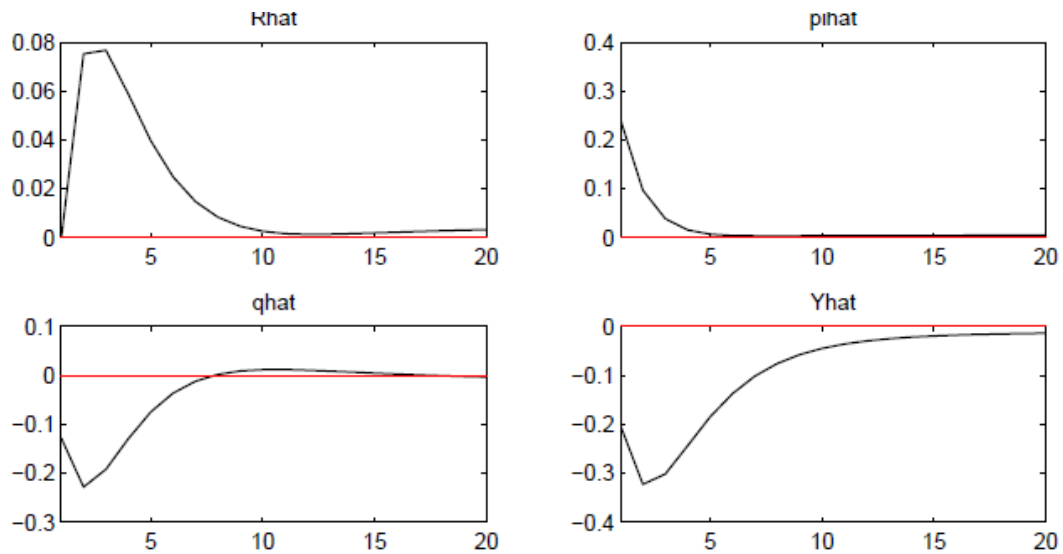


Figure 5.6.4.6: Full information effect of inflation shock:



Even the interest rate response rule provides a different outcome, most likely because the effect on output Y is initially of different sign and later followed by a small fall. It is also delayed, so that under the same inflation shock, the Taylor rule under partial information does not result in an increase of the interest rate to the same level as in case of full information solution.

Note that these different results for different information assumptions are following similar patterns, with notable differences though, to the effects in IRF test performed on the initial, single (representative) agent models as explained earlier in 5.7.. These results are along the lines with the very recent works of Lubik, Matthes and Mertens (2016) and Gabaix (2016) who claim that different equilibria occur under different information being available to different agents. However, those are only preliminary results and more research work is needed in this unexplored field of asymmetric information under imperfect information assumptions.

5.7 Conclusion

In this chapter presented were theoretical concepts and background as well as and estimation results for several application of Partial Information solution for DSGE models based on work PCL'86.

In addition to more realistic estimates of parameters and of the persistence of simulated shocks' effects shown in the results of this research as part of implementation of Partial Information solution with heterogeneous agents in Levine et al.(2012), results seemed somehow surprising to identify that majority of the heterogeneous agents appeared to accept adaptive instead RE driven forecast.

However surprising in the first moment, these are in line with other findings of lack of empirical evidence for using or behaving in RE manner expressed in Chow (2007). They are also in line with the conclusion of the previous chapter on rationality that stated that only larger enterprises and organisations, where decisions are performed in team discussions, whether in the management or the board meetings could act in a fully rational manner. The hypothesis was that only they have both financial and man-power resources to process all information and ability to then, in same time, form basis for a kind of (trans-personal) communicative rationality akin to one described by Habermas (1983/96). This may be, (but will needs to be researched in more depth at this stage),

where subliminal priming, subconscious and emotional influences of individuals may often, but not always, cancel-out within a larger group and teams of communicative decision makers. And, it may be where, also, a larger amount of relevant information can be accessed and processed rather than just assumed to be known by the automation of being in public domain as per assumptions of efficient market hypothesis and rational expectation models. One can then refer to this form expectations creation and decision making as bounded communicative rationality.

In the last section of this chapter, one could also see how partial information solution can produce very different model impulse-response functions depending on which information agents had at their disposal, results similar to those of the recent works by Gabaix (2016) and Lubik et al. (2016).

5.8 Possible Future Research:

One can take-up a further analysis whether the above discussed “slow”, fully rational thinking is driving higher stability of e.g., a parliamentary democracy acting in RE manner. Or, whether the “fast” intuitive can, on the other hand, drive faster adaptive response and higher dynamics in a system lead by one person, a somehow authoritarian president, or a CEO, with prerogative of high powers of authority. Or, whether the latter system, can be exposed to higher danger of an inadequate personal bias and/or potentially higher volatility of its policies. A working hypothesis would then be that the fast reactive mode in imperfect (partial) information forcing bounded rationality may be optimal in short term and exceptional circumstances driven by high, exogenous uncertainty. Another situation however would be a state closer to a longer-term equilibrium when slower but RE based group decision making may be more optimal one.

Part 3: The 2007/8 Recession and its Causes

6 Debt accelerator and Large Scale Crises

This chapter (6.1) provides some background literature analysing causes of the two large scale crises, 1929 and 2007/8⁹¹ whilst the following one (6.2) focuses on the less discussed accelerator mechanism that was, according to this research, the likely cause and also the channel for their evolution to their large scales. (Perendia(2015)),

Though apparently departing from the main theme of DSGE modelling, this section of the research shows a bigger picture of more systemic and complex issues that were contributing to the overall process leading to the 2007/8 crisis rather than just limitations of insufficiencies of DSGE tools (and that many authors tend to blame for the crisis, as discussed in ch. 3) or any other econometric tools or methods. It, instead, shows likely importance of the effects of liquidity shortage shock and its causes, but also, the effects of an under-analysed debt-accelerator and of the possibly inadequate information (or omitted data) for the evolution of the crisis. It appears that this initial, household and SME liquidity shortage shock was introduced by a possible misspecification of the macro-economic models, this in turn, most likely due to a kind of rational inattention on part of the market monitoring, investment management and policy driving institutions. Such miss-specification or rational inattention and the resulting data omission, if occurred, would, however not be specific to any one particular methodological approach such as DSGE but would be then widespread across the variety of models and tool-kits used by the policy institutions.

⁹¹ the presentation, Perendia(2015), was given in December 2015 at Large Scale Crises: 1929 vs 2008, a conference held at Universite de le Marche at Ancona, Italy.

Methodological focus

This section of the project will be mainly relying on different methodologies to DSGE such as empirical analysis of data and graphs, VAR or Granger causality analysis when appropriate and only to a limited extent on DSGE. A full-scale DSGE model for analysis of such complex problem as the Great Recession and the crises of 2007/2008 are, as it turned out to be from this initial analysis, has yet to be developed in future.

6.1 Seeds of the Great Recession and Globalisation

6.1.1 Foreign Direct Investment Abroad and Globalisation

Whilst many authors (see below) focused on the collapse of mortgage based securities and their derivatives (MBS) as the trigger for 2007/8 crisis, and the subsequent international contagion of the financial crisis once it started, only a few other research papers have been dedicated to the background relation between the Great Recession on one, and, the international trade and globalisation on the other end. These two aspects have however been analysed in relative isolation from the international financial economics sector. Whilst the financial globalisation boom accompanied by the flow of relatively large-scale private investment, in great part directly from the developed countries into the emerging and developing ones has been widely discussed and analysed, the resulting domestic under-investment and its effects have been largely neglected.

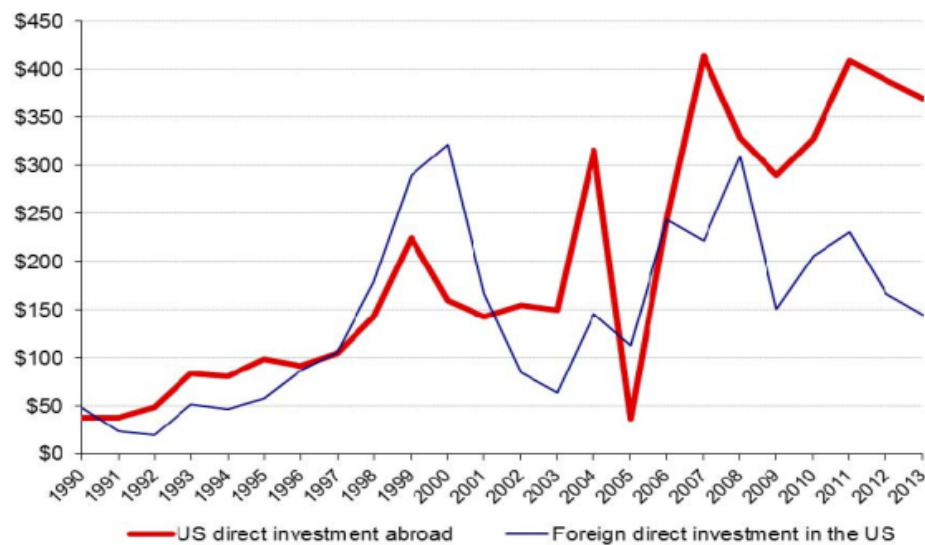
The boom in the (non-tradable) housing markets at home, fuelled by both the low interest rate and the lower cost of living resulting from the lower cost imported substitutes relatively to the domestic tradable goods, was another side of the globalisation effect. On the other hand, the same low interest rates throughout the early 2000s that fuelled the over-optimistic investment in outsourcing the manufacturing and the tradable services to the lower wage developing countries, also resulted in a stagnation of domestic industrial production of both, tradable goods and services. This

was done on a scale beyond the initial expectations of the leading economists. The actual FDI flow and their cumulative values are difficult to track down.

Table 6.1.1.1: Cumulative US Foreign Direct Investments (FDI) abroad

<u>Period</u>	<u>FDI Inflow</u>	<u>FDI Outflow</u>	<u>Net Inflow</u>
1960-69	\$ 42.18 bn	\$ 5.13 bn	+ \$ 37.04 bn
1970-79	\$ 122.72 bn	\$ 40.79 bn	+ \$ 81.93 bn
1980-89	\$ 206.27 bn	\$ 329.23 bn	- \$ 122.96 bn
1990-99	\$ 950.47 bn	\$ 907.34 bn	+ \$ 43.13 bn
<u>2000-07</u>	<u>\$ 1,629.05 bn</u>	<u>\$ 1,421.31 bn</u>	<u>+ \$ 207.74 bn</u>
Total	\$ 2,950.72 bn	\$ 2,703.81 bn	+ \$ 246.88 bn

Figure 6.1.1.1: Foreign Direct Investment into the United States and U.S. Direct Investment Abroad, Annual Flows, 1990-2012 (in billions of dollars) showing that outflow outpaced inflows in the years preceding and the after the recent crisis.



Source: U.S. Department of Commerce.

Note: The drop in U.S. direct investment abroad in 2005 reflects actions by U.S. parent firms to reduce the amount of reinvested earnings going to their foreign affiliates for distribution to the U.S. parent firms in order to take advantage of one-time tax provisions in the American Jobs Creation Act of 2004 (P.L. 108-357).

(Reproduced from Jackson (2012))

Those high Foreign Direct Investments (FDI) abroad have been partly driven by the widespread adopters of the Ricardian law of comparative advantage. This theory is widely taught and, as part of the new theory of trade in the globalised world, encouraged by many of the world-renowned economists (e.g. Dombrusch, Fischer and Samuelson 1977, Krugman 1991 or Krugman and Obstfeld 1997). Economists of all backgrounds were hoping for the better overall output and welfare outcome for both of the worlds. Jackson (2012) for example claims that there is no conclusive evidence of actual job shifting abroad and that majority (cca. 70%) of the US FDI abroad went into the developed, mainly EU countries with similar wages.

However, in addition to corporate FDI, there are other flows of investment funds. A Post-Keynesian economist, Paul Davidson (2011) pointed-out, the Ricardian law of comparative advantage expects that both capital and labour are confined to their countries. Along similar lines, the Heckscher-Ohlin-Samuelson endowment factor theory also assumes that the endowment factors of production e.g. skilled labour and natural resources are confined to their original state/space. Davidson, however, points out that, whilst the labour (and some other endowment factors) was mainly confined, the capital was not, and so, the resulting flow of foreign direct investment into developing countries then led to outsourcing of the industrial production and services, and consequently, it invalidated the original Ricardian law.

Krugman (1997b) was aware of the dangers of capital outflow to the developing countries and that that may lead to lower wages in the West, but at the time of his writing in mid 1990s, the interest rates in US were higher and outflows much lower than those following in 2000s. Consequently, his view at the time was that the outflows (contemporary at the time), were too small to be able to affect the local wages or lead to their reduction. Leamer (1996) however, shows that consumer prices of tradable goods even in 1970s declined by about 30%. This was paralleled by a 40% reduction in salaries for unskilled worker at the time of the US's rapid opening up to and dependency on foreign trade. It should be noted this trend reversed in 1980s by 20%. The author also performs a component analysis and shows that the globalisation was

the dominant factor over technological advance, which is usually perceived to be the main factor for such wage decline.

Lamer's analysis however does not extend beyond the mid-90s but the two graphs below do show a striking coincidence of declining real hourly wages (deflated using GDP deflator) from mid-2003 to mid-2006 and a sharp rise of imported goods over the same period.

Figure 6.1.1.2: US real hourly wages (USD) and Figure 6.1.1.3: US Import

Figure 6.1.1.2

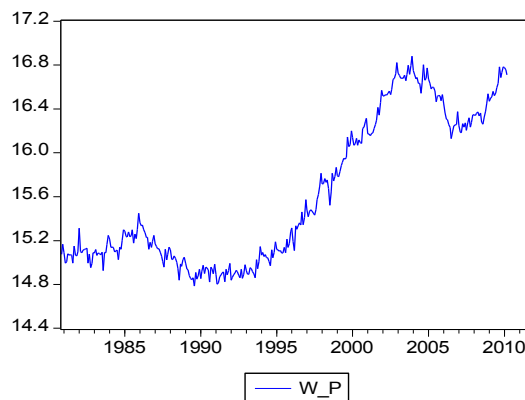
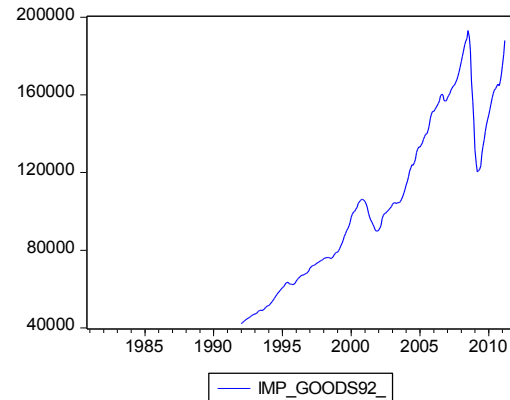


Figure 6.1.1.3



For example, most of new job creation in US tends to be in areas of financial and other non-productive or non-tradable services, hi-tech IT or in the low-wage, private health and care services (e.g. see table 8.1 on page 219 of Krugman (1997b) for early 1990s).

Nevertheless, US wages remained relatively high in the high tech sector and, as a result of lower lending rates in early 2000s, with financial flow deregulation one could observe increased FDI capital outflow from the US. As a consequence of those high flows of FDI capital, it was the law of absolute advantage, resulting from the lower wages for the production of tradable goods and services, which started prevailing over the law of comparative advantage in attracting the capital that was seeking higher growth related returns. To paraphrase the example used in Davidson (2011), instead of

low-tech bicycles being produced mainly in the specialised East and the high-tech computers in the specialised West, both bicycles and computers started to be produced in the low wage East. This was fuelled by the liberalised capital flows in the form of direct foreign investments.

On the other hand, Davidson (2011) also claims that the resulting higher overall output by all involved countries was not automatically matched and absorbed by the sufficient rise in the demand for those tradable goods and services across the globalised world.

Davidson however does not provide any quantitative indicators for this claim. As the second result, the resulting more diminishing returns on the foreign direct investments than initially expected, though used to finance foreign imports spending and to compensate for the trade imbalance, could not compensate for the loss of jobs in the tradable goods sectors at home caused by the outsourcing, and therefore provided an additional recessionary momentum.

In the immediate aftermath of the 2008 credit crisis, investors pulled back large sums of their investments in 2008 to maintain liquidity at home instead of partially financing the imports, which fell around 30% from 836bn USD in Q2 of 2008 to 575bn Q2 of the following year. The foreign investment pullback (i.e. a re-importation of the previously exported capital) resulted in share slumps in foreign asset markets and probably also accelerated the parallel drop in the now under-financed exports around 25% from 693bn to 522bn over the same period.

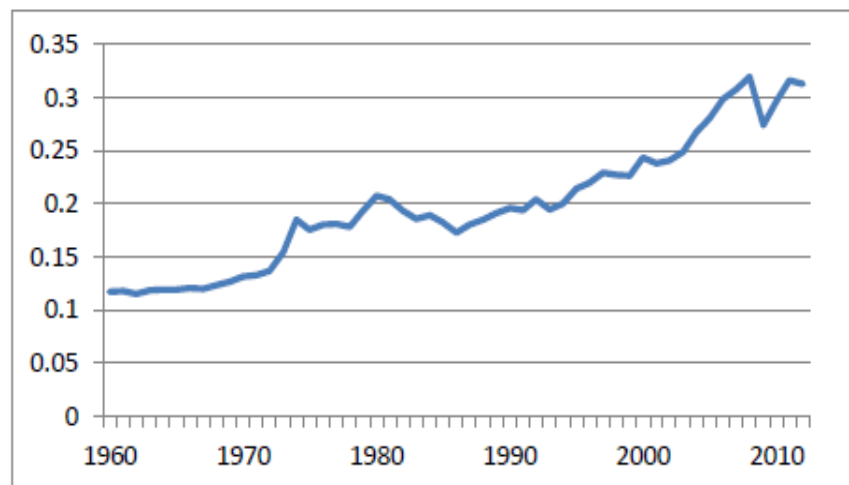
Levchenko, Lewis and Tesar (2011) analyse the international trade collapse during the 2007-2009 financial crisis. They state that the collapse of about 20% far exceeded the GDP decrease of about 3.8%. The highest drops in trade were among durables, cars and intermediate products. They are puzzled by the relative extent of the trade collapse and identify that the most likely causes are fall in domestic production of goods needing intermediate goods from the imports but do not find links to the shortage of credit provision for the trade.

They however do not take into account the complexity of the possible effect of the above-mentioned pullback of investment funds. These funds would otherwise have been used in part to finance capital goods imported from the US (i.e., the US exports) directly.

The fall in the market share net value of those foreign companies due to the FDI investment withdrawal and the market sell-off reduced their own import credit-worthiness. On the other hand, there was a likely an effect on the import of this rapid pull back of the returns on the earlier investments that, as this research work expects, would have been used to finance the imports to US (or other Western countries) instead, engaged directly at their source whilst avoiding foreign-exchange levies. These possible linkages will need to be explored in another study however. However, Podkaminer (2014), points-out that, though the growth of global trade contributed to the growth in exporting countries, there is no compelling evidence that it also contributed to the growth in the importing ones.

He shows that the global trade grew more than overall GDP - see figure below:

Figure 6.1.1.4: Trade/GDP ratio, quoted from Podkaminer (2014)



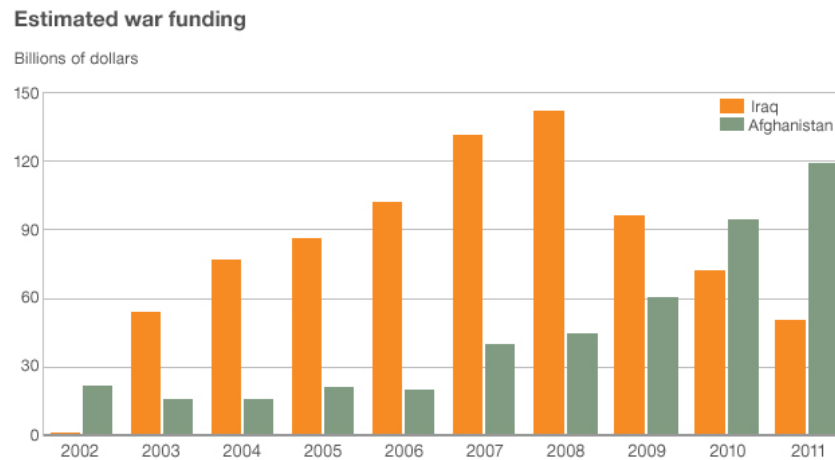
Using Granger causality test, the author shows that, though the rise of output Granger

causes growth in exports, the opposite does not hold and the rise in exports and trade do not Granger cause the output growth per se. On the contrary, basing his analysis on estimation and simulation of VEC models, the author claims that the rise in exports and the trade can cause decline in output. More importantly, the author shows that, though global trade increased, the real global growth rate has declined since the trade increase and the recent globalisation started in mid 1970s. Though the reasons may be different, the author finds the most plausible roots for such an unexpected development from the point of view of classical economics, in the trade imbalances and in the decline of wage share compared to the rise of profit related income that is facilitating investment rather than expenditure. We can say that such findings are in line with both the earlier outlined miscalculated ex-ante predictions of the effects of the global trade increase, and the already mentioned effects of the increased investment share over consumption goods on the reduction of the demand for goods on domestic markets.

6.1.2 Some Unusual Expansionary Fiscal Interventions

As it turns out, the military spending for the Iraq war may have been another boost for the US economy between 2003 and 2007. (See Appendix 9). However, coinciding with the looming crash, in 2008 one can observe another falling economic category not usually considered to be caused directly by the economic crisis, this one in the US government's Iraq war funding. Although not a result of the looming economic crisis, this decline in funding may have been one of its contributing factors. Whilst the start of the Iraq war and the increase in US government spending to support it may have accelerated the bubble growth since 2003, so the anticipation and realisation of the cuts in government orders related to the Iraq war from 2008 would have at least accelerated, if not directly triggered, the rise of unemployment in related industries, therefore contributing to the stagnation if not even to a recessionary trend leading into the 2007-8 crash.

Figure 6.1.2.1 replicated and quoted from the BBC website, sourced by US Congressional Research Service.



Source: Congressional Research Service

Historical evidence of this kind of countercyclical fiscal intervention gives strong grounds in its own right to endogenise countercyclical government spending in economic (e.g. DSGE) models rather than treat it as an exogenous shock. Some aspects of countercyclical government spending and fiscal multipliers are dealt in Perendia and Tsoukis (2012) detailed later in this research work.

6.1.3 Elections in 2004 and 2008 and politico-economic cycles

On the lines of Alesina et al. (1992) and other works discussed earlier in the section on politico-economic cycles, we can also observe some interest trends in different interest rate policies used in the 2004 and 2008 election years in US under different FED governors. The US fiscal and monetary policies appear to followed similar patterns as the pre-election political-cycles movements described above during the G.W. Bush's second, 2003/4, pre-election period when FED was pursuing unusually low, in real terms negative, policy rates (Taylor,(2008) for example), thus, boosting both debt and the economic growth and housing bubbles in the last years of Greenspan's leadership. However, rather different trends were observed for the 2007/8 pre-election period with

FED rates stepping up from 2005 onwards and through a (possibly resulting) stagnation and a recessionary trend starting in 2006.

6.1.4 A Summary of the Main Errors Made by the Financial Services Sector leading to Sub-prime Mortgage Crisis

“But anyone who has looked seriously at how we got into this slump knows that private debt, especially household debt, was the real culprit: it was the explosion of household debt during the Bush years that set the stage for the crisis.”

Paul Krugman, NY Times, 22. Jan. 2012

There is, however, no doubt that the reckless borrowing and over-rating of the new types of derivatives such as Collateralised Debt Obligations (CDOs) and Mortgage Backed Securities (MBS) securitization mechanisms provided the commercial financial sector with the needed spin for the bubble to grow beyond sustainability. Because this aspect has been analysed by many authors in great depth and detail, this research work will only mention the early analysis by Ashcraft and Schuermann (2009) who identify five main adverse selection and moral hazard frictions in the sub-prime mortgage market's securitization mechanisms that contributed to the Sub-prime Crisis:

1. Adverse selection and predatory lending and borrowing of complex, difficult to understand, mortgage products in relation between the mortgagor (the borrower) and the originator (the original lender).
2. The issue of the principle agent between the asset manager and the less informed investor who does not understand the risks attached to the investment and the manager who does not spend enough time explaining.
3. Adverse selection friction between the arranger, who has a better understanding of the quality of the loans, and the third parties providing the securitization, including ultimately, the asset manager: the arranger's due diligence is reduced

by the reduced asset manager's due diligence.

4. Information asymmetry between originator who has better understanding of mortgagor quality and the arranger (packager)
5. Frictions between the investor and credit rating agencies which did not assign proper ratings to the MBS due to honest and dishonest errors.

Among others, more recently, Lysandrou (2012) point-out to demand for derivatives created by the hedge funds as the main driving factor in the sub-prime crisis, hence, asking for their better supervisory control.

6.1.5 Practice and Role of Credit Rating Agencies in the Crisis

6.1.5.1 Moral Hazard Issues

As a follow-up to the Ashcraft and Schuermann (2009) friction No. 5, referring to the credit rating agencies that did not assign proper ratings to the MBS due to either honest or dishonest errors, it is important to note several aspects:

1. there is a small number of recognised Credit Rating Agencies (CRAs) in the US but more than one,
2. they are commercial institutions competing on the market to gain commission fees from the asset (e.g. bonds and mortgage backed CDO) issuers.
3. the issuers are seeking best value for the fees paid and, even more, for the expected income from the initial offering. They thus seek the best ratings and valuations they can.

There is therefore an issue, raised by several authors, of a moral hazard (friction) embedded in the rating agencies stakeholders and employees, all financially motivated to approve and give better, more optimistic ratings to more instruments than they may have deserved in a more rigorous, objective assessment. On the other hand, moral

hazard was present also among the issuers who were seeking instruments' rating service only from agencies prepared to provide such over-optimistic rating in a systemic manner.

Pagano and Volpin (2009) indicate that there was a case of "rating inflation" in relation mortgage based securities leading to mispricing of the risk as one of the main contributors to the crisis. The authors provide a very comprehensive analysis of the issues but the main issue seems to come from a conflict of interest and two facts - that the agencies are insufficiently regulated and that they are multiple commercial organisations⁹² that compete on the market for the instrument-issuers. The authors therefore analyse alternative options for their funding and explore the possibility of the agencies being paid by the investors instead.⁹³

Another related issue is that under the Basel II Accord rules, banks can use credit rating agencies' (CRAs) ratings for the assets they hold to assess their working capital requirements (Haan and Amtenbrink (2011)). This too may have provided an incentive to encourage banks to seek rating agencies prepared to provide higher ratings for those instruments.

6.1.5.2 Some financing problems with the rating practices

There is also a problem with the instruments or their underlying institutions' credit rating practice as the rating agencies provide their ratings based on average values over a longer period of time which are business cycle agnostic⁹⁴. In their defence, CRAs however claim they cannot include market or liquidity risks into their calculations as those are beyond the scope of credit risks rating. Such a practice has been widely

⁹² Status of US Nationally Recognized Statistical Rating Organizations (NRSROs) was awarded only awarded to Moody's, Standard & Poor's, and Fitch until recently.

⁹³ To address the issue of insufficient regulation and conflict of interest, the new, so called Dodd-Frank regulation (named after senators B. Frank and C. Dodd who introduced it on request of US President B. Obama in 2010) offers a compromise solution and forbids the rating agencies employees involved in the rating process to have their pay linked to the financial performance of the agency.

⁹⁴ that is, invariant to the overall changes in the economy along the phase of the RBC paths

accepted and it is within the recommendations of BASEL II and III Accords, and so, it provides for an additional, informational friction (Bhatia,(2006)). CRAs have been also criticized for slow adjustment of their ratings (Haan and Amtenbrink (2011)).⁹⁵

That would mean that the ratings are consistent only in relative but not in their absolute values. An organisation's or instrument's (time) distance to default may drop dramatically with market changes but that will not necessarily trigger a change the instrument's (or the organisation's) relative rating as long as other organisations are exposed to proportionally similar, market changes. Though this friction paints an incorrect picture in times of either peaks or troughs, it is allowing public asset management institutions to maintain their portfolios within the legally required rating boundaries without making any major changes in their structures even in recessions. This also applies to the Federal Reserve (and other central banks) that accept collateral from financial institutions within legally required rating limits and for those banks who back their working capital requirements using potentially much riskier and hence effectively less valuable instruments.

However, according to some economists, the use of the long-term average (time-less), or even of the over-optimistic ratings may be favoured even by the authorities. This kind of the RBC "image air-brush smoothing" may provide a more optimistic, stable view of the economy and may then require a lower level of fundamental strength to keep the economy running even in shallow troughs, or may help the economy recover from the troughs earlier.

Holden, Natvik and Vigier (2011) analyse if rating agencies can affect real economy outcomes. They look into alternative ways of awarding the rating agencies for their service. They indicate that, amid the growing criticism that current service awarding methods for the commercial rating agencies result in a bias towards over-rating their client's products, the problem of the socially optimal way of their service awarding is

⁹⁵ " For instance, on the day before Lehman Brothers went bankrupt the major CRAs still gave the bank an investment grade rating", ditto.

not easy to resolve. The authors state that if the rating agencies are not funded commercially by the issuers but by the authorities (or by the investors through some investment tax mechanism), a posteriori, proportionally to the success of their guesses, they may be inclined to take an overly optimistic view again and over-rate the assets. This is in part as such optimism may fuel self-fulfilling prophecy of the economic success and of the success of their guesses accordingly (or vice-versa). The authors simulate a game based model and find that those attitudes may be self-defeating and that optimism may induce more durable crises whilst pessimist prognoses may help to avoid them. However, the authors have accepted this researcher's comment that these arguments apply irrespectively of whether the agencies' services are awarded by the issuers or by the authorities.

It is in the view of this research that a due attention should be given to the awarding mechanisms for credit ratings and that a model of a single, independent, non-profit making rating agency should be set and researched. This task however, is beyond the scope of this research.

6.1.6 Other Possible Causes

The aim of the preceding chapter was to identify the main causes and driving forces leading to the 2007/8 crisis (Great Recession). This piece of research concludes that a number of political (e.g. elections) and wider, real economic issues (e.g. global over-investment and domestic under-investment) probably played a role on the stage preceding the crisis and possibly caused a recessionary trend that triggered the big financial crash that was mainly felt within the financial industry: collapses of the major banks and other financial institutions throughout 2008.

This work thus concludes that the recessionary trend starting in 2006 led to both the recession and the crisis of the financial system in 2008. It is not the other way around as it is mistakenly assumed. However, the onset of the major 2008 financial crisis and the extremely high losses that banks suffered, in turn, certainly accelerated the recessionary

trend even further, triggering the start of the official recession as late as Q3 of 2008, though already in making since 2006.

One area this research work does not address, but is probably worth looking into, is how much the crisis resulted from the oil price bubble, itself encouraged by low interest rates and the low US Dollar; thus whether it was the high price of oil that fuelled the recession which triggered the crisis.

However, some areas that this research work will address are the endogenisation of the government lead counter-cyclical fiscal spending aimed to smooth the effects of business cycles and potentially give a boost to the economic system to move out of recessionary (or near –recessionary) state.

6.2 Recessionary Debt Accelerator and possible effect of the Fed's inflation targeting on financial bubble in 2008 crisis

6.2.1 Introduction Summary:

This research is posing a hypothesis to the likely existence of a, to our knowledge, hitherto probably overlooked, “positive” (recession accelerating) feedback channel. This additional channel may have even further suppressed consumption demand due to cash-flow difficulties caused initially by rises of existing, floating loan interest rates in heavily indebted economies. Consequently, this channel potentially contributed to both, recessionary trends and the prolonged depression in both the 1929 and 2008 crises. This paper poses a hypothesis that there was likely an additional channel that accelerated Fed’s contractionary policy at that time of high levels of both private (mainly real-estate) and public debt, a channel that it may have inadvertently significantly contributed more directly and with a higher accelerating effect to the demand downturn effects in case of 2008 as it admittedly did in 1929 crisis, and, if a further analysis should be conducted. This research concludes that its initial analysis is affirmative one, meriting further analysis into this hypothesis

6.2.2. The Backstage in a new perspective: The Great Depression 1929, its Causes in Existing Literature

In the aftermath of the Great Depression few authors dedicated their research to its causes and remedies. Among the rest, even then Keynes pointed out that one of the main causes for the crash was irrational panic and the herding. “Animal Spirit” that greatly contributed to the bank runs, the market crash and its spread throughout the world economy.

Among the more recent analyses, Galbraith (1954, pp 194-200) summarises and lists several key causes for the Great Depression following the stock market crash in October 1929⁹⁶. This research work would like to pay attention to two of the issues:

1. The bad banking structure: the failure of a small number of weak banks lead to the epidemic of failures of other banks which suffered runs.
2. In the footnotes he also mentions under-consumption as a possible accelerator but states under-investment as the main reason.

Another under-reported aspect that preceded and significantly contributed to the Great Depression are the so-called “silent-runs”. Rockoff (2004) points to a large number of under-reported and less visible monetary transfers taking place mainly from small to larger banks and to larger financial centres. These starved the smaller local banks and, consequently, their regular business borrowers from the needed cash-flow funds and credits. For example, whilst during the 1929-30 period New York banks experienced a 15% rise in deposits paralleled by similar rises in other large industrial centres, small regional banks in rural areas suffered great losses. As Stiglitz and Greenwald (2003) (S&G 03 henceforth) show in their analysis of credit rationing, the borrowers of bankrupt banks could not have just gone to another bank, either small or big local ones, or even less so to any large bank in a distant centre to borrow money on the same

⁹⁶ Galbraith also lists:

1. Bad (unequal) distribution of income,
2. Bad corporate structure: short term-ist dividend demands over expansion investment,
3. Dubious state of the foreign balance:
4. Poor state of economic intelligence.

preferential terms as those banks did not know their credit history. Such “silent run” transfers hence created credit shortages (“rationing”) and undermined the stability of the economy at that time.

For the above reasons, S&G03 claim credit-worthiness is heterogeneous (and asymmetric) and an aggregate assessment can be misleading since the surplus of funds in one bank is not a substitute for the lack of funds in another, the client’s usual lender. This is in part because the bank which has sufficient funds may not be accessible to a borrower for various reasons such as logistic access. Another reason is such a bank may not have sufficient credit information on the client and may either refuse the loan all together or charge too high interest rate resulting from both the increased risk premium and the increased agency costs.⁹⁷ Due to information and the resulting credit asymmetry, S&G03 claim that credit allocation is not Pareto efficient and that its effects are highly non-linear – e.g. a bankruptcy resulting from increased interest rates cannot be undone by decreasing interest rates after the bankruptcy.

Mishkin (1978) takes a different slant in his analysis and states that most previous authors surprisingly omitted to pay attention to the effect household balance sheets and the sharp (approx. 12% and 20% on average) increase of household credit liabilities throughout 1928 and 1929 (respectively) for the economic contraction leading to 1929 Great Depression. Mishkin there dis-aggregates the net aggregate effect of the asset income and the liabilities on household cash-flow (liquidity) and monitor effects of the so composed household balance sheet portfolio. Mishkin points to the stock market crash as the main culprit for the decline in houses’ asset prices and, consequently, the demand downturn, but he does not go further into analysis of the causes of the crash.

The first issue of banking bankruptcies leading to the Great Depression has been analysed in great detail by many academics. Bernanke (see Bernanke 1983 and 1995) gives an overview of financial economic factors leading to the Great Depression such

⁹⁷ The agency cost is what Bernanke et al. (1999) perceive as one of the main mechanisms behind the financing positive feedback mechanism exacerbating business cycles they termed “financial accelerator”

as wage rigidity amidst deflation, lending risks, and demand shocks. His work is however focusing mainly on the importance of the gold standard, agency costs, on Fisher's accelerating debt-deflation crisis ("debt-crisis") but also, bank runs, panic and monetary shocks and international contagion in accelerating further the spread of the Great Depression post 1929 Crash. Bernanke asserted that the monetary contraction pursued in years preceding the Depression was the most likely cause of the depression.⁹⁸ He also points out that the countries that abandoned the gold standard and pursued monetary reflation found a way out and recovered from the depression earlier than those sticking to the standards did. This finding is affirmed by recent research by Albers and Uebele (2012) who point out that there was a higher co-movement among countries accepting the gold standard than with the ones outside the standard, including the Sterling countries, and which recovered earlier⁹⁹. Albers and Uebele (2012) also find that the agricultural countries experienced approximately a one year delay in entering (and also in getting out of) the Depression. This is understandable when one takes into account the delayed and prolonged production cycles of agricultural products in comparison to those of most of industrial ones and also, the human existential dependency on relatively smooth consumption of food-stuff compared to the usually more volatile and pro-cyclical consumption of durable industrial goods¹⁰⁰.

⁹⁸ Bernanke states that the US Fed, (as several of most developed countries) pursued a contractionary policy reducing money base 6% in period from Summer 1928 to Summer 1930, initially trying to reduce speculative use of the money despite increase in gold reserves.

⁹⁹ We can then consider that the gold standard countries correlate (and co-move) more than those controlling (protecting) the exchange rates because the gold standard fixed exchange rate, results effectively in creating an in-flexible, mutually fixed exchange rate monetary union. Such (gold standard) union makes the "member-states" more vulnerable to cross-contagion, although it may be intended to alleviate risks.

¹⁰⁰ - food demand is stickier – it is existentially dependent good which humans can not stop consuming and buying just because it is a crisis - thus, affecting industrial economies quicker and deeper (non-linearly) than the agriculture.

- food production cycle extends to a year - thus agricultural production goes on through its annual cycle before it reacts...and so the whole countries based on it..

- food is often sold at commodities future markets in advance (would be interesting to investigate that too) so, there is no need to stop harvest either as the hedging farmer can still get the expected, long in advance contracted price .

- there is therefore about 6-12 month time lag for reaction of agricultural producers whilst production life-cycle of the industrial goods (and worker dismissal notice then) is usually considerably shorter, few days to weeks, and, being affected more, the latter may react quicker to recession trend...but also, the recovery trend too.

Bernanke (1983, 1995) explain the causes of the (Post-Crash) Great depression as a loss of confidence in the banking system and debtor insolvency mainly resulting from deflationary “debt-crisis” – effectively a variant of the famous Fisher’s (1933) debt-deflation accelerator. Bernanke (1983) points to the resulting insolvencies of debt and mortgage holders, the doubling of debt service cost/GDP ratio from 1929 to 1933 and the prolonged effect on the increased (agency) costs of financial intermediation in the post-crash economy as cause of prolonged depression.

Bernanke (1995) looks at the drop in aggregate demand in 1930s and finds that it was correlated to the monetary contraction resulting from the poorly managed monetary policy aimed at re-introduction of the international gold standard. He sees demand drop being triggered by that contractionary policy which also triggered negative credit supply shock resulting in high interest rates. This is, as he claims, in the line with the monetarist Freedman and Schwartz (1963) view that the banking difficulties created a money shortage leading to a downturn in the aggregate demand and output and causing the financial crash¹⁰¹. Henceforth, one of more vocal, famous solutions for such crisis caused by shortage of money and resulting high interest rates is the so-called “Helicopter drop” of money.

However, what about the other way around, will not the rate rise in an over-indebted household and over-leveraged businesses driven economy trigger liquidity shortage, recession and crisis? It appears to this author as if that Mishkin (1978), Bernanke (1995) and many other modern analysts may not have paid a proper attention to all details of the mechanism of the contractionary policy propagation channel.

This research is posting a hypothesis of existence of another, not explicitly investigated, “positive” (accelerating) feedback factor that could have suppressed consumption demand due to cash-flow difficulties caused initially by rises of existing, floating loan

¹⁰¹ Bernanke states that this monetarist view was opposed in 1976 by Temin who claimed that the real cause of the Great depression is in the real economy and that output contraction was preceded and caused by a consumption contraction and both of these were before (and caused) the monetary one but this view has been broadly criticised.

interest rates in heavily indebted economies, triggering both, recessionary trends and the prolonged depression in a way that has not been explored so far. Namely, we question if it is likely that the Fed's contractionary policy at that time of high level of both, private (mainly real-estate) and public debt, may have contributed more directly and with a higher accelerating effect to the severe demand downturns in both durable and non-durable sectors that Mishkin shows in his analysis.

6.2.3 Introduction to interest rate triggered recessionary debt accelerator

To be able to understand better my comments in analysis of the existing literature on the causes of two major recessions the earlier described 1930s and the 2007, I would like at this stage to introduce a theory of potentially novel or, at least a possibly neglected channel for interest rate affecting economy – a **recessionary debt accelerator** (initially discussed as part of Perendia 2010). The aim of this research is to show that this neglected but potentially crucial factor may have significantly contributed to both, the recent 2007-08 financial and economic crisis known as the Great Recession, and very likely, the earlier Great Depression too.

Figures 6.2.3.1: Real estate investment loans as % of GDP and 6.2.3.2: the US Fed policy target “real” rate (blue) showing its substantial rise from 2004 to 2007 compared to inflation (red):

Figure 6.2.3.1

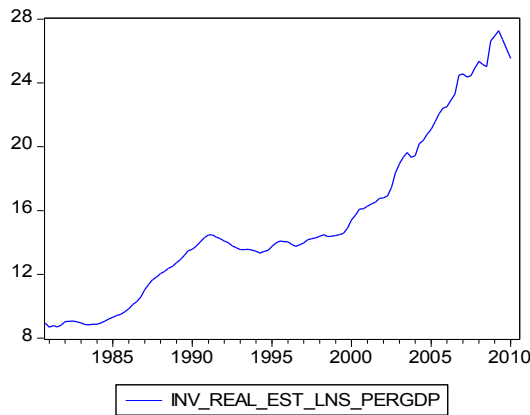
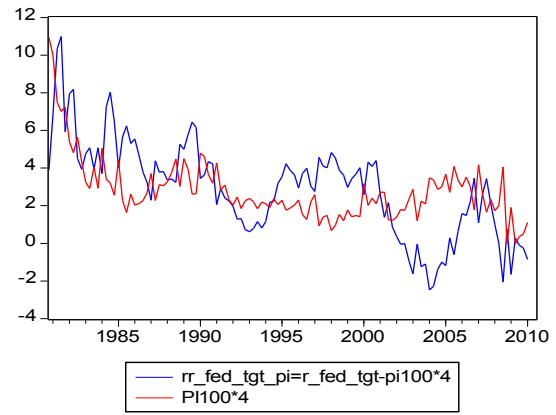


Figure 6.2.3.2



The point this research paper is making is that there were other accelerating forces suppressing consumption demand and accelerating initially mild recessionary downturns into full-blown recessions. Also, one of the main causes for the 2007 crash is likely to be the same accelerated recessionary trend caused by a slowdown in aggregate demand, itself caused and triggered by what this research introduces and refers to as the **recessionary debt accelerator**.

A monetary tightening (e.g. an interest rate rise) at a time of high levels of both household and corporate debt triggered a remaining cash-flow crisis and then debt-accelerated demand-cutting positive feedback (i.e. spiralling decelerator) effect. This accelerator’s positive feedback affected the cash-flows, demand for both the (every-day) non-durable, and even more for the (usually) debt-financed durable goods and services and triggered bankruptcies as early as 2005 at the rise of Fed rate, their 2nd wave and unemployment later and, in whole 2006-8 period, the multitude of foreclosures.

6.2.4 The total real cost of credit and borrowings

Rather than using just a real rate of return as the cost of borrowing, we can observe the total amount of the real return on the borrowing based on real rate of return (rr) multiplied by the inflation-adjusted (deflated) total credit borrowing:

$$\text{ccr_df} = \text{total_credit_deflated} * \text{rr} \quad (6.2.4.1)$$

Figures 6.2.4.1 and 6.2.4.2: total real return on credit and its level in relation to GDP using monthly US data 1980-2007.

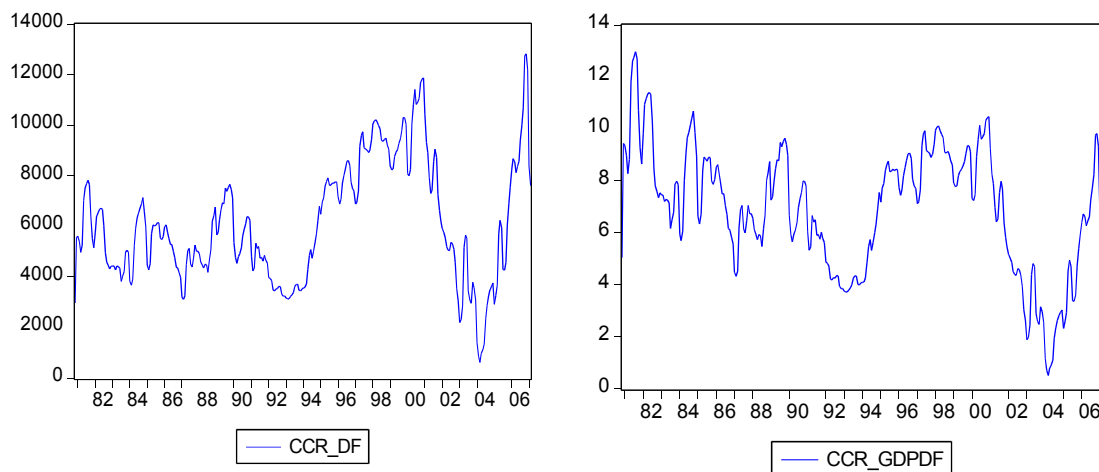


Table 6.2.4.3: Unit root on total rear return on credit

Null Hypothesis: CCR_DF has a unit root		
	t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic	-1.966332	0.3018

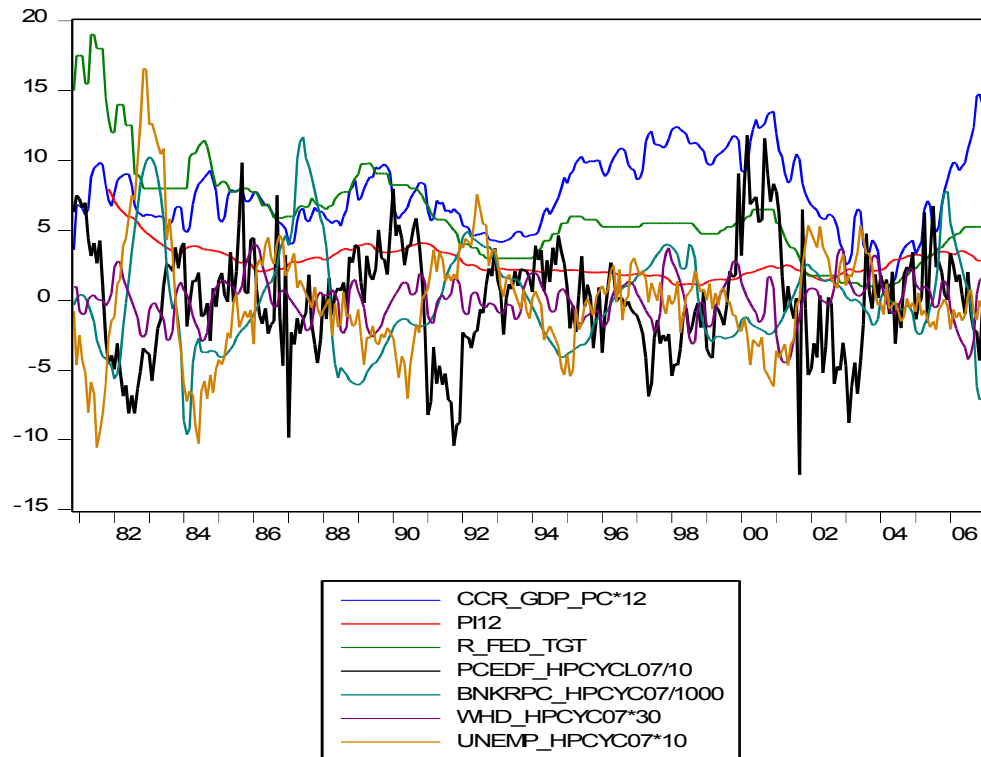
We can notice that, with some variations, the total amount of borrowing return, main income of retail banking is rather stationary, especially before 1995 deregulations, and steadily increasing in its value and variance. It can also help put into perspective lowering of the interest rates midst even higher income form the proportionally even higher borrowings...that is, when higher interest rates allow for that.

Thus, another claim is that if we monitor and start targeting the total amount of credit and/or its return (or its normalised value per GDP, graph above right) then we can expect that some more realistic estimates and forecasts could be achieved.

6.2.4.1 VAR Estimation Data – Preparation and Inspection

In this section for later econometric analysis we use a set of US monthly data downloaded from US Fed from Nov. 1989 to Feb. 2007, mostly HP detrended and then normalised (except for the Fed policy rate and inflation) and, also, had added a derived total return on credit/loans as per above section. This work was done in Eviews.

Figure 6.2.4.1.1: Combined, overlapping graphs of major measures or their HP cycles, normalised to fit the illustration and allow easier comparison
(See Appendix A.1 Figure A1.1.1 for the individual data graphs)



Where: CCR- Consumer credit real rate return (blue) per GDP: $CCR = CC * rr / GDP$
where rr = real interest rate: $rr = \text{prime_rate} - \text{inflation}$

PI12 – Annualised inflation

R_FED_TGT – US Federal Reserve policy target rate.

PCEDF_HPCYCL07 – HP filter cycle component of deflated personal consumption

BNKRPC_HPCYC – HP filter cycle component of bankruptcies

WHD_HPCYC – HP filter cycle component of hourly wage

UNEMP_HPCYC -HP filter cycle component of unemployment rate (however, in the VAR analysis we will be using more reliable and informative employment data:

EMP_HPCYC - HP filter cycle component of employment hours

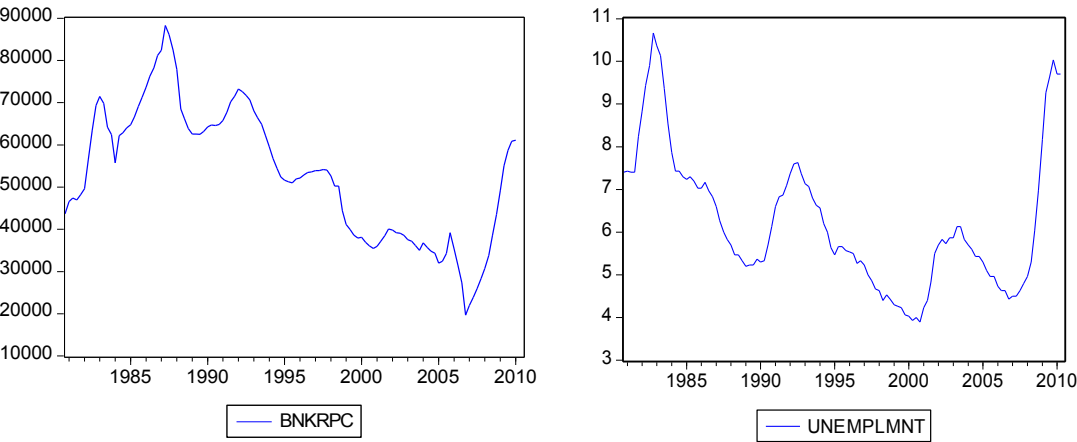
The above figure shows overlapping graphs of major measures or their HP cycles, normalised to allow easier inspection of their correlation and timings (See Appendix A.1 Figure A1.1.1 for individual data graphs). We can see that credit return payment increased 6 fold from 2003 to 2006, boosting banking profits and depleting households' and SMEs' liquidity and consumption ability. The consumption level remained to

increase but its growth declined sharply from the growing trend from 2005 (this being the case until late 2007 when the Fed and the real return interest rates started falling).

6.2.4.2 Further Data Analysis and Tests Discussion

In this section, econometric methods are applied to the set of US data downloaded from US Fed and HP detrended¹⁰².

Figures 6.2.4.2.1 and 6.2.4.2.2: Second wave of bankruptcies and unemployment respectively, both start rising in 2007:



Also, in the below tables we show Granger causality test among pairs of (un)employment cycle and that for Fed policy rate and for bankruptcies respectively.

¹⁰² This initial and the later, VAR data analysis was done using Eviews.

Table 6.2.4.2.3: HP filtered cyclic components of bankruptcies, unemployment and employment respectively:

Null Hypothesis:	Obs	F-Statistic	Probability
EMP_HPCYC/2000 does not Granger Cause R_FED_TGT/12	342	2.34772	0.00674
R_FED_TGT/12 does not Granger Cause EMP_HPCYC/2000		1.38142	0.17313
BNKRP_HPCYC/10000 does not Granger Cause R_FED_TGT/12	341	3.02199	0.00049
R_FED_TGT/12 does not Granger Cause BNKRP_HPCYC/10000		1.94819	0.02852

This above, initial, Granger causality analysis of US data indicates that all but one can be rejected with different levels of confidence and that it is more likely that changes in the Fed policy rates (R_FED_TGT) are Granger caused by the changes in employment and, the cyclic bankruptcies rates (BNKRP_HPCYC). However, with less certainty one can reject that the Fed rate changes do not (Granger) cause employment changes.

Table 6.2.4.2.4: Granger causality tests between HP filtered cyclic components of bankruptcies, unemployment and employment respectively.

Null Hypothesis:	Obs	F-Statistic	Probability
BNKRP_HPCYC/10000 does not Granger Cause UNMP_CYCLE	341	1.59758	0.09087
UNMP_CYCLE does not Granger Cause BNKRP_HPCYC/10000		1.19713	0.28385
EMP_HPCYC/2000 does not Granger Cause BNKRP_HPCYC/10000	341	1.01825	0.43156
BNKRP_HPCYC/10000 does not Granger Cause EMP_HPCYC/2000		1.83998	0.04130

The above table 6.2.4.2.4 with Granger causality tests between bankruptcies and unemployment and employment respectively is showing a stronger Granger causality of employment changes than unemployment changes caused by bankruptcies rather than

bankruptcies being Granger caused by either of the two labour measures.

However, the above more clear Granger causality of employment over unemployment relation to bankruptcies is based on statistical occurrences of unemployment or employment-change cycle ahead or after of bankruptcies and, it may be explained by unemployment data being less reliable than employment changes. Consequently, the latter are giving more clear sequence based precedence (i.e. Granger causality) especially since laying-off employers does not cause unemployment to rise during their usual redundancy payment period.

In Appendix A 1, Table A.1.1: VAR estimation measures of R^2 we can observe that the variable least explainable by others is private consumption with its R^2 0.69 comparing with most of other being above 0.95. This is because, as noted earlier (and identified also in Levine et al. 2009-2012), the lifestyle rigidity (incl. habit) drives the rigidity (or the “stickiness”) of private consumption so that even increased income from e.g. interest rate revenue, does not immediately find its way in increased consumption by the savers as expected by the classic macro models, but, as explained earlier, to great part probably goes into re-investment.¹⁰³ In fact, the consumption level continued to increase but declined sharply from such its trend from 2005 coinciding with the rise in the interest rates and the credit revenues.

The two other less explained variables with their low R^2 (e.g. below 0.9 for VAR(4)) are wage and (un)employment, the first of the two being the well-known “sticky” variable from the Keynesian and NK theories and models, (discussed also in Levine et al. 2009-2012), and the latter, the (involuntary un-)employment, probably needs to be “disaggregated ” from the sticky wage contracts (i.e. as in most of the NK models), and, instead, modelled as a separate sticky variable (this has been, but only in part addressed later, in Ch. 7 of this research and, also, in Perendia and Tsoukis 2012).

¹⁰³ And, for those with possibly decreased income, it will motivate loan borrowing and debt accumulation up to the level allowed by the banks.

6.2.4.3 VAR Estimations and Comparison with Standard DSGE IRFs

Using same data downloaded from US Fed, an unrestricted VAR(12) was estimated using more reliable and informative employment data (EMP_HPCYC - HP filter cycle component of employment hours) instead unemployment statistics. (For details please see Appendix C6.1). Here are presented four sets of one standard deviation innovation impulse response functions (IRFs) with two standard deviation confidence ranges. The shocks analysed were to bankruptcies, consumption, employment, and finally, to the un-observed, derived variable private credit (loan debt) real interest revenue levels. (See Appendix C6.1, Fig. A.C6.1.2 to A.C6.1.5 respectively).

The first three figures are illustrative of system reactions to shocks to observed variables and how the VAR responds usually pretty well along the lines of expected theory and stylised facts.

In figure A.C6.1.2, unstructured VAR(12) for 60-month-(5 year) period response functions (with two standard deviations certainty range) to one standard deviation shock rise in bankruptcies indicates, as expected, that it is resulting in significantly long initial drops in consumption, wage and employment. It was as well generating increased volatility to credit interest return and its underlying real rate of interest.

In Fig A.C6.1.3 and A.C6.1.4 we can see very similar (though opposite) effects from the one SD shocks to consumption and employment respectively on to the other respective endogenous variables including drops in bankruptcies. Note however that the visible “positive” effects to reducing bankruptcies and unemployment and rising wage to positive impulse to consumption should be imagined working in opposite if the shock was negative to consumption or employment driving economy downward.

Finally, in figure A.C6.1.5 we can see unstructured VAR(12), 60-month-(5 year) period response functions with two standard deviations certainty range to one SD shock rise in the newly derived variable, the private credit (loan debt) real interest revenue returns

(D(CCR...)) – i.e. we will use its first difference (D(*)) due to unit root presence in the level data). It is resulting initially in some 15 month of substantial rise in bankruptcies and drop in wages (bottom left). It also triggers a rather volatile, and small rises, over some 15 initial month-periods in consumption and some 25 in employment, and, as well, volatile increases to the interest rates (however, the real rate of interest rr is one of its components anyway).

Effects of shocks and rises of the policy rate on other economic variables can be observed in the IRF functions diagrams to that shock from simulation presented in Appendix C6.2 below. They came from running IRF response functions to the DSGE model provided by Smets and Wouters (2007) using US data to 2nd quarter of 2004 as they supplied, estimated and simulated using Dynare DSGE estimation and simulation package and clearly indicate that the existing DSGE models already expects drops in output, employment, investment, wages and consumption as a result of such rate increase even with already known channels. That SW07 model, however, did not have credit/loan revenue or the credit as its variables or measurements.

6.2.4.4 Discussion on Results

Whilst the above, first three IRF responses results are not overly surprising or new, the new and so far unexplored factor (un-observed but derived variable) there is the derived credit revenue per GDP and this is just a preliminary analysis. The responses to the credit return rise appear to have “positive” effects by increasing employment (which is unexpected) but, expectedly “negative” on increasing bankruptcies and lowering wage, which are likely triggers for a spiralling down-ward trend through their impact on consumption demand.

We also need to bear in mind that effects presented by IRFs are to one-off, one period increases whilst US economy was exposed to prolonged “shock” if not trend of policy and commercial interest rates increase over two years, 2005-2007.

6.2.5 Discussion

This research therefore, proposes that the interest rate rise induced “debt-accelerator” channel contributed to both triggering and prolonging the downturn of the 1930s Great Depression more than the known channels would normally do. The same mechanism I believe even more prominently contributed to triggering the recent “Great Recession” of 2007. Both crises were shortly preceded by two different modes of monetary tightening taking place in two periods of highly indebted private sector of US economy.

Prior to both of these contractions, trading had increased rapidly in the increasingly over priced stocks by the rapidly widening community of the mid and lower income public who were taking advantage of low loan borrowing interest rates over several years preceding the stock market crashes. This resulted in an increased amount of consumers’ usual base income becoming increasingly invested in the stock market midst hopes of high returns whilst substituting today’s consumption for tomorrow’s, in spite of low interest rates. This shifting of the aggregate inter-temporal substitution factor and investment-to-income ratio thus contributed to a further reducing of aggregate demand.¹⁰⁴

In addition to the US FED tightening the monetary base, to reduce the outflow of its gold reserves and cool-down the over-heated stock market, it increased its discount rate in 1928 from 3.5% to 5%, further increasing it in August 1929 to 6%. In the opinion of many authors, this is likely to have led to a slowdown in the real economy (see e.g. Field (1984) and (2015)) in a similar fashion as that of the earlier recession of 1921 which, according to some authors, was also triggered by an inadequately steep rise in the Fed’s policy rate. (This inadequate move in 1921 is perceived to be caused by inexperience of the newly founded Federal Reserve Bank’s Board.)

The interest rate increases in 1928 and in August 1929, however, I believe, also triggered the recessionary debt accelerator and so contributed to the then downturn of

¹⁰⁴ That is, the current consumption was forgone as they invested with the hope of higher future returns.

the aggregate demand. Both effects ultimately then triggered a recessionary trend. This recessionary trend may have then contributed to a further demand decelerating shock amidst a high-investment-led overproduction. All of these were contributing factors to the industrial product stock build-up in the summer 1929. They acted as additional triggers for the overall economic concerns that then triggered the reduction in the value of stocks on the NY market, the panic and the stock market crash.

6.2.6 Comparing Recessionary Debt Accelerator and other similar Accelerators and Decelerators in related literature

Bernanke and Gertler (1989) and Bernanke et al. (1999) (BGG later-on)) revive the importance of Fisher's (1933) notion of on "debt-deflation," They introduce the well-known "financial accelerator" (explained in more detail later in the text). However, the BGG accelerator is based on agency costs for tackling asymmetric information between the lenders (the banks) and the borrowers. Therefore, by both the nominal definition and in substance it is rather different from the debt accelerator introduced above. The BGG accelerator reduces loans in time of downturns (regardless of the level of debt) and only indirectly affects, and reduces employment, supply and the debt-driven demand. The latter, the Fisher's debt deflator, however, directly affects overall aggregate demand by the already indebted agents and then, indirectly the other factors too. The debt accelerator effect also usually precedes the financial decelerator effect introduced by BGG.

Iacoviello (2005) also introduces and augments his model with another type of accelerator – a demand shock driven effect of asset and interest rate rises, allowing for higher collateralised loans and even more demand (and the opposite, supply shock "decelerator"). Though it is applicable to both corporate and household agents, this demand shock accelerator is however a different from, and, eventually may be dampened by the recession "debt accelerator" (or decelerator) which is introduced in this research - an accelerator that is resulting from the loan interest rates rise in an already highly indebted economy (see earlier explanation).

Burgstaller (2006) uses VAR to analyse effect of the interest rate spreads between the loan and deposit rates and finds empirical evidence of higher spreads slowing the economy, in line with the decelerating financial accelerator hypothesis of Bernanke, Gertler and Gilchrist (1999) acting in downturn and refer to the effect as financial decelerator but it is effectively a variation on Bernanke, Gertler and Gilchrist (1999) one when acting in downturns.

Another similar decelerator was analysed and introduced by Kiyotaki and Moore (1997) who show that asset value loss affects credit and ability of firms to borrow and then further affecting asset-prices in a manner of a positive-feedback, either as an upwards accelerator or as a downwards decelerator. Kiyotaki and Moore (1997) build their model of the asset collateral value credit constrained agent upon the earlier work of Bernanke and Gertler (1989) and Greenwald and Stiglitz:

“Borrowers' credit limits are affected by the prices of the collateralized assets. And at the same time, these prices are affected by the size of the credit limits. The dynamic interaction between credit limits and asset prices turns out to be a powerful transmission mechanism by which the effects of shocks persist, amplify, and spread out”

Applying a form of game of life model: the predator (credit-unconstrained) vs. the prey (i.e., a credit-constrained firm) relation analogy, they find, among the rest, that credit constraints in down-turns spirals down credit worth of a firm and their collateral asset prices which, in turn further reduces their creditworthiness. They also find that the marginal productivity of a constrained firm is higher than that of unconstrained ones. This, on other hand, has an accelerating effect on output in business cycles when output of (and employment by) a constrained firm is more affected by asset value fluctuations in business cycles.

In a later research, Harrison and Weder (2010) use a limited supply of one asset (land)

as the collateral constrained borrowing limit in a relatively simple model based on Kiyotaki and Moore (1997). They then show that in credit friction marred markets there can be an in-determinacy of equilibria, driven by agents' self-fulfilling (i.e. optimistic vs. pessimistic) prophecies.

Another of the closest accelerators to the above recessionary debt-accelerator is Fisher's 1933 debt-deflator accelerator. Fisher's debt-deflator has been perceived as one of the main triggers for recessions and starts to affect an economy when intensive debt liquidation starts following a "Mild Gloom and Shock to Confidence" (Fisher (1933), pg. 343), and that is likely to be when a recessionary trend becomes visible. Though the debt accelerator starts and acts in similar conditions, it, on the other hand, directly affects different agents and slows down the demand of the highly indebted agents who cannot dispose of or liquidate their high debts. This is mostly due to those agents having borrowed to invest in less liquid assets such as domestic or commercial real-estate, or due to them using those assets as their collateral. In addition, the debt accelerator introduced here is directly triggered by an increase in interest rates, either as a part of a credit rationing (when the interest rates on risky loans rise), or, when monetary tightening and/or the central bank policy rate increase forces a rise in commercial banks' loan rates. That means that, ahead of Fisher's deflation, it is the price rise and the consecutive inflation targeting action by a central bank that may trigger this form of debt accelerated recession, it triggering the other decelerators (including the Fisher's debt-deflator) then too. However, a monetary tightening may also lead to debt liquidation and start the Fisher's deflation cycle independently of the effect of the debt accelerator described above.

A similar situation is explained by Eggertsson and Krugman (2012) who provide a small scale New-Keynesian (NK) model with private debt¹⁰⁵ aiming to model Fisher's debt deflation effect and the deflationary trigger event as an exogenous deleveraging

¹⁰⁵ The authors also depart from the single representative agent and the agents' preference shocks driven models. They model two categories of agents: the impatient borrowers driving by debt funded demand build-up, and the patient savers..

switch from the high debt limit to the low debt limit reducing demand.¹⁰⁶ Their model however assumes that agents can easily move from high to low debt levels and clearing (consuming) the saver's extra income from increased interest rate on saving from debtors in a closed economy and does not have investment and financial sectors or the foreign investment leakages. On the contrary, many families reduced spending as they could or did not deleverage to low debt midst increasing rates, drop in housing prices and negative equity. Also, whilst consumption clearing assumed in their model would simply shift consumption demand from borrowers to savers, data show overall reduction in consumption, this, possibly along the lines that the saver prefers to continue to save and gain higher income (see also Kumhof et al. (2013)). At this stage they may want (as financial institutions do) to purchase more of lower risk, now cheaper (i.e. higher yield income) government debt instead. Eggertsson and Krugman (2012) also seem missing that the high debt deleveraging "switch" is likely to be an endogenous event, e.g. either driven by an increase in central bank's policy rate as elaborated in this paper, or, possibly, by a series of endogenous defaults described by Kumhof et al. (2013). They nevertheless indeed rightly conclude that fiscal spending intervention is needed to accelerate spending in such situation, something however that seems to have been rather delayed in 2007/08 crisis.

Another example of a similar financial accelerator (referred to as financial decelerator) was introduced and analysed in a small, two period model by Elul (2005) who presents effects of strategic bankruptcy when house owning agents decide that it is more opportune to fill for bankruptcy in case of asset value reduction than to commit to service their existing loan obligations. The author is mostly concerned with strategic bankruptcies when agents can obtain other loans ("*...repayment is always an option in that agents do indeed have sufficient funds to cover their debts even when house prices fall.*" *ibid.*) rather than forced bankruptcies when agents are not any more in situation to repay existing or obtain alternative loans, thus, events which may occur even in the state of economic equilibrium. (Similar model of endogenous rational default induced by gradually increasing income-debt leverage was explained in Kumhof et al. (2013)).

¹⁰⁶ The authors refer to the debt limit switch moment as the "Minsky moment"

Though the recessionary debt-accelerator introduced here overlaps and may include such strategic bankruptcy and/or Kiyotaki and Moore (1997) cases at a later stage, it is primarily concerned with the earlier phases, before the assets fall in values, more as one of main causes of their fall – the triggering of early recessionary and unemployment trends caused by the lower consumption or forced bankruptcies, either due to the successive cash-flow difficulties among already highly-indebted households and small businesses that are in turn caused by shocks in either the policy base and/or the (resulting) floating retail loan interest rates rises.

Paul (2015) present an overview of the recent literature on crises modelling and a novel parsimonious DGE model of monetary policy simulating effects of a long expansionary one usually followed by a short contractionary one just ahead of endogenous rise of financial crises. In his model focusing on the role of financial sector intermediaries, these endogenous crises are rooted in the high leverage of these financial intermediaries initially taking opportunities of the low interest rates during the expansionary phases, when their leverage increases due to a subsequent drop in their asset values during the monetary contraction.¹⁰⁷ The model successfully show the potential effects such leveraging among the financial intermediaries could have had on development of the 2008 financial crisis but excludes leveraging of the households.

Muellbauer (2016) and Duca and Muellbauer (2013) also introduce a feed-back amplifier i.e. an accelerator, which shows how indebted households became vulnerable due to high debt triggering crash. His model of accelerator, however, is not explicitly identifying rise in interest rates as trigger which turned that vulnerability into the liquidity shortage crisis leading to the initial reduction of house prices triggering crash but presents that crucial price reduction as an event which “subsequently” follows their rise, but the model of debt lead feed-back accelerator and its effects seems similar if not same as the accelerator introduced as part of this research (Perendia (2010) and (2015)).

¹⁰⁷In the pen-ultimate chapter, the author also states that “.... In the short run, contractionary monetary policy may increase financial instability instead of decreasing it.” and concludes that

Despite that Muellbauer (2016) misses to point to interest rate as a likely cause of liquidity constraints, nevertheless, both Muellbauer (2016) and this research conclude that one of the main causes is probably a misspecification in that US FED (and probably few other central bank models) did not have proper specification of households' debt that can show its effect on the consumption and the economy.

A part of such non-linear accelerator are asset-value-liquidity positive feedback mechanisms modelled by Iacoviello (2005), Iacoviello and Neri (2010) as well as the Guren and McQuade (2014) foreclosure triggered households home asset downturn reducing even further the liquidity of households or SMEs. Whilst the former one can work in both direction, the latter is downturn accelerating only and each can be triggered by interest rate shocks in opposite directions.

There is also an ongoing discussion on how to mitigate such risk in future and while this research and Muellbauer (2016) point out that central banks should have stronger role in accounting if not even adjusting rates for household debt build-up, Duca et al. (2016) seek better macro-prudential policies and mechanisms to be put in place in the regulations for the lending banks and similar institutions so to prevent such debt build-up. Experience however indicate that regulations left alone without being monitored and reinforced by adequately equipped and empowered impartial institutions will can do little good if not being even more damaging by giving impression of false security..

6.2.7 Effects of the accelerators working together

In order to understand effects of different accelerators, this section discusses effects of the accelerators working together in a rather crude mode of a business cycle. One of the points is that those accelerators may act in different moments of the business cycle. Iacoviello's (2005) demand shock accelerator would follow the BGG financial one in boom times.

The boom then may be followed by increases of the policy or retail banks' interest rates

which, in highly indebted economies, triggers both the Fisher's debt deflation decelerator effect and the (introduced here) recession debt accelerator (i.e. decelerator). Both of these are then dampening the initial positive effects of the Iacoviello's demand shock accelerator that acted in the up-cycle. These decelerating effects may be paralleled by Iacoviello's supply shock decelerator and, then, further, by BGG's decelerating effect of agency costs in recession.

It is however difficult to assess the impact of any specific accelerator as they often work together and models usually measure only one. It is therefore quite possible that data based estimations of e.g., BGG accelerator effects exaggerated its importance and presence as the authors assumed their financial accelerator is a single one whilst it is just a measure for aggregate effect of those partially the overlapping decelerators including the here introduced debt accelerator without recognising its presence and measuring its specific effect.

Such a fine analysis of the effects of different accelerators is beyond the scope of this research study and it will be left to another study. One thing, however, this research wants to stress is that the debt driven deceleration forces need to be taken into account within macroeconomic models. To begin with, one can use an aggregate of the two components: Fisher's debt deflator and the here introduced recession debt accelerator (i.e. decelerator).

6.3 Backstage repeated: The Great Recession of 2007

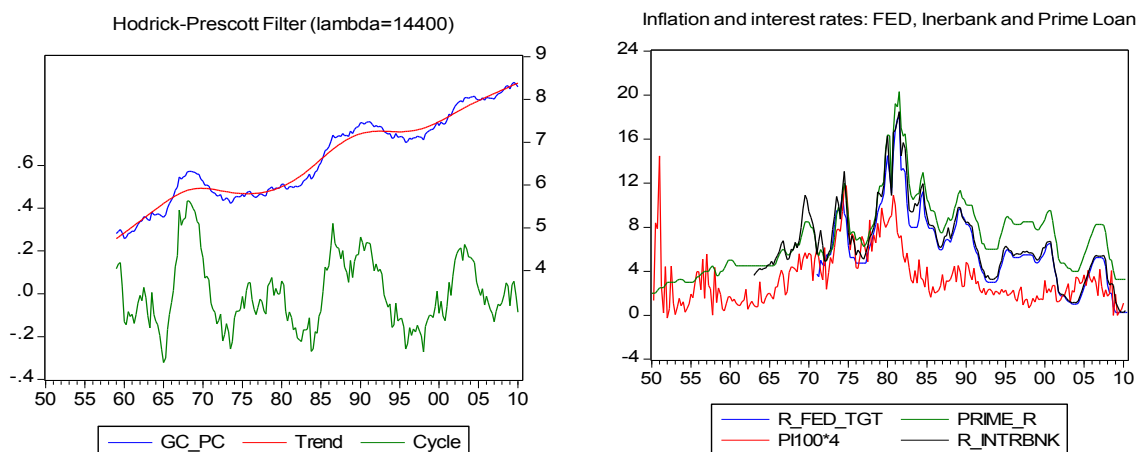
“But anyone who has looked seriously at how we got into this slump knows that private debt, especially household debt, was the real culprit: it was the explosion of household debt during the Bush years that set the stage for the crisis.”

Paul Krugman, NY Times, 22. Jan. 2012

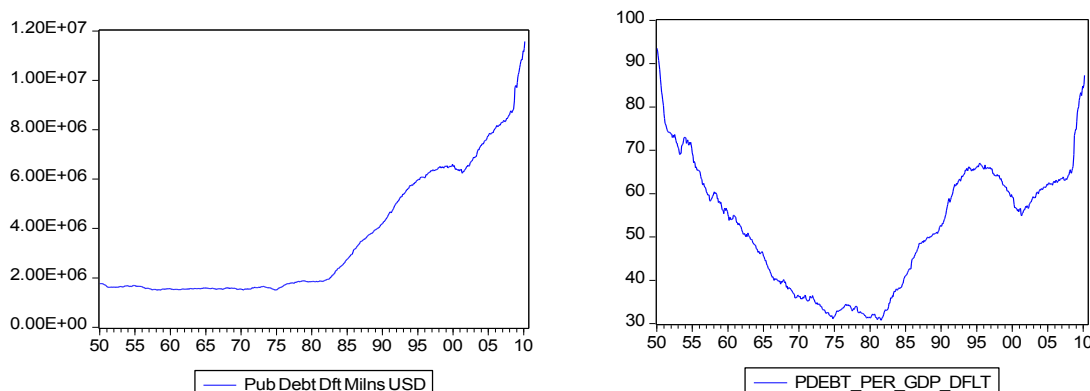
6.3.1 Fiscal Policy of Sovereign Debt driven Growth

The so-called “years of great moderation”, the years of relatively stable and low inflation since early 1980, when FED and other governments let their central banks exercise inflation targeting with rather low target goals of around 2%, were all but that. Though this was a period of steady and of stable, low inflation and interest rates, it was also accompanied by increasing government spending per capita (see below Figures 6.3.1.1 and 6.3.1.2). These low inflation and interest rates in the long term, were green lights for many others, homebuyers, impatient consumers and speculative investors, to start borrowing excessively with expectation of low loan repayment rates. In addition to the consumers and investors, the followers of this trend included also many of the world governments including the US (see below Figures).

Figures 6.3.1.1 HP filtering of government spending per capita (left), and, 6.3.1.2: the Fed’s target policy, prime and interbank interest and inflation rates form 1950-2010 (right)



Figures 6.3.1.3 and 6.3.1.4: US public debt in levels (left) and the public debt / GDP ratio (right) from 1950-2010



The above graphs illustrate rapid rise in US public debt from 30% of GDP to around 60% during Reagan administration in those very same early 1980's. It rose further until the Clinton administration increased taxes and started reducing the debt in absolute value (left diagram 6.3.1.3) and as a percentage of GDP (right diagram 6.3.1.4). It reached its recent minimum in the 2nd Q of 2001 – that is, just before the 2001 September 11 events and has experienced rapid growth ever since to nearly 100% in recent years.

However, following a common practices of “political monetary cycles,” (e.g. see Alesina, Cohen and Roubini (1992) and the earlier chapter “Elections in 2004 and 2008 and politico-economic cycles”) many of democratic governments spent more in pre-election periods to please their voters and, reduced interest rates and taxed less to please their investors to get re-elected. Consequently, for implementation of their own, publicised policies, the governments had to borrow more, though, also at lower rates. Presumably, they all (rationally) expected perpetual high growth and the low debt repayment interest rates to bring sustainability to their excessive borrowings.

Starting from late 1970s or early 1980s, most of the countries in the developed world started building their public debt and increasing their debt-to-GDP ratios. As research from the IMF (2010) shows for the G7 countries, the increase of public debt was

mainly caused by loss of revenue (i.e. tax income). Whilst an increase in expenditure for health (particularly for US) constituted the largest part of the rise in total expenditure (and relative “size of the government”) in the pre-crisis period from 1965 to 2007, it is small in comparison to the loss of tax revenue. The tax revenue reduction was mainly due to substantial reduction of corporate taxation “*as competition for increasingly mobile capital and profits intensified*” the report states.

Consequently, the more the households borrowed, the more they would spend creating higher demand and, the resulting, higher GDP output was enabling their governments to borrow and spend even more. The low inflation was supported by import of cheap goods from developing countries and the trade deficit was balanced by government debt being sold to the same, mainly exporting countries of East Asia whose foreign reserves rocketed from 2002.

Therefore, governments potentially have an interest to keep the interest rates low to reduce the costs of both their borrowing, and indirectly, to encourage household consumption and so accelerate the growth bubble. Industry and the other business agents such as the financial intermediaries and central banks also shared some of these interests.

6.3.2 Debt and Growth

Many authors, in particular those from IMF background, traditionally argue that an increase in public debt reduces the prospects of growth. This is mainly due to the resulting pattern of under-investment that is caused by potential investors’ expectations of higher long-term interest rates, future taxation, inflation and economic volatility¹⁰⁸ e.g. see Marcet and Scott 2003 and Kumar and Woo (2010). However, the authors state this pattern may not be so prominent in the developed countries. If this is the case the rapid growth of US public debt did not result in a crowding out of capital investment, an increase in interest rates (strictly controlled by central banks) or a fall in GDP.

¹⁰⁸ though in some cases, a low growth may cause, or accelerate public debt,

However, Kumar and Woo consider a country's openness by the sum of its imports and exports in relation to its GDP and its government size by proportion of government consumption of the GDP but their analysis does not consider government contribution to GDP through investment.

On the other hand, a few authors show that in some cases increased debt may be beneficial for growth. According to Crotty (2008), recent US GDP growth was driven by a rise in consumption despite a continuous decrease in real wages thanks to the rise of household debt from 48% of GDP in 1985 to over 100% in late 2008.

Traum and Yang (2009) and Traum and Yang (2011-13) go beyond the common position of non-productive government spending. In their NK Smets and Wouters derived DSGE model they introduce two types of government expenditure, the productive investment [which may attract complementary private investment], and the more traditional, non-productive spending. Similar to Levine et al. (2009) they also have both the myopic non-saving and the rational, forward looking saving (Ricardian) agents. They then show that if an increase in government debt was used to reduce capital gains taxes on business investment, then further investment can be attracted (crowded-in) instead of being discouraged (and crowded-out), leading to an increase of GDP output.

In their study Greiner and Finke (2009) define criteria for a sustainable government deficit as a scenario where, at least in the long term, the government ensures that the increase in the government budget surplus to GDP ratio is higher than the increase in the debt to GDP ratio. They then similarly show that a short term increase in sovereign debt aimed to finance productive public spending and encourage investment can increase balanced growth and the government budget surplus. But, as authors state, this is feasible only as long as the government switches to the aforementioned sustainable budget scenario in the long term and wages are sufficiently flexible to maintain employment to its near full natural levels. If wages are, however, very rigid and the debt increase leads to higher unemployment, then the effect of productive spending is

non-existent unless the government is also the creditor with surplus funds.

Though the US appears to have followed a policy grounded on principles similar to those outlined above, growth of GDP in the prolonged conditions of reduced taxes was not sufficient to offset for the budget deficit and the US debt continued increasing to reach again levels close to 65% GDP just before the start of the 2008 financial crisis.

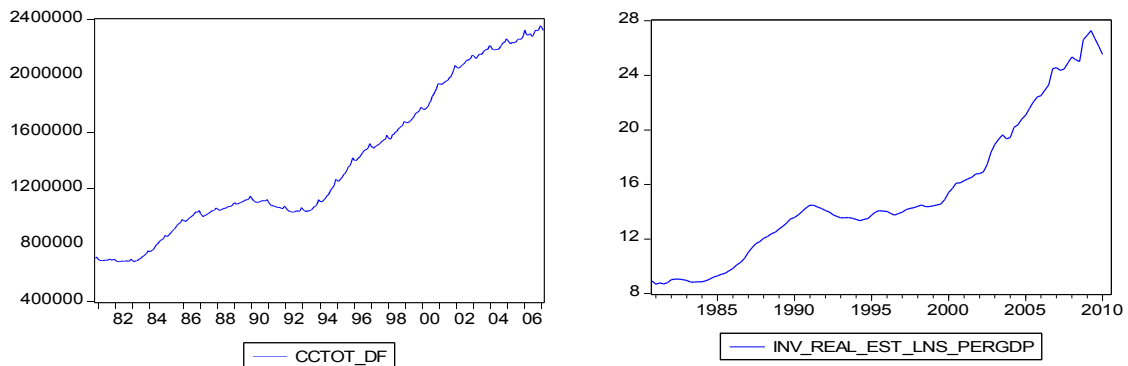
6.3.3 Bubble growth

Among many, Arrow (2010) points out that midst bubble growth most investors and bank managers took a biased rational decision to engage in highly risky investment, in sub-prime MBSs, since the potential incentives of high bonuses and high returns over-weighted the perceived risks of losses. The perspectives of “the worst-case scenarios” such as bankruptcy, loss of bonuses or even job losses were over-shadowed by the expectations of high gains.

It may be argued however that the group of those rational agents could be extended to include many sub-prime households and small-to-medium-businesses. For example, a few authors point out (e.g. Dokko et al. (2009)), the lowering of the federal funds target rate from 6.5% in 2000 to a mere 1% by mid-2003 may have accelerated both private industrial and the private housing investment borrowing as well as the sale of both prime and sub-prime mortgages¹⁰⁹.

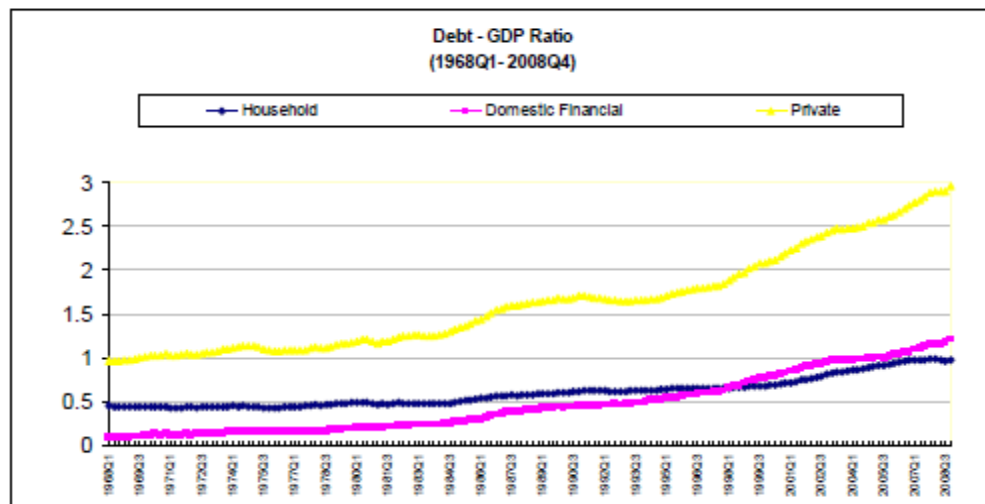
¹⁰⁹ As well as the sale of public debt treasuries and bonds.

Figures 6.3.3.1 - left: Total consumer credit (mill. USD, deflated, data from Federal Reserve of St. Louis), and, 6.3.3.2 (right), real estate investment loans per GDP



Beaudry and Lahiri (2009) show how the total private debt rose to 3 times GDP:

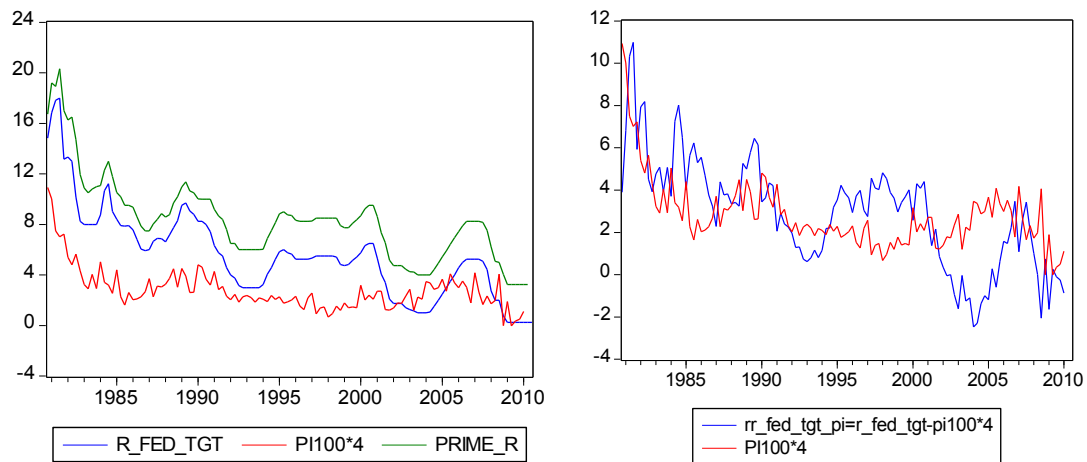
Figure 6.3.3.3 Growth of the total private (top), domestic and household debt to GDP ratio from Q1 1968 to Q3 2008. (rep. from Beaudry and Lahiri 2009)



As one can see in the diagrams below, in spite of rising inflation, the Federal Funds target rate was lowered even further from 2002 to 2004 (left) and the resulting, “real” Fed funds target rate (right) i.e. the $r_{fft} - \pi$ (inflation) was actually around negative

2.5% in Q1 of 2004 and then it rose, starting from Q2 of 2004 to nearly +3.5% by Q4 of 2006 and stayed rather high throughout 2007.

Figures: 6.3.3.4, left: Fed’s policy target rate (blue/middle), inflation (red/bottom) and banks’ prime rate (green/top), and, 6.3.3.5: (right): The real Fed’s policy “real” rate, as a difference between the nominal target rate and the inflation rate (blue) and the inflation rate (red), both 1980-2010.



In response to the criticism that the Fed’s policies facilitated the housing bubble, the Fed and Mr B. Bernanke¹¹⁰ reject such responsibility and, prefer to focus on the crisis contagion mechanisms. On the other hand, Taylor (2007) is one of the earliest authors who indicated that a “too loose” monetary policy during 2003-2004 period (after a combined Sep. 11 2001 crisis and DOT-COM bubble recession), probably lead to the extensive housing activity. Gordon (2009) also analyses the causes and points to many similarities between the 1927-29 and 2003-06 bubbles. He refers to the highly leveraged (90%) and low interest rate loans for stock and housing purposes respectively, to the regulatory failures caused by repeal of Glass-Steagall Act. Gordon then states (ibid, pg. 6):

¹¹⁰ E.g. in the hearing at [Financial Crisis Inquiry Commission](#) held on 2nd Sep. 2010, Mr. Bernanke maintained that the Fed did not aid the housing bubble by keeping interest rates too low for too long in 2002-4.

“It is widely acknowledged that the Fed maintained short-term interest rates too low for too long in 2003-04, in the sense that any set of parameters on a Taylor Rule-type function responding to inflation and the output gap predicts substantially higher short-term interest rates during this period than actually occurred... thus indirectly the Fed’s interest rate policies contributed to the housing bubble”

One explanation for the adherence to a prolonged low target rate during the 2003-2004 period is the fear of a Japan styled deflation after 2001/2002 recession (Taylor (2007)) that was implied by the Fed at-the-time using real-time PCE inflation indicator data but this trend was only later revised not to be deflationary (Dokko et al. (2009)).

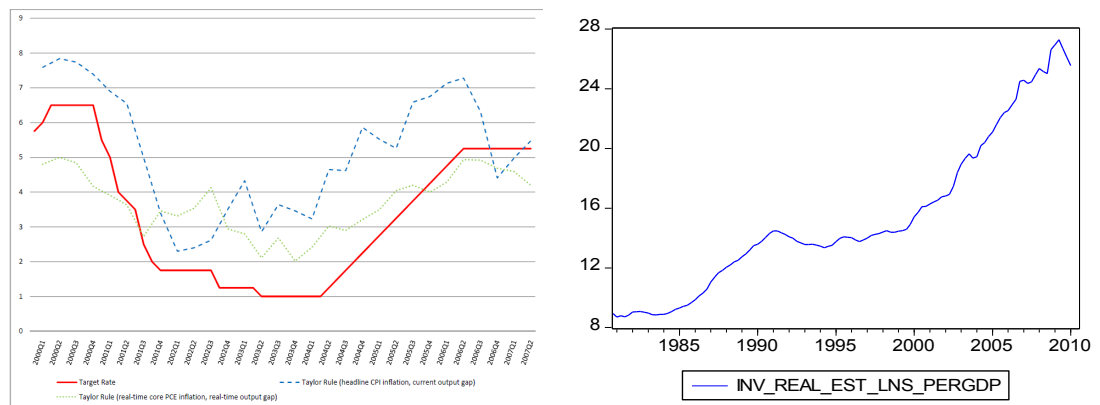
As Ahrend (2008) shows, monetary easing can lead to an excessive increase in asset and real estate prices. Whilst the initial stages of globalisation kept the prices of tradable goods low and consequently the officially accounted CPI based level of inflation and interest rates in the last two decades, the market values of non-tradable goods such as real estate and other assets have rocketed rather excessively. As Ahrend shows, the most excessive increases in real estate values, and to a much lesser extent of the equity assets, are associated with periods when short-term rates were kept well below the level that the Taylor rule would prescribe. This was often in or after periods of lower GDP and amidst the fear of following Japan into deflation. Ahrend argues that such monetary easing over extended periods leads to housing booms followed by a financial or banking crisis. UK, Japan and Finland are cited as examples of having earlier episodes of such developments around the developed world in the late 1980s, only to be usually followed by financial or banking crises in the early 1990s. In addition, similarly, the recent easing in period 2002 – 2005 would have provided the grounds for both the recent housing boom and then the financial crisis of 2007-2008.

Whilst Dokko et al. (2009)¹¹¹ admit that the Federal Reserve target rate was up to 2%

¹¹¹ Article published by Federal Reserve Board, Washington DC, 2009

below what the traditional Taylor rule prescribed, they still deny that monetary policy facilitated or triggered the housing bubble. Please see the diagram (Figure 6.3.3.6, below-left) reproduced from their report. It shows the fed target in full red and the Taylor rule rate in dotted-blue line), They also admit what the below right diagram shows, that there was a sharp rise in the growth of the housing loans for residential investment (in relation to GDP) from 2003:

**Figure 6.3.3.6 (left): Taylor expected (dotted) and Fed (red) rate, and
Figure 6.3.3.7 (right): Real-estate investment loans as percent of GDP, repeated for
comparison.**



The authors note “...that the measure of inflation reported in these documents shifted from overall PCE inflation to core PCE inflation from the years 2003–04 to the years 2005–06”

It is however known that reducing the inflation measure to so-called core (or “net”) may create an inadequate response and higher variance in both the inflation and the target rate. Mishkin (2007, pp 376) and Jonas and Mishkin (2005) state that the net inflation construct is frequently more volatile and that it leads to targets being missed more than would have been case with the headline inflation.

Focusing the inflation target on the core inflation without the “bubbling” property and

energy prices may have encouraged Fed to keep interest rates lower than they may have been set otherwise. Lansing (2008) , a Senior Economist at FRBSF, states that it is controversial whether the increase of the Fed's rate to the level expected by the Taylor rule in 2003-2005 would have prevented or reduced the growth of the housing bubble and whether central banks should engage in asset bubble control and targeting.

6.3.4 Distribution and Underinvestment

The additional explanation for the crashes comes from analysis of the common underlying causes for both crises. Livingston (2010) and Belabed (2015) point-out that both crises were preceded by a significant shift from wage income to profit income and increases in inequality . Livingston claims that unusually high household consumption beyond their income means and the parallel high retention of the profit with a small proportion of profit re-investment, in part due to insufficient investment opportunities, resulted in the recession.

Kumhof et al. (2013) develop model which shows that savings of the higher income group enables the low and the medium income group to borrow and compensate for the loss of real income so to maintain consumption to levels close observed in the US data between 1983 and 2008, increasing danger of crisis. They then conclude that rising income inequality may lead to increased saving and wealth-accumulation in the high income group and the decreasing relative and real incomes among the lower and the middle income groups, thus, both facilitating and inducing build-up of, eventually, high debt and debt-to-income leverage among the latter two groups that will be endogenously contributing to increased risks of crises through mechanism of endogenous, rational defaults of households.

6.4 Bubbles Burst

6.4.1 Corporate Financing Structure and Burst of Economic Bubble

“... From 2003 to 2008 the [debt] liabilities of small companies ballooned from

roughly equal to sales to three times sales, according to Sagesworks, a financial data company that tracks 1 million small private businesses. "In the crazy times, people were like drunken sailors—they'd project that in two years they'd double their earnings, [so they would] overvalue their companies, and as owners in love with their businesses, take on debt, right or wrong," "They got away from the historical debt-to-equity parameters of their industries." Banks and credit-card companies did their part, too, heedlessly throwing offers of credit at entrepreneurs. Some 636 million business credit-card offers went out in 2007, according to, a research group. That works out to about 27 offers mailed to each company in the U.S." ;

Jill Hamburg Coplan, Bloomberg Businessweek, Dec. 4, 2009

During the time of the bubble bursting, corporate finance structures changed in favour of bank loan debt over equity. This made many businesses much more vulnerable to bankruptcy or liquidity problems when interest rates started rising between 2004 and 2006, thus accelerating the recessionary trend beyond that which historical data based model estimations would have predicted. For example, the foreclosures on sub-prime but adjustable rate mortgages (ARMs) exceeded foreclosures on any other type mortgage type. The cumulative rise since Q2 2006 also exceeds the fixed rate, either sub-prime or prime mortgage foreclosures, the number of which did not show much of a rise with the interest rate rise (Murphy (2009) and USGAO (2009)).

Such an increased debt-to-equity ratio however, also accelerated the valuation downturn of both the corporate debt (bonds, if issued) and of the company shares as the risk premia shot up in the wake of increased bankruptcy risk. Again these moves were disproportionate to the historical data estimates, this in turn spiralling the corporate liquidity problems and bankruptcies of the small firms rising from late 2006 and, as well unemployment rising as early as Q1 2007 (see below figures).

Figure 6.4.1.1: Bankruptcies

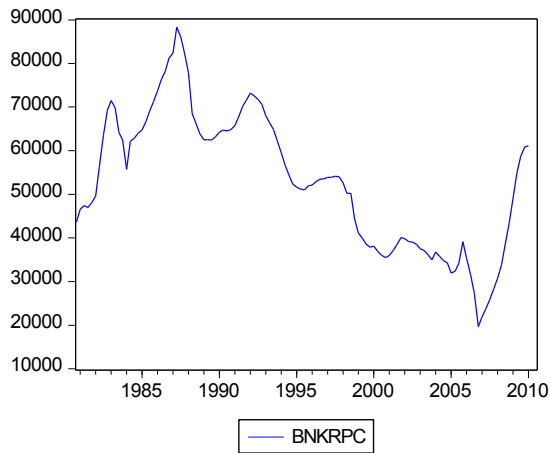


Figure 6.4.1.2: Unemployment

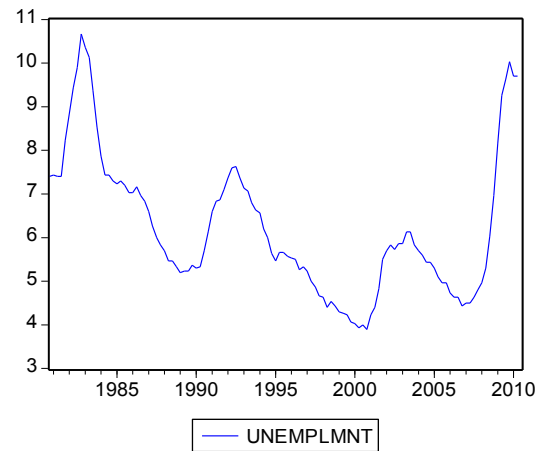
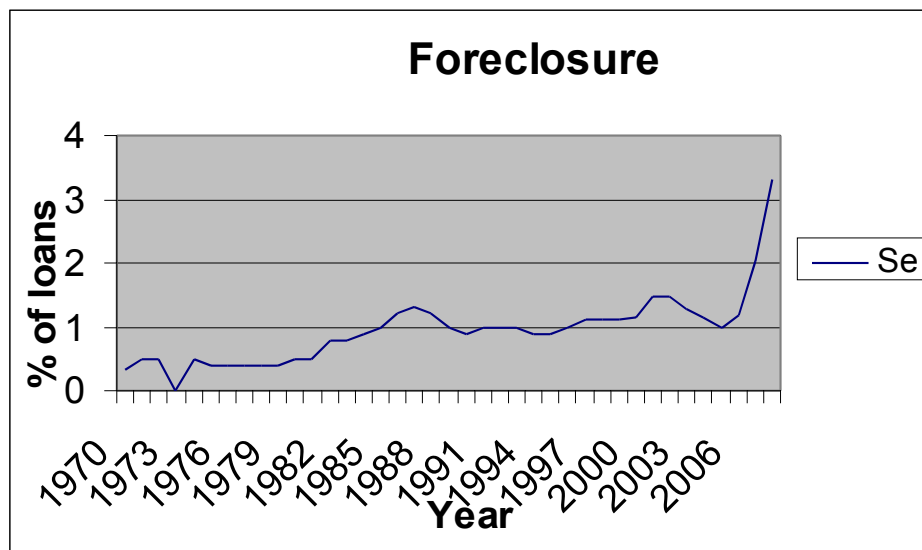


Figure 6.4.1.3: Foreclosures 1970-2008 as percentage of loans, (source: US Census)



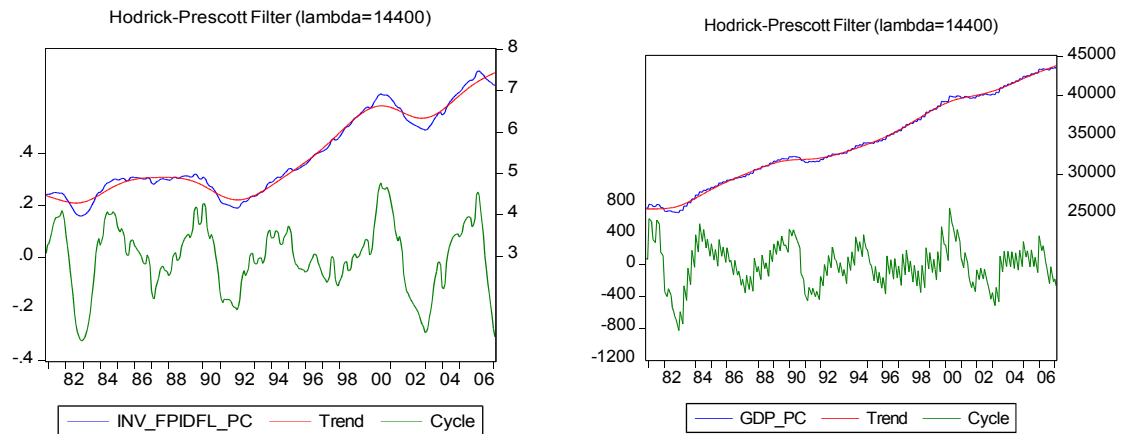
We can see that number of foreclosures¹¹² decreased in the period 2002-05 and started increasing again in 2006 slowly but not substantially until Q2 of 2007. That 2007 rise coincides if not follows the rise of unemployment and bankruptcies which started in Q1 2007. The point we need to make here is that the rise in foreclosures seems to be more

¹¹²Foreclosures 1999-2011 as % of loan customers per the US state have been the highest in Nevada (NV), Arizona (AZ), Florida (FL) and California (CA) (Source - N.Y. Fed)

of a result of, or an accompanying (non-trivially) parallel channel with the two other major movements contributing to an overall recessionary trend – bankruptcies and unemployment - rather than their main cause. In addition, whilst there is no strong direct causal link from the rise of foreclosures to a major recession at this stage, there is definitely a direct causal link other way around, from the stagnation and minor recessionary trend to the increasing number of foreclosures. On the other hand, increase in foreclosures is likely to reduce credit-worthiness of the market and banks inclination to provide further credit, thus in turn facilitating further bankruptcies, unemployment and foreclosures.

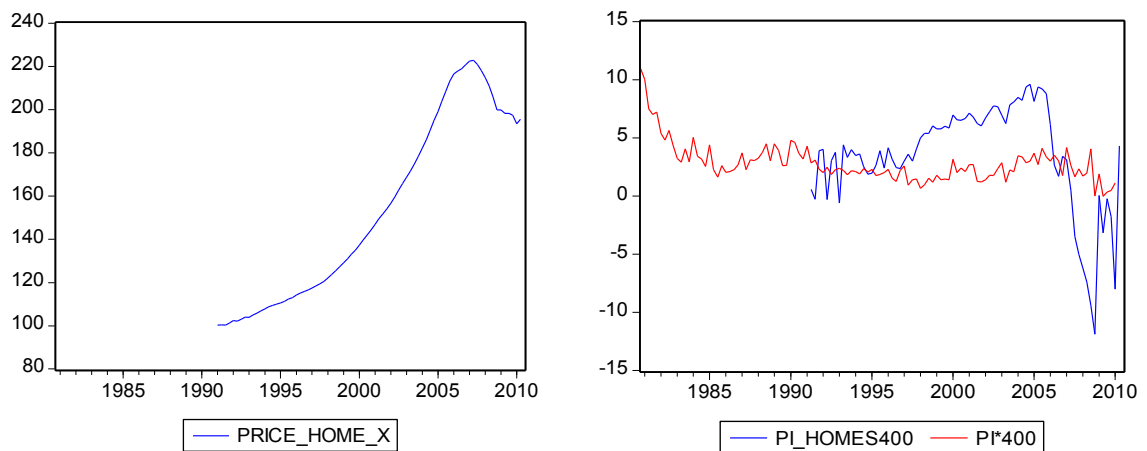
For example, Schelkle (2011) analyses mortgage default theories and their fit to the US 2007 crisis defaults and identifies that a double problem, such as the occurrence of both the negative equity and unemployment fits the US 2007 crisis data the best. On the other hand, from the graphs below one can see that, though house prices peaked in Q2 2007 and started to decline in Q3 2007, their inflation started slowing as early as Q1 2005. On the other hand, the “real” house price rise actually went “negative” (i.e. below the average consumer price inflation) in Q2 2006, thus, creating a pretext for occurrence of negative equity as early as mid-2006. This was the same quarter that private investment per-capita peaked and started its downward trend (see graph later below) and the overall GDP per capita slowing its growth below its mid-term trend, thus, both signalling slowdown though not yet a clear turn to a recessionary trend.

Figures 6.4.1.4: private investment per-capita (left) and 6.4.1.5: the overall GDP per capita and their HP filtered trends and deviations (right) respectively.



The increase in unemployment in early 2007 (fig. 6.4.1.2) then added the second necessary ingredient needed to accelerate the already started foreclosures, trigger the second wave of bankruptcies and finally, the financial crisis that further spiralled the economy along the now well-known path.

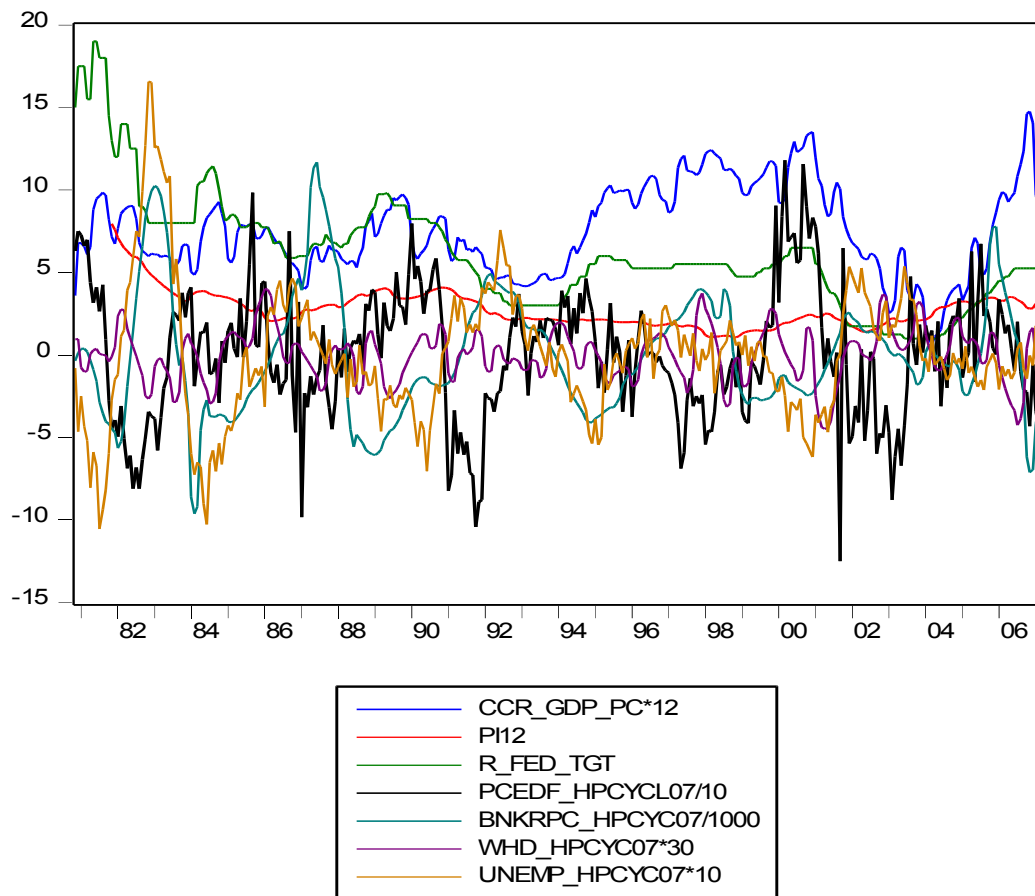
Fig. 6.4.1.6 Average US Home prices (left), and Fig. 6.4.1.7 (right): Annualised average US home, (blue) and consumer price (red) inflations.



But, as US Fed planners may appear not to have considered trends and changes in housing inflation or possibly even the level of overall debt, the impact of the increasing

unemployment and foreclosures to be a threat to the economy to a sufficient extent, it continued raising the target base rate in Q3 2006 to 5.25%. Fed subsequently kept the rate at that high level until Q3 2007, two quarters after the unemployment and bankruptcies had started rising rapidly, thus, apparently, fuelling the recession and the foreclosure trends (and the resulting financial crisis) even further.

Figure 6.4.1.8: Combined, overlapping graphs of major measures or their HP cycles normalised to fit the illustration and allow easier comparison:



CCR- Consumer credit real rate return (blue) per GDP: $CCR = CC * r_r / GDP$
 PI12 – Annualised inflation
 R_FED_TGT – US Federal Reserve policy target rate.
 PCEDF_HPCYCL07 – HP filter cycle component of deflated personal consumption
 BNKRPC_HPCYC – HP filtered bankruptcies
 WHD_HPCYC – HP filtered hourly wage
 UNEMP_HPCYC HP cycle of unemployment rate

In the above figure we can see that credit return payment increased 6 fold from 2003 to 2005, boosting banking profits and depleting households' and SMEs' liquidity and consumption ability. The consumption level measures remained to increase but declined sharply from their trend (this being until late 2007 when the fed and the real return interest rates started falling).

Real hourly wages declined in levels and potentially accelerated slowdown in consumption which seem to have been sticky due to lifestyle rigidity and whose fall was counteracted mainly by further increasing credit, however, up to a time limit when further credit was not feasible due to fall in housing assets prices. Sticky, unemployment started eventually rising too which appears to have finally prompted lowering of the US Federal Reserve policy and the real interest rates later in 2007. These events are all however, preceding the financial crisis: the collapses of the major banks and other financial institutions throughout 2008 and this research therefore concludes that it was the economic stagnation and a minor recessionary trend starting in late 2006 and early 2007 that contributed to, if not triggered, development of both the recession and the crisis of the financial system in 2008, not the other way around as it is, often, I believe incorrectly, assumed.

6.4.2 The Burst of the Financial System Bubble

Many articles discuss the causes of the sub-prime mortgage based securities (SMBS) bubble and show how, after their collapse, the contagion of the resulting sub-prime bubble collapse spread beyond the borders of US and caused recession (e.g. Kamin and DeMarco (2010), Mishkin (2010), Kolb (2011) and Brender and Pisani (2010). Among few others, Farmer (2012) also points to the drop in demand caused by the financial crash as the cause for the economic crisis that, according to their analysis, followed the financial crash. Not many, however, show why the collapse started.

One of the recent, earlier bursts of the financial sector occurred in late 1987. Konings (2010) indicates that Volker's policies of high interest rates introduced in early 1980s to

curb inflation did not do the job as intended. While the price inflation of goods in the real economy came down, monetarism worked its way around it and liquidity was on increase in the financial sector. However, instead of causing inflation in the real economy, the liquidity remained within the financial institutions contributing to inflation of financial assets instead. Inflows of foreign assets increased exchange rates, both contributing to an under-investment in the real economy paralleled by the over-investment in the financial sector. This trend then contributed to a two-way economy: the real economy heading for a recession and the financial sector bubble growth, the instability, the Savings and Loans crisis and then the 1987 financial market crash.

In 2005-6 period we can similarly see a rise of interest rates together with inflation of securities, but also, increase of investment into emerging markets and foreign capital outflows which created additional shortage of consumption demand liquidity, thus, following pattern of debt accelerator explained in previous section, leading into stagnation and eventually decline in real consumption demand and rapid rise of bankruptcies. This trend was to retreat in early 2006 but to resume with further bankruptcies after a prolonged exposure to high interest rates depleted liquidity in another batch of businesses and households. By then, they probably spent most of their cashflow reserves, thus, now, mutually accelerating even further the slowing-down of consumption demand growth. Starved from further credit midst the stagnation in values of their main collateral assets (e.g. their houses) asset prices started to decline and so, gradually trigger the other financial accelerators (e.g. BGG and Iacoviello 2005) and, eventually, the collapse of MBSs. As mentioned earlier, US foreclosures on sub-prime adjustable rate mortgages (ARMs) exceeded foreclosures on any other type mortgage type and all fixed rate ones, either sub-prime or prime mortgage foreclosures, whilst the number of the latter two did not show much of a rise with the interest rate rise (Murphy (2009) and USGAO (2009)).

Mishkin (2010) appears to be one of few authors who explain the development and spread of the mortgage based securities collapse-led crisis, however, without trying to explain its underlying roots of the MBSs value collapse. He was trying to make an

implicit parallel to the Great Crash of 1929. and asserted that, in the wake of the modern Great Recession there was a series of events such as the bank runs, (that led to a few, including the 1929 crisis) but that this time they occurred on the shadow banking system (i.e. non-depository, investment banks or hedge funds).

Whilst in classic (e.g. 1930s) bank runs depositors withdraw the short-term bank's liabilities consisting of their deposits or transfer funds to bigger banks along the lines of the "silent runs" explained by Rockoff (2004), in the shadow banking it is the long term asset-backed short term loans (e.g. asset repurchase agreements or repos) that are the key for understanding the problem. Usually, a borrower institution is expected to provide some less-liquid, long-term assets (e.g., mortgage-based securities – MBS) as collateral with their total nominal value higher than the amount of the loan. The difference is the so-called haircut, a form of risk insurance and interest rate on the short-term loan.

However, as the value of MBSs fell amid the increased uncertainty and mortgage defaults, the haircuts rose from what was mere 5-10% to up to 50%, thus, accelerating the bubble bursting. Whilst Mishkin (2010) refers to this effect as a form of modern, shadow-banking bank run, it can be argued, however, that it was a shadow market crash caused by the MBS credit crash that was then accelerating further the MBS price decline, the shadow banking market crash and then, the crash of the shadow financial institutions too. The short-term lending intermediary institutions then withdrew their credit to their short-term borrowers who were using MBS as collateral deposits, thus, accelerating further fire sale of MBS.

The overall effect of MBSs collapse was equivalent to lowering the credit-worthiness of the borrowing parties and their resulting cash-flow shortages accelerated the recession in a similar fashion as the "silent runs" did in 1930s as explained by Rockoff (2004).

6.5 Sovereign Debt Accelerator

6.5.1 Sovereign Debt Driven Debt Accelerator

Whilst earlier explained mechanisms for debt accelerator were driven by private debt and liquidity shortage, there may be a more endogenous mechanism driving it and one such mechanism will be discussed in this chapter.

Increase in sovereign debt, at some point on the scale of its rise, will usually lead to its debt instruments not to be accepted on the open market unless they yield higher interest rates (and the risk premiums) whilst increasing the cost of debt pay-off and the total liabilities. That raise would then probably trigger another, a sovereign debt-risk-premium-accelerator effect where higher default risk premiums and resulting interest rates seek even higher premiums and thus, even higher interest rates.

However, in addition, each rise of sovereign debt interest/yield rate would then probably trigger rise of the commercial banks deposit and loan rates which, it can be then argued, in case of already exiting high private debt obtained on flexible rate as it has been recorded in 2006/7 may then trigger another, a sovereign debt-recessionary debt-accelerator effect where higher default risk premiums on commercial loans interest rates are leading then to recession as described earlier.

Increased debt liabilities, may result in high taxation leading to both financial and human capital flights distorting even further the Ricardian equivalence. Currently this would turn most developed and indebted economies with an already ageing population into old-people homes and dormitories for their low wage basic service workers and unsustainable pension liabilities, raising problems in both, some EU countries and US states.

Any of the above stages may create a contraction pressure that may affect its growth path and prevent the government from creating the revenue needed to pay for the existing coupons, and even less, for higher risk-premiums and interest rates on the debt.

Thus, a self-fulfilling sovereign default may then occur too.

6.5.2 Endogenous Debt Accelerator in Smaller Countries

Smaller countries are exposed to additional external capital inflows that are following the principles of credit default risk for large corporations and small countries, where the market agents assess default risk and the required premium. There, highly indebted institutions are thus forced to increase interest rates on their debt obligations and this then creates pressure on an indebted smaller country to increase its interest rates (Márcio and Rigobon (2004) and Jens Hilscher Yves Nosbusch 2008).

On the other hand, higher relative indebtedness over GDP may occur in the time of crisis if a government followed an inconsistent, short-termist pro-cyclical spending policy and then lacking resources to switch to a counter-cyclical management of a downturn crisis with increased spending. This could have been avoided if it was, instead, following a consistent counter-cyclical budgeting and spending. However, the reduced form models used (e.g. by Márcio and Rigobon (2004)) cannot show that and their results are therefore often inconclusive.

6.5.3 Some Fundamental Issues of Small Government Debt

A large proportion of debt instruments traded or used as high-class collateral are sovereign bonds and treasuries whilst, since the 2007 crisis, MBSs are regarded as low quality ones unsuitable as collateral. However, in a recent move, Danish FSA has issued a directive that domestic MBSs should be treated as AAA products, stepping outside of the recent international trends to critically assess MBSs and avoid their use as they were at the centre of the recent, 2007 Great recession. Large amounts of sovereign debt among the majority of the developed, leading countries, provides at the same time, high quantities of high-grade assets for collateralisation or pension investment. However, like the other Scandinavian countries, Denmark has small government debt and its debt is insufficient to satisfy requirements for the high-grade domestic debt needed by the

pension funds and other players in the Scandinavian domestic financial markets.

Whilst a government's regular financial obligations should be met from ongoing taxes and reserves, any additional debt issued in extraordinary situations only, such as war or another calamity, which needs to be financed in an emergency or in a short term, is expected to be recovered through increased taxes in the longer term.

On the other hand, two of the main purposes of agent's/households' saving now for spending later would be:

- precautionary, consumption smoothing, for the rationally expected future times of lower income, such as retirement.
- saving for an investment: a big purchase or investment in either business, physical assets (house, car), financial or human assets (education or children). (Where the latter (b) may be related to the former retirement investment (a)).

In each case, traditionally, an agent would save cash but even better, if available, invest in an interest or a return yielding instrument rather than keep cash under pillow.

If the saving is aimed for precautionary purposes, e.g. retirement (a), the agent may want the investment to be secure and of a high grade; a (e.g. government) bond may be the only acceptable alternative to cash in a retail bank deposit account (or to cash under the pillow). On the other hand, if there is not enough government debt (and certificates) floating on the markets, the only alternatives are low risk bank deposits, keeping cash ("under pillow") or opting for a balanced risk portfolio of cash and more risky, commercial assets.

But a legal framework (e.g. Solvency 2) has been put in place which obliges financial and pension institutions to keep in pension funds, or use as a collateral, only high grade assets akin to treasuries or gov. bonds, whilst the risky commercial ones are not an

acceptable option, that is, unless they are up-graded as is the case of Danish MBSs¹¹³.

On the other hand, the owners of existing debt seek income and to protect their asset and their monopoly on the rental income from the government debt. They are likely to fear the dilution of their debt value with more bonds being issued on the market. This would happen when creditors seek a higher yield and hence lower prices, thus, force the initial creditors towards a loss.

6.5.4 Voluntary Default

This is a brief discussion on whether a country may decide to resist interest rate pressure and protect the sustainability of its growth by opting to default on its debt.

Wray (2014b) analyses the theory of money and sovereign debt and takes a rather unorthodox approach. He derives the conclusion that, like Japan, no government should face involuntary default and that the issue of money (IOU) is limited only by the danger of inflation whilst the issue of debt securities, like bonds, with the aim to cover the budget deficit, is unnecessary and has limited demand - it only has the goal to control interest rates and draw out surplus of money (and reducing inflation). Following along the lines of other unorthodox authors, he goes that far to claim that taxation is unnecessary too, and that the main reason for taxation is just to give value to the IOU money issued by the state.

For this very interesting, unorthodox view Wray does not, however, provide an estimate of the point at which demand for a currency will start diminish its value, leading to inflation, nor any support by any analytical model other than the loose reference to the Japanese economy that successfully maintains low interest rates and high sovereign debt. In a case similar to that of the US, as the US Dollar is a world reserve currency and foreign investors and sovereign funds are happy to stock both US

¹¹³ Aboulain, B (2012): Pension funds assess investments in government debt, Financial Times, October 8, 2012: <http://www.ft.com/cms/s/0/df07bcd6-0c95-11e2-a776-00144feabdc0.html#axzz3AyNQrztK>

Dollars and US Treasuries, inflationary pressures are reduced on the US Dollar. In the case of Japan, cheap Yen loans are converted by global investors to US Dollars keeping the Yen low relative to the Dollar and making Japanese goods even more affordable on the world market. On the other hand, smaller and emerging economies do not have such a luxury and need to keep foreign reserves as guarantees for trade agreements whilst emissions of their own currencies would quickly result in inflation if they were not issuing debt obligations to drain the surplus currency from the market. However, Wray's considerations certainly merit a more analytical approach that is beyond the scope of this research.

However, though the potentially resulting inflation (with or without additional monetarisation stimulus) may be detrimental for growth, the higher domestic inflation may be preferable midst a stagnating economy (stagflation) since the higher inflation will also ease some of the debt costs, thus, compensating for higher government liabilities and also, reduce risks of deflation, that is, as long as the debt is in the local currency. Such inflation may also depreciate the local currency and that in turn may be eventually beneficial for both the international debt reduction (again, as long as the debt is in the local currency) and the increase of exports, helping a return to growth. These solutions however, come at a cost, mainly to the lenders (the local banks and savers, and, the foreign investors and governments) whose debt portfolios and cash savings would plunge in market value, whilst other countries' competitiveness on the international market will be reduced. This may then potentially create either or both, a domestic and an international financial, and possibly a political crisis too. On the other hand, to satisfy the balance of payments¹¹⁴, an indebted and overly importing country may resort to import protectionism and the promotion of domestic products with similar implications on the international markets.

¹¹⁴ Balance of all monetary transactions between a country and the rest of the world over a period of time, usually a year, needs to be satisfied. e.g., if the trade balance is in deficit, the shortfall has to be balanced e.g. by returns from any foreign investments, paying for the difference from country's foreign reserves or by selling debt to and receiving loans from other countries. The main components are the current account and the capital (or the financial) account: $BOP=CA-FA$.

6.6 The conundrum: why does the yield curve forecast growth, or its lack

Note: This text uses the terms ‘yield curve’ and ‘term structure’ interchangeably

The determination of yield curves and (a variety of) risk premia by the estimation and forecasting of macroeconomic models has been a subject of great many research projects. Gagliardini, Porchia and Trojani (2009) explore the effect of ambiguity aversion on the term structure and show that ambiguity premia can be larger than the usually modelled risk premia.

De Graeve, Emiris and Wouters (2008) (DEW08 henceforth) present as an unexplained problem that yields on long term bonds did not rise-up in 2004 as fast as the increase of the short term Treasury rate, resulting in an unexpectedly large reduction of the spread perceived in 2003/4.

This issue was also raised and analysed in Rudebusch, Swanson and Wu (2006). It refers to A. Greenspan’s statement that in 2004, long-term yield curves did not follow the short-term rate increase but some, the 10-year bond yields, took opposite direction, declining from 4.7% to 4.5%.

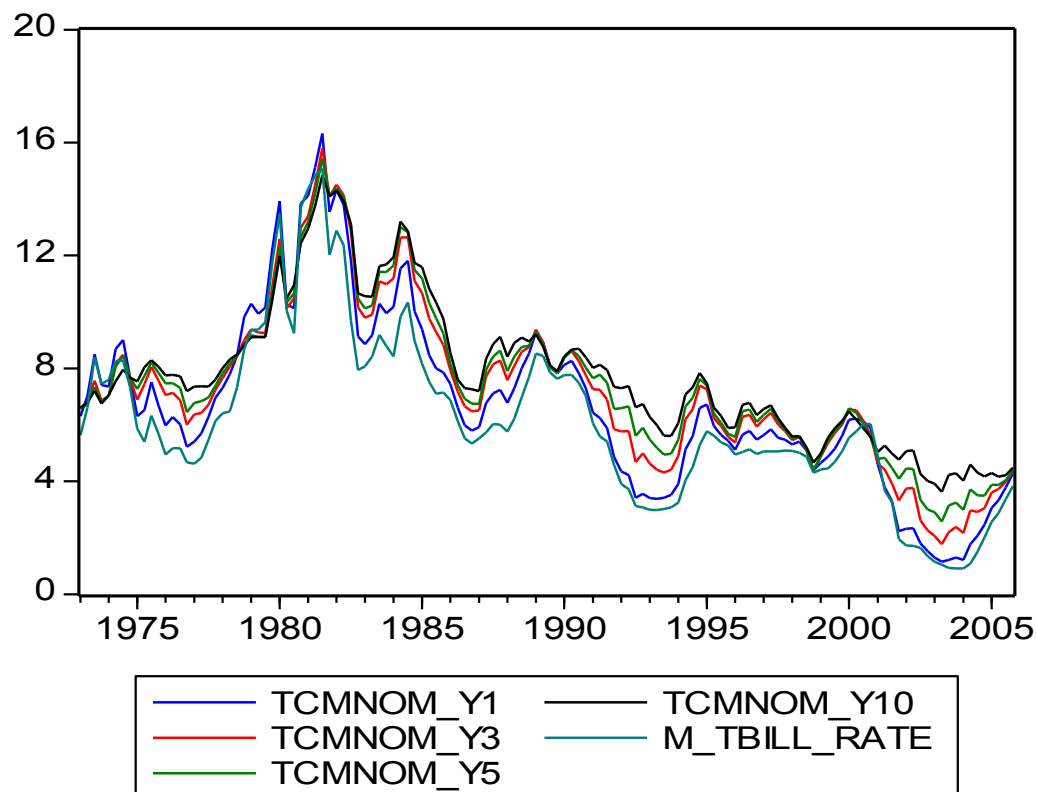
Similarly, our analysis shows a higher gap between the US FED base rate and retail banks’ loan rates just after the FED started cutting rates at the start of the 2007 “Credit Crunch” than the gap has been in the preceding years seen in figure below. Such an “*interest rate spread puzzle*” has been observed earlier and Stiglitz and Greenwald (2003) (S&G03 henceforth) seem to have found an explanation for that situation. They focus on the importance of credit rating and its supply, and conclude those factors are affecting the modern economy equally or even more than changes in the central bank’s monetary supply and interest rates, which is in line with Goodhart and Hoffman (2004) too (see above).

The author of this paper however does not see these events as a conundrum. Whilst the long-term yield is aligned with rational expectations of inflation based on its long-term

target, short yields show higher variations closely in line with short-term rates. This pattern of behaviour is visible in the figure below and was present throughout the depicted period, particularly since the mid-1980s, therefore, coinciding more with the later period of systematic inflation targeting.

In the Figure 6.6.1 below, one can see that the shorter the US Treasury term bond is, the closer is its yield to the short-term rate (i.e. one period or 3 month M_TBILL_RATE in the graph below) and those close spreads are more prominent in periods of very low or very high short-term rates.

Figure 6.6.1: Yield structure of US government bonds



Similar phenomena in different markets have also been discussed in Curtberthson 1996) and he shows that such spreads between long and short rates show a regular pattern but their extent differs between developed countries.

What is more, the two visible departures of that pattern can be considered as exceptions or conundrums, appearing the early 1980s and in the year 2000. However, the year 2000 was election year in the US and, as explained earlier, political uncertainty and cycles- related factors may be contributing to that pre-election shift.

Similarly, the Greenspan 2005 conundrum of the small opposite move of the long term structure yields in 2005, may be attributed to the general criticism and observations that the short-term fed rates in the preceding period were far too low (negative in real terms, see earlier in the text). However, year 2004 was also another election year and the 2005 upward move of the fed rate affecting short term T-bills, was simply recognised as a necessary, or possibly even an over-extensive, post-election (over-)correction for the preceding, pre-election period of far too low rate. This was probably even more so considering that the inflation was still within limits (see earlier chapters and in Rudebusch, Swanson and Wu (2006)). Another factor, asserted as being influential by Rudebusch, Swanson and Wu (2006) and initially indicated by Bernanke, is the so-called international “Saving Glut”, where mainly exporting countries went on shopping sprees for high-grade long- term bonds, mainly the US treasuries, driving their interest rates low regardless of other movements.

It is interesting to note that DEWO7, using variance decomposition, show that inflation target shocks are the strongest determinant of the yield curve. Such a “conundrum” may then be explained by a (gradually) increasing confidence in central banks’ policies, their commitment to inflation targeting in the long run, and in the consequential reduction of the interest and inflation rates risk premia of the longer-term bonds.

Consequently, short-term bonds are more affected by short-term reduction (increase) in interest rates in down (up-) turns and the subsequent expectations of those interest rates increasing (lowering) slowly in medium-to-long-term whilst affecting the yield of the bond more the shorter its maturity is.

That is the rational expectation (i.e. the prospect) of an immediate mid-term increase in output and, consequently, of the interest rates and inflation, reduces the expected yield of the short-to-mid term bonds more than long-term ones that are more co-integrated with the inflation targets.

From the above we can however also conclude, in the retrospect of the years following it, that the conundrum most likely arose because long term yields are based on longer term expectations and that rise of the short term rates was not considered to be remaining in the long term and/or that they were rather too high for the level of inflation.

Whatsoever, considering findings of Rudebusch and Williams (2008) that the long-short bond yield spread predicts recessions (or is an anticipation of its coming), the financial industry would have already anticipated that the rate rise would be unsustainable in the long term. It could have then also expected that the rate increase would be even more detrimental for the consumer liquidity and future of the economy, a conclusion that the economic recession and financial collapse of 2006-2008 eventually reinforced.

6.7 Discussion: Could the Fed Acted Differently?

Mishkin (2010) states that many economists claimed that the Treasury' and the Fed's decision to let Lehman Brothers collapse escalated what would have been a relatively small financial crisis into a much larger, wider spread and largely a panic driven world crisis. At the time of the crisis, however, he stated that there were no legal grounds on which the government bodies could have intervened directly.

In addition, in their 1963 seminal work on causes of the Great Depression, "A Monetary History of the United States" (1963), Milton Friedman and Anna Schwartz accused monetary and credit contraction for the Great Depression rather than financial crash, an opinion adopted and shared by Ben Bernanke. During Milton Friedman's 90th birthday

conference in 2002, Bernanke, at the time a member of the Federal Reserve's (Fed) board, in his address to Friedman and Schwartz regarding the Great Depression, said the following: *"You're right, we did it. We're very sorry. But thanks to you, we won't do it again."* (Bernanke 2002).

On the other hand, as Livingston (2010) points out, in her 2008 interview, Anna Schwartz noticed that, like in 1929, it was monetary tightening after period of loosening that had significantly contributed to the current 2008 crisis : *"As in the 1920s, the current "disturbance " started with a "mania.""The particular asset varied from one boom to another. But the basic underlying propagator was too-easy monetary policy and too-low interest rates that induced ordinary people to say, well, it's so cheap to acquire whatever is the object of desire in an asset boom, and go ahead and acquire that object. And then of course if monetary policy tightens, the boom collapses."* (Carney and Schwartz (2008))

Ms. Schwartz is then arguing that the immediate triggers, i.e. the bubble pricks, for the two financial crashes preceding both the Great Recession and Great Depression are similar – the monetary tightening imposed by the Federal Reserve.

An explanation could be that standard classic single representative agent equilibrium models assume that increase in interest rate on borrowing may reduce demand and increase investment saving among borrowers but that would be, assumingly, balanced-off by the increase in consumption demand of the lenders receiving higher income from savings, either for consumer goods or for investment consumption. However, in more heterogeneous reality, lenders have smaller consumption demand elasticity, and, instead in (just reduced) domestic consumption, higher rate yields were then increasingly reinvested with a large proportion into foreign investments, effectively even more reducing domestic investment consumption demand too.

Another explanation for the Fed policy rate rise between 2004 and 2006 could be that, then already highly indebted US government found it difficult to sell the lower-yield treasuries and bonds and that the Fed was under pressure from the banking and the

institutional investors to raise short-term yields regardless of the small inflation. This may also explain the conundrum discussed earlier and why the industry, pre-cautiously, lowered the long-term yields instead of raising them. However, this institutional pressure may have then triggered the above mentioned sovereign debt accelerator mechanism that then may trigger the private, household and SME debt accelerator as outlined in earlier sections. Such hypothesis however, then puts on the spot the issue of the Fed's and central banks' independence.

Another, very valid explanation frequently referred to is that at the time, the output growth was booming and so there was space for higher rates and yield to slow-down the over-heating economy and bring the rate closer to the normal and Taylor rule expectations.

In any case, based on the findings of the previous chapter, indicate possibility that the combined damaging effect of investment capital foreign outflow and the high private (household and SME) may had been underestimated or overlooked (e.g., “myopically”, as a case of a rational inattention) when decisions to pursue rate increase between 2004 and 2006 were made. However, any firm answers and conclusion regarding the above posed questions, requires a further and a much more detailed research.

6.8 Conclusion and afterword

While many authors quite correctly explained that collapse of house prices and MBSs market lead to the unprecedented international contagion and collapse of international financial market in 2008, it is less said, as John Taylor (2008), (2016) did, that Fed's policy of very low rate facilitated rise of the housing and economic bubbles in 2003-2005. It is however even less said (except in non-academic press and interviews, e.g. Carney and Schwartz (2008)) that it may be possible that the extreme and a relatively fast and high rise in Fed's policy and the resulting commercial real interest rates contributed to the monetary tightening (not unlike that in 1929) driven bubble burst. This bubble burst, also, may have been accelerated by increased outflows of capital into

foreign investment rather than domestic investment or consumption. All the above, taking place shortly after the prolonged period, and the resulting formation of expectations of long-term low rates, may have facilitated triggering of the 2007/2008 crisis.

This would be also in line with earlier mentioned arguments of Goodhart and Hoffman (2004) who then, in 2004, claimed that the two most famous economic disasters - the 1929 Great Depression in US and 1990 crisis in Japan - have both been caused by their respective central banks trying to prick market bubbles. In the US, it was the assets bubble and the real-estate one in Japan. A similar opinion but pertaining the 2007-8 crisis, was also voiced in a very recent blog by [Muellbauer \(2016\)](#).

Based on all of the above analysis, I therefore postulate as a hypothesis (but not at this stage claim that being the fact), that the rise of the interest rates amidst increased debt in period 2004-2007, and hence, increased, income-debt leverage related risk of endogenous defaults (e.g. as in Kumhof et al.(2013)), is likely to have contributed to the mutually accelerated collapses of several of major factors in the US economy ahead of the 2008 financial crisis. These were households' and SMEs' liquidity, housing prices and then credit supply, all of them leading to the mutually accelerated reduction in consumption and rises in bankruptcies, foreclosures and, eventually, unemployment. Those then very likely contributed to the downward spiral of a recessionary trend and triggering of other known decelerators and bursting of the bubble ahead of the financial crisis and, eventually, triggering it. I would refer to this, more neglected and overlooked rather than unknown additional channel that probably contributed to both, first a minor recession and then, eventually, to the collapse of the financial market too as a **recessionary debt accelerator**.

In addition, contrary to the expectations of classic economic and NK economic modellers who mostly consider US as a large closed economy where liquidity loss in one group of consumers will bring rise in another and balance-off the consumption, it happened that some very large sums went into FDI abroad. A fierce discussion arose recently on the issue of capital investment, its foreign outflow and then a possible lack

of job creation facilitating under-employment even if not the official unemployment rate in the recent decades in the US. The hypotheses of outflow of funds and the resulting domestic under-investment were some of the main additional factors brought-in in the previous two chapters as probable contributors to the recent crisis¹¹⁵. We may therefore want to measure more precisely the impact of this channel and to seek to review both existence and roles of possible misspecifications in estimates of the central banks' policy rates. In addition, one should analyse and consider any viable steps that the monetary authorities could have done to prevent the crisis.

Some plausible measures that can be undertaken after further, in depth investigation on their potential effects could be:

1. targeting loan debt/GDP,
2. housing asset price bubble targeting included in the Taylor rule,
3. adding a control mechanism in a more complex but more realistic, multiple (heterogeneous) agent models so that bubbles can be contained better, or,
4. improved monitoring of international capital flow and/or balancing of the sovereign current account.

¹¹⁵ And one that came into prominence during the recent changes in US politics.

Appendix C6.1: VAR Impulse Response Functions' Outcomes

Presented here are data used and a subset of the resulting IRFs (Impulse response functions) based on an estimation of an unstructured, twelve month lagged and pre-processed and normalised data VAR(12), using Eviews as a statistical toolbox.

A.C6.1 Data:

The original data are monthly, taken from US Federal Reserve FRED database and spanning from 11/1980 to 02/2007, covering the pre-2007/2008 crisis “Great Moderation” period.

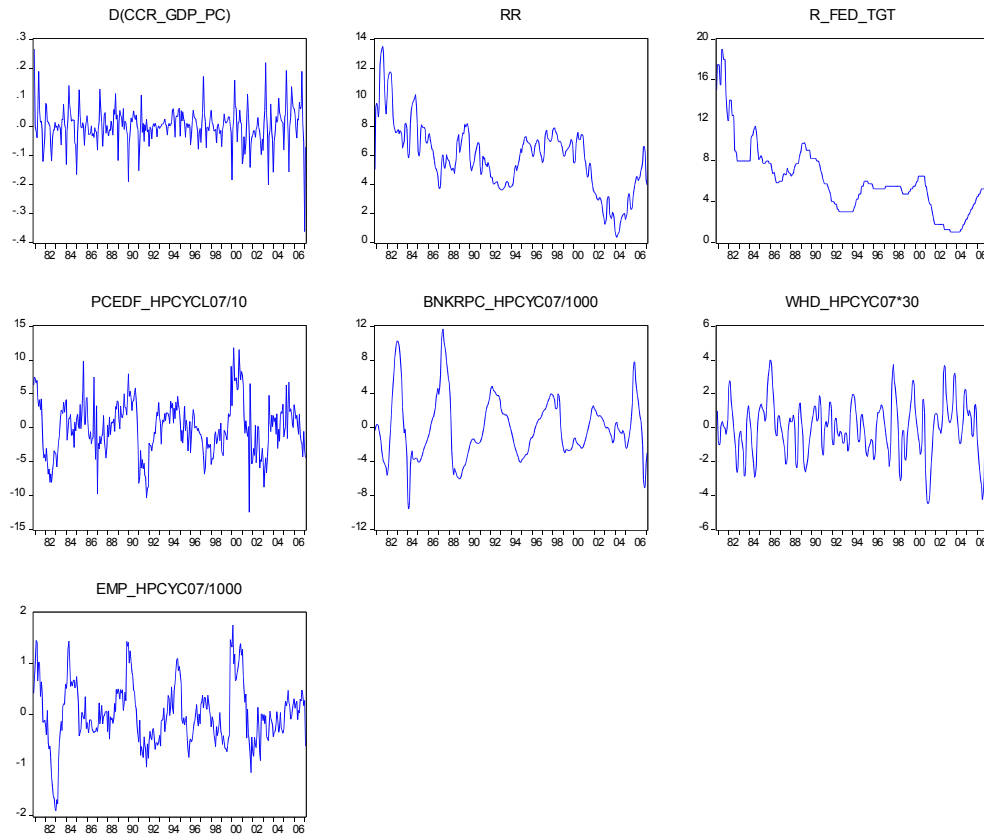
Due to unit-root being identified in level of the hybrid (derived) variable credit revenue return CCR_GDP_PC using Augmented Dickey-Fuller test (as available in Eviews), VAR estimation and IRF simulation will use the 1st difference of that derived series D(CCR_GDP_PC-). In addition, the roots of the lags are within the unit circle.

Data are pre-processed or derived as follows:

CCR_GDP_PC- Consumer credit CC * real rate return and GDP:
$$\text{CCR_GDP_PC} = \text{CC} * \text{rr} / \text{GDP} * 1000$$

however, due to a unit root, VAR uses its first difference: D(CCR_GDP_PC)
R_FED_TGT – US Federal Reserve policy target rate.
PCEDF_HPCYCL07 – HP filter cycle component of deflated personal consumption
BNKRPC_HPCYC – HP filtered bankruptcies
WHD_HPCYC – HP filtered hourly wage
UNEMP_HPCYC HP cycle of unemployment rate was used in initial trials but
EMP_HPCYC HP cycle of employment hours is used as a more reliable measure
RR – real interest rate: $\text{rr} = \text{prime_rate} - \text{inflation}$

Figures A.C6.1.1: Seven Normalised data series used in VAR(12) estimation.



A.C6.2 Estimation and tests of its residuals:

Unrestricted VAR estimation and IRFs were performed using Eviews. The estimation residuals have been plotted and tested for unit root and normality. The residuals' plots did not show visible regularities and no unit roots were found using Augmented Dickey-Fuller tests. However, further descriptive statistics tests in the below table A.C6.1.1 showed some skewness in all of the residuals, whilst Jarque-Bera tests indicated we can reject the null hypothesis of normality and, consequently, a departure from normality for all but for two variables, the US Federal reserve policy inters rates and the HP filtered consumption. On the other hand, considering that we have sufficiently large sample of 303 monthly observations, departure from normality is not deemed to affect greatly the reliability of the result.

Table A.C6.1.1: Descriptive Statistics of the VAR residuals.

VAR Residual Normality Tests				
Orthogonalization: Residual Covariance (Urzua)				
H0: residuals are multivariate normal				
Date: 09/02/18 Time: 00:35				
Sample: 1980M11 2007M02				
Included observations: 303				
Component	Skewness	Chi-sq	df	Prob.
1	-0.397403	8.134676	1	0.0043
2	0.101893	0.534769	1	0.4646
3	-0.156607	1.263274	1	0.2610
4	0.249082	3.195660	1	0.0738
5	0.093638	0.451632	1	0.5016
6	0.131371	0.888947	1	0.3458
7	0.684265	24.11718	1	0.0000
Joint		38.58614	7	0.0000
Component	Kurtosis	Chi-sq	df	Prob.
1	3.221764	0.773598	1	0.3791
2	1.799431	18.49499	1	0.0000
3	3.333441	1.654488	1	0.1983
4	3.044235	0.054282	1	0.8158
5	4.651813	37.06092	1	0.0000
6	1.774825	19.27379	1	0.0000
7	4.926033	50.21816	1	0.0000
Joint		127.5302	7	0.0000
Component	Jarque-Bera	df	Prob.	
1	8.908274	2	0.0116	
2	19.02976	2	0.0001	
3	2.917761	2	0.2325	
4	3.249942	2	0.1969	
5	37.51255	2	0.0000	
6	20.16274	2	0.0000	
7	74.33534	2	0.0000	
Joint	766.5520	294	0.0000	

A.C6.3 Autocorrelation

Two alternative residuals' autocorrelation tests, Portmanteu and the Lagrange Multiplier (LM) tests, both showed presence of autocorrelation up to 48 lags. The autocorrelations were complex and not just AR(1) so that an attempt to use first differences (as recommended in literature) did not bring about much different outcome for autocorrelation nor the other measures.

Following recommendations in literature, alternative data and models were tried to reduce autocorrelation. As we can show on request, in additional tests of an alternative system estimated using first-differences of both the original (unfiltered) data, and the filtered data, the effects of. e.g. Cholesky 1 SD innovation IRFs for shocks to credit revenue, did not in principle bring substantially different results either. Adding GDP as an additional (possibly missing) variable had similarly no substantially different effect on the movements to consumption, bankruptcies and wages under innovation of credit revenue we discuss here either.

With autocorrelations in residuals, the estimators may remain unbiased but inefficient. On the toher hand, statistics will be biased and thus, unreliable. Hence, we will need to be careful interpreting the results of estimations with such autocorrelation.

A.C6.4 Heteroscedasticity

However, the estimation residual heteroscedasticity tests did identify two variables for which one can reject the null hypothesis of no heteroscedasticity (i.e. homoscedasticity or no misspecification) with an error probability being less than 0.05 when using Chi-sq. statistics. These variables are the US Federal reserve policy rate (also identified above as departing from normality conditions) and bankruptcies. As noted above, estimation of the US Fed's policy rate was not subject of this exercise and so its heteroscedasticity, with its residuals' volatility declining over the years of "Great Moderation", will again be set aside for now. As far as bankruptcies are concerned, it is more complex as its residuals' volatility is visibly higher at both ends of the data sample period, stabilising in its middle, throughout 1990s and early 2000s, something visible even from its filtered, input data series in the above figure A6.1.1.

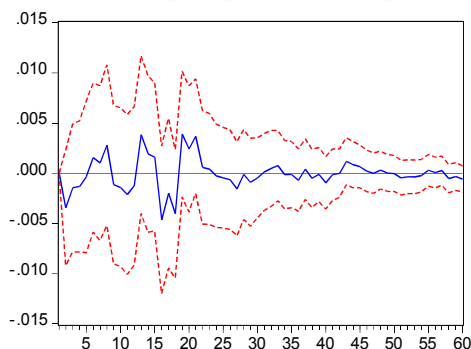
Considering that heteroscedasticity, generally does not create bias but only reduces the efficiency of the estimation, for now, both variables will stay in the model as it is estimated. We shall just not rely on the precision of the effects of the IRF shocks on/from those two estimated variables, one of which, the policy rate, is not directly of interest for this study. In a future exercise, we could consider splitting the period in 3 with two regime changes. For now, however, following that logic, we can expect that effects 1-SD shock of bankruptcy in the final period would actually be higher, and the below results for IRFs for bankruptcy shocks are under-estimated since the level of its 1-SD in that period is higher than its overall (average) is. Equally, it may be expected that effects of other, below depicted shocks to it, would be similarly under-estimated. E.g. a subsequent estimation, using log of the policy rate to reduce an impact of that variable's heteroscedasticity, however, produced IRFs only marginally different from those with the rate in the level. On the other hand, the variation in the volatility of bankruptcies should probably be a subject of a more comprehensive future study in its own merit, possibly utilising volatility estimation tool such as variants of GARCH.

NOTES: A more comprehensive set of estimation results and IRFs are available on request.

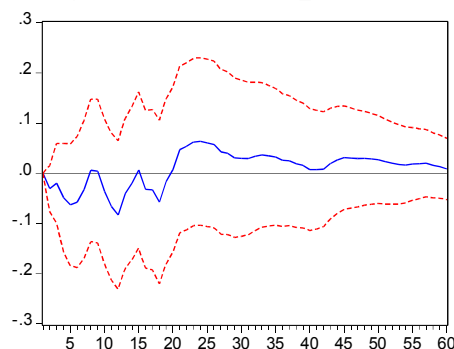
Figures A.C6.1.2: Unstructured VAR(12) 60-month-(5 year) period response functions with two standard deviations certainty range to one SD shock rise in bankruptcies. It is resulting in drops in Consumption (PCEDF...mid-right), wage (bottom- left), employment (bottom right), as well as volatility to credit interest return (top-left) and real rate of interest (top-right):

Response to Nonfactorized One S.D. Innovations ± 2 S.E.

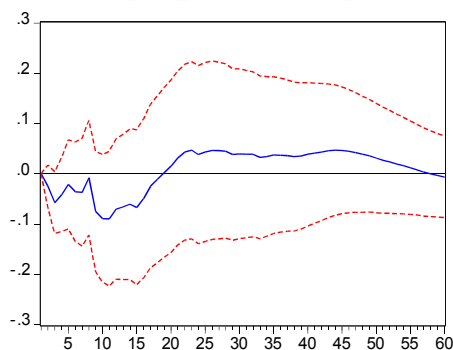
Response of D(CCR_GDP_PC) to BNKRPC_HPCYC07/1000



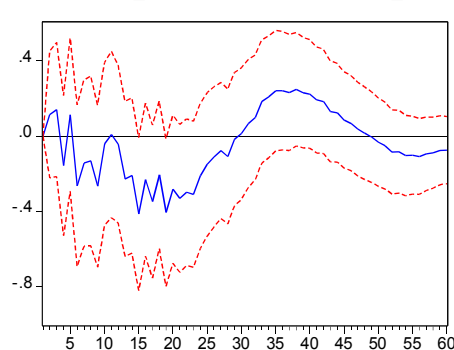
Response of RR to BNKRPC_HPCYC07/1000



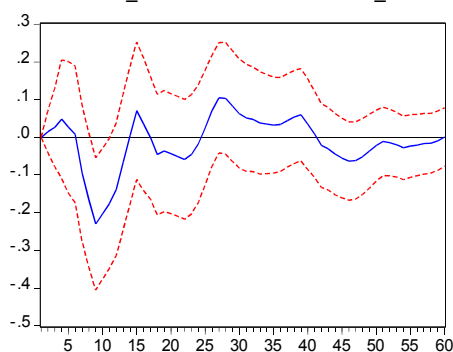
Response of R_FED_TGT to BNKRPC_HPCYC07/1000



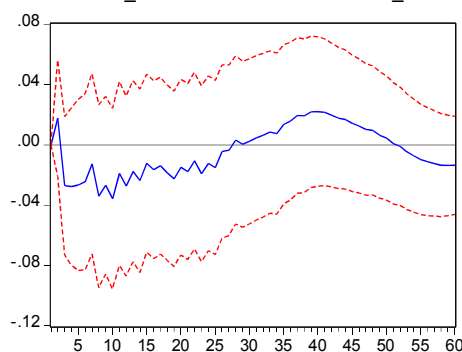
Response of PCEDF_HPCYCL07/10 to BNKRPC_HPCYC07/1000



Response of WHD_HPCYC07*30 to BNKRPC_HPCYC07/1000



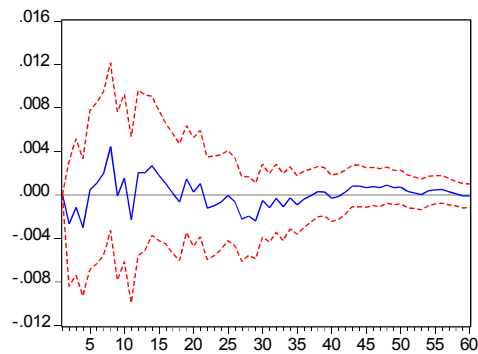
Response of EMP_HPCYC07/1000 to BNKRPC_HPCYC07/1000



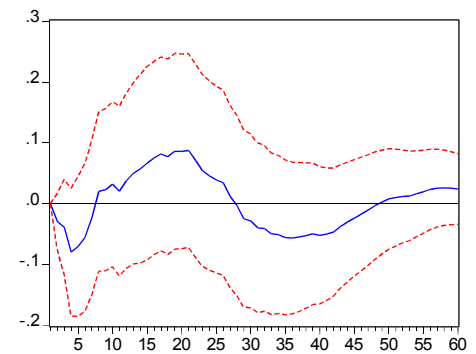
Figures A.C6.1.3: Unstructured VAR(12), 60-month-(5 year) period response functions with two standard deviations certainty range to one SD shock rise in consumption resulting in initial 20 month drop in bankruptcies (mid-right), and rise in employment, both interest rates, and, as well as increased volatility to other variables:

Response to Nonfactorized One S.D. Innovations ± 2 S.E.

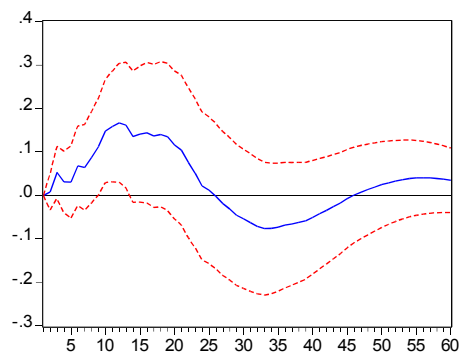
Response of D(CCR_GDP_PC) to PCEDF_HPCYCL07/10



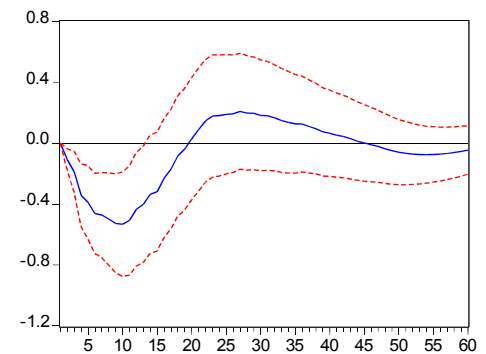
Response of RR to PCEDF_HPCYCL07/10



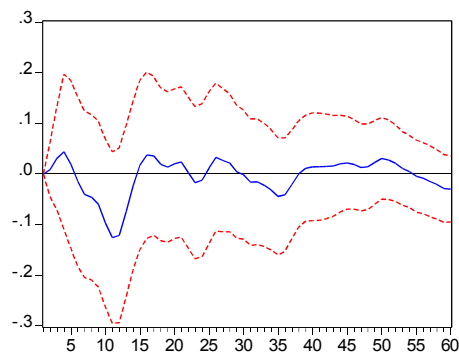
Response of R_FED_TGT to PCEDF_HPCYCL07/10



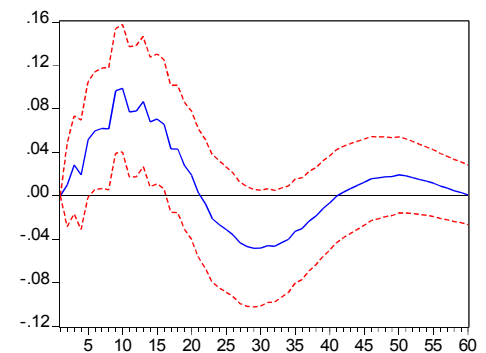
Response of BNKRPC_HPCYCL07/1000 to PCEDF_HPCYCL07/10



Response of WHD_HPCYCL07*30 to PCEDF_HPCYCL07/10



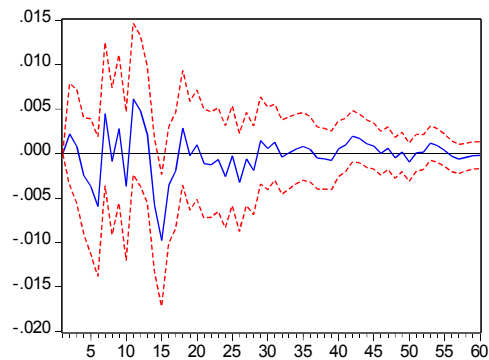
Response of EMP_HPCYCL07/1000 to PCEDF_HPCYCL07/10



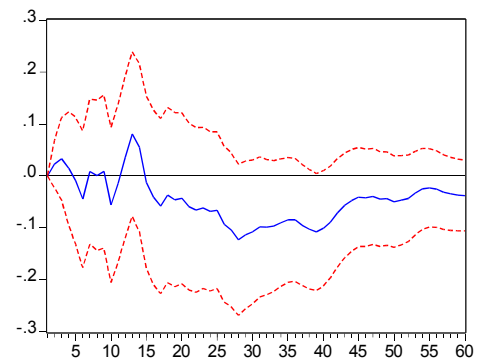
Figures A.C6.1.4: Unstructured VAR(12), 60-month-(5 year) period response functions with two standard deviations certainty range to one SD shock rise in employment resulting in initial 20 month drop in bankruptcies (bottom left), and rise in consumption (PCEDF...mid-right), as well as increased volatility to other variables:

Response to Nonfactorized One S.D. Innovations ± 2 S.E.

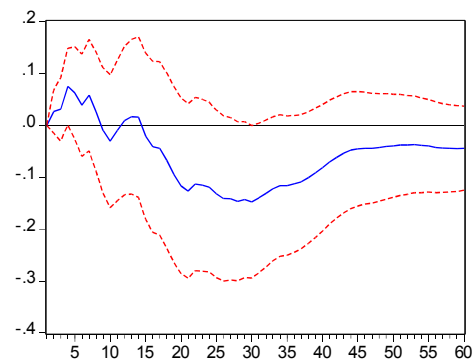
Response of D(CCR_GDP_PC) to EMP_HPCYC07/1000



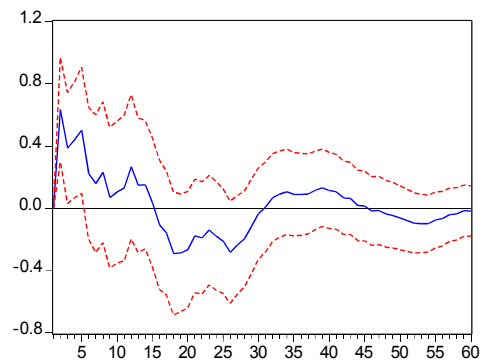
Response of RR to EMP_HPCYC07/1000



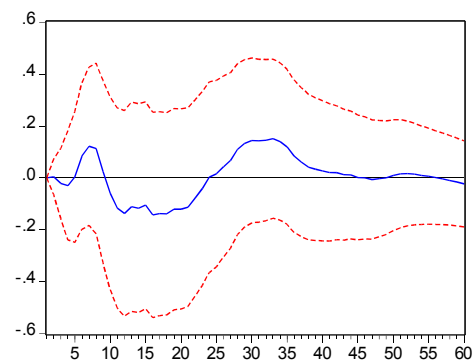
Response of R_FED_TGT to EMP_HPCYC07/1000



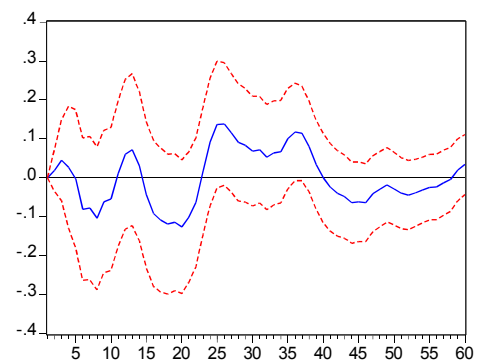
Response of PCEDF_HPCYCL07/10 to EMP_HPCYC07/1000



Response of BNKRPC_HPCYC07/1000 to EMP_HPCYC07/1000

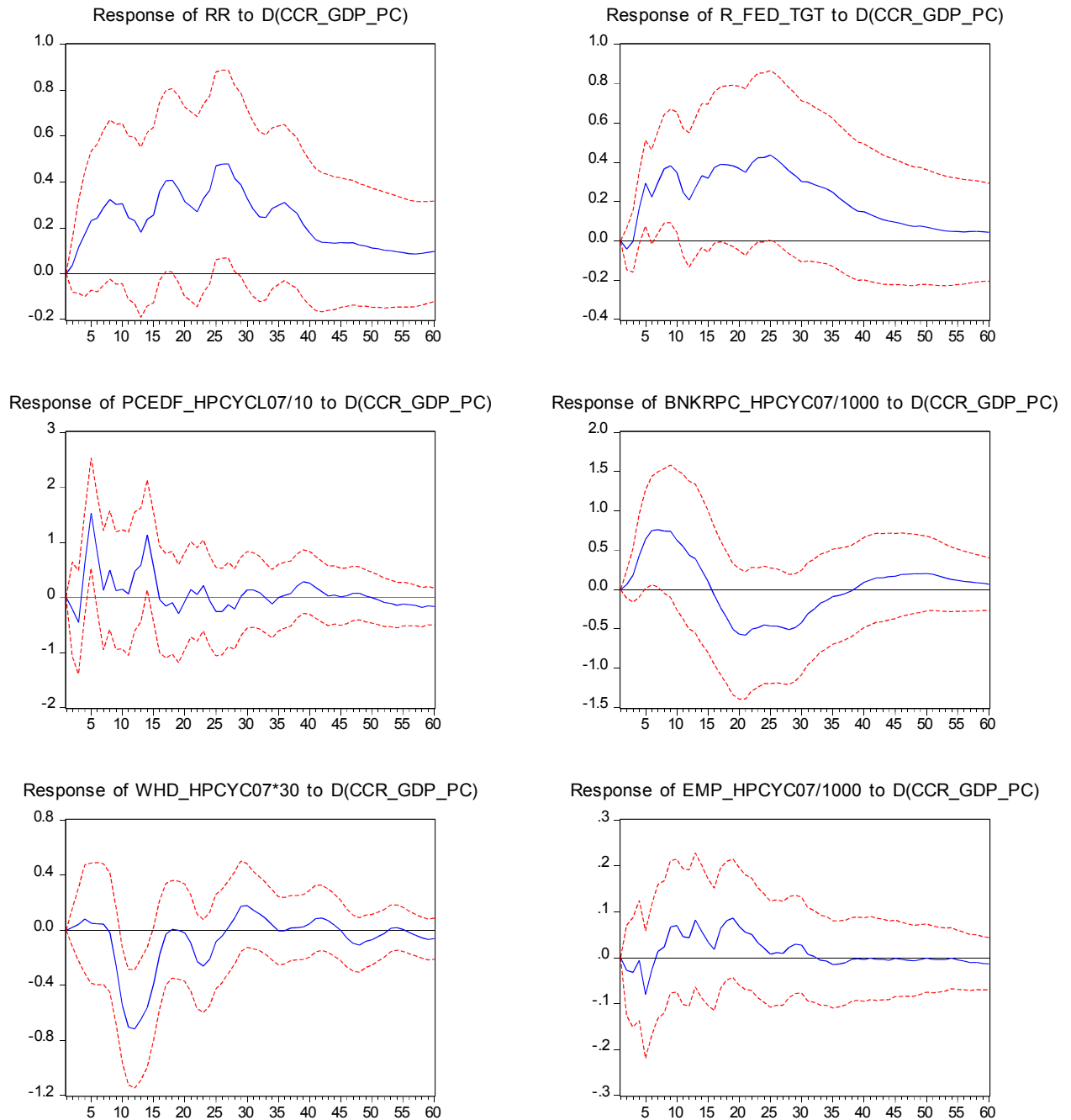


Response of WHD_HPCYC07*30 to EMP_HPCYC07/1000



Figures A.C6.1.5: Unstructured VAR(12), 60-month-(5 year) period response functions with two standard deviations certainty range to one SD shock rise in the first log difference credit returns (D(CCR...)) resulting in initial 20 month rises in bankruptcies (mid-right), drop in wage (bottom left) and volatile rises in consumption (PCEDF...mid-left) and employment , as well an (volatile) increase to interest rates:

Response to Nonfactorized One S.D. Innovations ± 2 S.E.



**Appendix C6.2: IRF response functions to monetary policy rate rise
from simulation of Smets and Wouters 2007 DSGE model**

dy – GDP growth ($\log(y_t/y_{t-1})$)

y – GDB

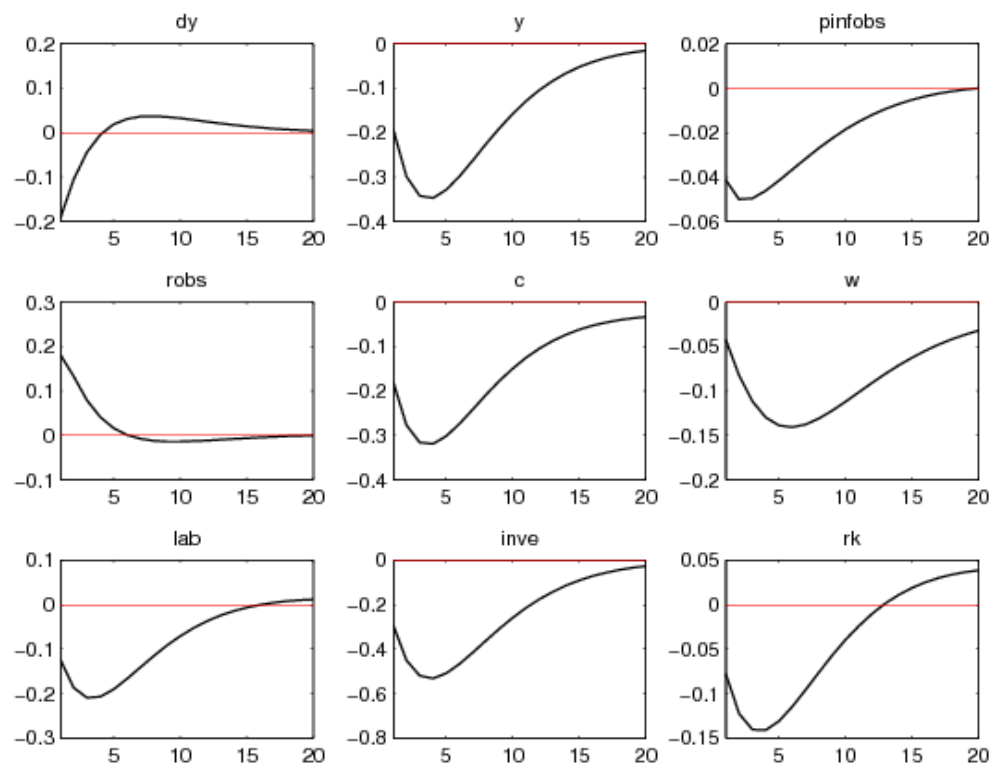
pinfobs- observed Inflation

robs – observed interest rate

c – consumption

w – real wage

lab – employment



inve – investment

rk – return on capital investment

Part 4: Standard Non-standard ways out of the crisis:

7. Fiscal Intervention Oriented Crisis Solutions

7.1 Introduction

7.1.1 Post 2008 Crisis Government Led Intervention

In previous chapters presented are already sections on debt driven growth and possible dangers from an excessive sovereign debt for triggering private debt recessionary accelerator (ch. 6.5). The following chapter provides some insight into how the more recent, post-2007-crisis economy revives Keynesian ideas and offers suggestions to overcome the crises such as 2007/8 crisis known as the Great Recession and a pragmatic return to growth. This chapter follows upon the more in-depth analysis of the causes that led to the crisis presented earlier (ch. 6). Since it is not in focus of this research, this section is not intended as an exhaustive coverage of the subject but presented just to provide an overview of few ways of thinking in those directions and as a background to a related and more in depth research presentation in the next chapter.

As Mr. Bernanke admitted, in the wake of looming recession 2008 (or even the 1930s-like depression), the central banks and governments may need to act as lenders of last resort not only to the commercial banks but to main street businesses and, possibly, even the mortgage borrowers. They may need to "helicopter money" to those non-banking organisations and individual mortgage burdened families more directly, bypassing the traditional risk-averse banking sector, to prevent a further spread of a recession and encourage economic growth instead. However, instead "helicoptering money", in the aftermath of the 2007-2009 credit crunch crisis, financial institutions of US and UK governments, in co-ordinated effort to provide necessary liquidity to the non-banking market agents, adopted policy of "Credit-Easing" to non-banking economic agents as opposed to more familiar policy of increasing monetary base through market operations of quantitative easing (QE). Though similar in their

technical mechanisms, the goals are a bit different.¹¹⁶.

In an analysis, which re-examines Modigliani-Miller theorem of the cost of capital being independent of the firm's debt-equity ratio, Stiglitz (1967) shows several limitations of that theorem. They concluded that, being based on a partial equilibrium analysis, the theorem may not hold for the firms under risk of bankruptcy or under similar credit rationing conditions and such firms may otherwise find it difficult to gain the needed finances through the usual, financial intermediaries. However, Wallace (1982) extends the Modigliani-Miller theorem to the macro-economic, government sector and argues that under certain limitation, the non-standard open-market asset exchange operations and content of government's asset portfolio have no impact on the equilibrium prices and consumption in an economy. On the other hand, De Negri et al. (2009) claim that the main issue with the Wallace's proof is that it relies on a limited, theoretical two-generation model that does not lend itself well to the effects of market and credit frictions. In their further analysis, they dismiss the Wallace's irrelevance

¹¹⁶ On those lines, in the aftermath of 2007/2009 credit crunch, US Fed and UK BoE in Feb. 09 assumed coordinated policies of "Credit Easing" (CE) – buying corporate commercial papers. They distinguish CE from the more familiar policies of quantitative easing (QE, usually assumed to be supplying additional money into the companies) because their primary aim is not to increase the monetary base but to increase "credit worthiness" of those corporations. To assert the difference, the UK Treasury, (according to the BoE website publications news item 2009/009.htm) covers the costs of the new Credit Guarantee Scheme managed under the newly established Asset Purchase Facility and parallels any BoE purchase of corporate commercial papers with equal amount of issue and sale of treasury bills so to keep monetary base intact. (see:

<http://www.bankofengland.co.uk/publications/news/2009/009.htm>)

In his January 2009 speech Bernanke also states: *"The Federal Reserve's approach to supporting credit markets is conceptually distinct from quantitative easing (QE), the policy approach used by the Bank of Japan from 2001 to 2006. Our approach--which could be described as "credit easing"--resembles quantitative easing in one respect: It involves an expansion of the central bank's balance sheet. However, in a pure QE regime, the focus of policy is the quantity of bank reserves, which are liabilities of the central bank; the composition of loans and securities on the asset side of the central bank's balance sheet is incidental. Indeed, although the Bank of Japan's policy approach during the QE period was quite multifaceted, the overall stance of its policy was gauged primarily in terms of its target for bank reserves. In contrast, the Federal Reserve's credit easing approach focuses on the mix of loans and securities that it holds and on how this composition of assets affects credit conditions for households and businesses. This difference does not reflect any doctrinal disagreement with the Japanese approach, but rather the differences in financial and economic conditions between the two episodes. **In particular, credit spreads are much wider and credit markets more dysfunctional in the United States today than was the case during the Japanese experiment with quantitative easing.** To stimulate aggregate demand in the current environment, the Federal Reserve must focus its policies on reducing those spreads and improving the functioning of private credit markets more generally."* (highlight by GP,

See: <http://www.federalreserve.gov/newsevents/speech/bernanke20090113a.htm>)

result. They instead incorporate in their model a number of credit frictions and show that the quantitative effect of various FED Credit Easing¹¹⁷ operations applied by the US FED, such as Term Auction Facility¹¹⁸ (TAF) or Primary Dealer Credit Facility¹¹⁹ (PDCF), can be very large: especially near zero interest rates. Limitations that firms face is a standard banking borrowing constraint (BC) rule that they may borrow only up to a fraction of their net returns and an investment-related re-saleability constraint (RC) that only a fraction of their illiquid capital may be sold for investment purposes. Therefore, any assets issued by the firm will face a re-saleability (liquidity) constraint that limits the firms' own liquidity. This illiquidity is contrasted by the much higher liquidity of government debt assets such as treasury bonds. The authors consider that the source of the 2008 crisis is a shock to the liquidity (tradability) of private assets that lead to the freezing of private credit market. They construct a new observable from flow of funds and use a relatively standard DSGE model similar to Smets and Wouters (2007) with other standard frictions such as wage and price rigidities and capital adjustment costs. They then obtained four main sets of findings:

1. In absence of price and wage rigidities, the non-standard operations have no effect on the economy
2. In their presence, both the shock and the intervention have a significant effect
3. In the presence of zero boundary on interest rates and the absence of intervention, the US economy then follows the route of the Great Depression

¹¹⁷ "Quantitative easing can be thought of as an expansion of the central bank's balance sheet with no intentional change in its composition," (Gov. Duke stated).

"That is, the central bank undertakes more open market operations with the objective of expanding bank reserve balances, which the banking system should then use to make new loans and buy additional securities,".

Credit easing is different [from QE] because it "focuses on the mix of loans and securities that the central bank holds as assets on its balance sheet as a means to reduce credit spreads and improve the functioning of private credit markets,"

¹¹⁸ "Under the Term Auction Facility (TAF), the Federal Reserve will auction term funds to depository institutions. All depository institutions that are eligible to borrow under the primary credit program will be eligible to participate in TAF auctions. All advances must be fully collateralized. Each TAF auction will be for a fixed amount, with the rate determined by the auction process (subject to a minimum bid rate)." - quoted from US FED website.

¹¹⁹ "The Primary Dealer Credit Facility (PDCF) is an overnight loan facility that will provide funding to primary dealers in exchange for any tri-party-eligible collateral and is intended to foster the functioning of financial markets more generally." (quoted from US FED website)

4. With intervention, it follows a route similar to what is happening in US economy. This is in line with some other researches, which show that the “multiplier” of government spending is very high when interest rate is near zero.

The work of Curdia and Woodford (2009) poses the question whether the FED should be dealing with other instruments and goals than interest rate policy and inflation targeting respectively. They assume agents’ household heterogeneity where an agent household can belong to one of the two main groups of agents: the impatient borrowers (b) and the patient savers (s) with the respective probabilities π_b and π_s where their consumption utility functions differ. The authors also introduce a credit spread between the two groups.¹²⁰ Along the lines of “positive economics”, they also presume that the Government’s issues of riskless nominal debt are one of three exogenous fiscal shocks, in addition to government spending G and the sales tax rate. The authors then conclude with an argument for additional Reserve Supply Targeting but only as a technical task on the side of the central banks’ technical staff, e.g. as a part of the work on adjustments of policy rate¹²¹.

On the issue of whether there is a role for the “Quantitative Easing”, they conclude that it could be useful if that is what is necessary to provide the optimal lending to the private investor sector.

¹²⁰ Remarks: Alternatively, the discount rate β could differ for different agents instead of for a more direct effect on the model as whole. Also the variations in the credit spread, which they specify, may not affect aggregate demand or reflect the reality of human behaviour - a high spread would simply discourage borrowers from borrowing and consuming and that can be offset by discouraging the savers from saving at the same time, or other way around, oscillating around the equilibrium. The spread is, however, to a greater extent reflecting the risk the intermediary is facing in relation to the two types of customer agents and its risk related return ratio, but a weighted spread may be more accurate. However, because in their model the ratio between borrowers and savers on average does not change, so the effect of the spread on the aggregate demand may be rather small.

¹²¹ “When the central bank acts to implement its target for the policy rate through open-market operations, it will automatically have to adjust the supply of reserves But this does not require a central bank’s monetary policy committee ... Once the target for the policy rate is chosen (...through condition (2.2)), the quantity of reserves that must be supplied to implement the target can be determined by the bank staff in charge of carrying out the necessary interventions”

They however state an “*irrelevance proposition*” for quantitative easing in their model with the help of an (extended) Taylor type rule for the central bank mechanisms that is valid under two conditions:

1. *“that the increase in reserves finances an increase in central bank holdings of Treasury securities, rather than an increase in central-bank lending to the private sector¹²²; and*
2. *that the policy implies no change in the way that people should expect future interest-rate policy to be conducted.”*

They however admit that the irrelevance is not applicable midst condition of credit frictions. In addition, from the Figure 4 from their article, one can observe that the largest increase in Fed reserves was that of MBSs rather than the reserves of the treasuries, which were initially reduced.

Charpe et al. (2009) provide an analysis of credit rationing affecting over-indebted workers and the role of the US Fed’s bailout monetary policy for economic stabilisation in the aftermath of the recent credit crisis from a NK perspective. The authors however adopt a model whose system stability is not based on reversal to some rational expectations directed clearing equilibrium and which differ from standard DSGE models because its stability depends on the interaction of the macroeconomic and financial feedback channels. The main purpose of their research is to analyse and prescribe adequate monetary policy for situation of excessive mortgage over-indebtedness. The prescription they suggest is that central banks step-in and buy a percentage of bad mortgage loans to drive nominal interest rate down and facilitate

¹²² i.e. is this just lending to the government which spends exogenously, thus, inherently inefficiently in case of a crisis – setting up a form of Ricardian equivalence situation, or also the purchase of government bond holdings from the private sector? e.g. in their previous (base) paper, they state that Ricardian equivalence holds in the version of their model without financial frictions. Also, whilst their form of QE may be similar to that of BoJ QE policy, note that, on the other hand, both BoJ and BoE QE has nominally a wider scope as it also includes purchase of corporate bonds and possibly other debt certificates too.

economic growth, which is in line with the Fed's actions in the aftermath of the 2007 crisis.

Furceri and Mourougane (2009) are among first authors to construct a DSGE model with endogenously driven government bond rates to analyse impacts of “*expansionary fiscal policy shocks on output and sustainability of sovereign debt in the Euro area*”. Their simulations show results in line with the other research papers (Traum and Yang (2009)) indicating that the most efficient fiscal expansion for the economy is to support economic activity in short term through increased public investment, wage tax cuts (accelerating consumption) but also through an increase in public consumption.

In addition, Lindé, Smets and Wouters (2016) extend the Smets and Wouters (2007) type DSGE model with zero lower bound (ZLB) rule, heteroscedasticity (variable variance) of some of the exogenous shocks and with a financial accelerator aiming to account for the effects of the 2008 Great Recession. Their comprehensive work does make a progress to that goal but they admit that it is insufficient to model in full the effect of the crisis or the non-standard monetary policies that followed the crisis. They also find that, in their model with financial accelerator with Baa-Aaa bonds spread as a measure of default risk and its premium, the overall impact of net-worth shock on macro-dynamic remains modest.

7.1.2 Discussion

Both Curdia and Woodford (2009, C&W henceforth) and De Negri et al. (2009) introduce heterogeneous agents in their models, investors and consumers, and conclude that the government (or CB) credit easing intervention in near-zero interest rate environment significantly contributes to reducing the effect of a liquidity crisis recession turning into full-featured 1929 style depression.

De Negri et al. (2009) consider the government as endogenous (acting together and integrally with the central bank), whilst, in the C&W paper, government is acting

exogenously and the central bank is one taking the active role of an endogenously intervening, active agent that manages the government debt too. Also, although De Negri's paper takes a more micro-economic entrepreneurs' credit rationing point of view whilst the C&W report takes more of a financial intermediary's credit crisis point of view they arrive to similar results and conclusions. This common result is likely to be due to the credit crisis inflicting the increased borrowing and resale-ability constraint spread that is fundamental in the De Negri model, and closely translates into the credit spread between the borrowing and the deposit interest rates fundamental for the C&W model.

It is also the opinion of the author of this research however, that fiscal actions as in Curdia and Woodford (2009) should not be treated as entirely exogenous. They are endogenous reactions to the economic situation, not a calamity, unless, of course, they are reaction on exogenous calamity (see Perendia and Tsoukis (2012) and the section 7.3 below).

Since in a crisis a central bank tends to enforce a low monetary policy interest rate whilst the increased risk of government debt may push the spreads of government bond rates high over the monetary policy rate, the authors distinguish the short-term central bank rate from the fiscal position dependent endogenous government bond rate in their model. The unemployment levels and related increase in paid-out benefit driven government consumption then also crowds-out private investment. Along the lines of Levine et al. (2009) and Traum and Yang (2009) models, the Furceri and Mourougane (2009)'s NK model was also derived from S&W02 model and extended with two types of heterogeneous households, the Ricardian (approx. 75% in Euro-area steady state) and the liquidity-constrained ones (approx. 25%). Though it also contains firms whose output gap is related to the capital utilization gap and an endogenous government sector, in contrast to the previous two models we discussed, (Curdia and Woodford (2009) and De Negri et al. (2009)), it does not contain a capital investment mechanism.

7.1.3 US Sovereign Debt Risks

As a research paper by IMF (2010) projects for G7 countries, the rise of public debt will be mainly caused by loss of revenue (i.e. tax income), interest re-payment and, despite common belief, to a lesser extent, by the fiscal stimuli and support for financial sector. At the same time, the countries face the risk of increased expenses for health and pension payments for ageing population. The IMF (2010) research states that under current trend, debt to GDP ratio for G-7 countries may reach an average 200% by 2030 and 400% by 2050 and this estimate is without taking into account the risks of further public debt incurred by longer-term reduction of GDP growth.

Similarly to the IMF report outlined above, in her report to US Senate, Reinhart (2010) states that the biggest cause of the US government deficit in the aftermath of crisis would not be the actual cost of the bank bailout or the other fiscal stimuli but the loss in tax revenues resulting from a prolonged decline in economic output. She, however, emphasised a danger of a high debt exceeding 90% of GDP since countries exposed to such level of debt experience much slower growth, this being mainly due to the expected later introduction of fiscal tightening and increased taxation: *“Seldom do countries simply “grow” their way out of deep debt burdens”* Reinhart then stated.

Her statement and her joint work with Rogoff (e.g. Reinhart and Rogoff (2010)), have, however, been widely criticised by quite few authors arguing for the prevailing benefits of government intervention and quantitative easing policies in curing the recent Great Recession. Such criticism has mainly come from the New-Keynesians, for their economic models (e.g. Nersisyan and Wray (2010)), and more recently, even for several technical, numerical and coding errors which have systematically lead the authors to the incorrect over-estimations of the dangers of high debt/GDP ratio on the future of growth (Herndon, Ash and Pollin (2013)).

In addition, Mishkin (2010) warns that holdings of long term MBSs present a double, the credit and the interest rate, risk to any financial institution holding them, including the Federal Reserve. In addition, purchasing of treasuries and the monetarisation of

government debt raises the additional risk of higher inflation and higher interest rates in the longer term.

7.2. Estimating the Effect of News, Fiscal Policy Rules and Accelerators in Full and Partial Information DSGE models

Many authors (e.g. Benassy-Quere, Coeure et al. 2010) distinguish between so-called positive and political economics, the two analytical positions where the former takes government decisions as exogenous and the latter as endogenous. It can be said that the following and many other recent papers analyse the non-standard, post-crisis policies which evolved from the more traditional academic position of positive analytical economics towards the position of political economic analysis. Thus, it departs from the position of semi-political economics of the Lucas' critique which takes only monetary policy (i.e. that of the central bank) as endogenous but leaves government (and its fiscal spending) as exogenous (a kind of "deus-ex-machina") and then includes it as an additional endogenous agent acting within the economic universe.

The approach of this research is to show the practices and benefits of having both the fiscal and monetary economy as endogenous, thus returning economic models closer to what may be referred to as a political economy. The research introduces two extensions to standard DSGE models which show importance of effects of expectation changing information shocks (news) and of the active, endogenised role of government fiscal spending, e.g. in pursuing post-crisis recovery, and in particular, when reacting to deviations in employment and to those shocks to the expectations.

The innovations tested and their results are in line with the recent return to Keynesian theory of fiscal spending as important contributor in the post-crisis recovery after years of its theoretical neglect. We show that government has a role in protecting viability of its economy and the welfare of its citizens and that its actions and intention to play such protective, countercyclical role need also to be publicly visible so to achieve even

greater effect even if not fulfilled to its full planned or publicised financial commitment level.

This may appear to be in contrast with the more traditional monetarist approach which is at least neglecting if not side-lining the role of public spending in recovery, whilst favouring the role monetary policy lead by an independent central bank as the sole mechanism of macro-economic control. However, we show that the fiscal and the monetary policies can be decided and effected independently by the government and the independent central bank respectively. However, it is still left to be affirmed if it is more optimal to pursue a closer cooperation between the two bodies and coordination of their policies in general, and especially when monetary policies are almost ineffective in a near-zero interest rate regimes like the one following the 2007-08 crisis.

This chapter reproduces some of the key aspects and results of a joint work with Dr. C. Tsoukis, which introduce endogenous fiscal policy, and a rule for its dynamics, here however, extended with additional discussion on its endogenous rules for the effect of news and unemployment as well as results of unpublished partial information DSGE solution based estimation. ¹²³

Perendia and Tsoukis (2012) built and estimated a medium-sized DSGE model to analyse the effects of a news channel on growth and unemployment. The model augments the standard NK model of fiscal policy studies to incorporate such Keynesian aspects as the multiplier and involuntary unemployment. More features that are Neoclassical include inter-temporal optimisation, an elastic labour supply, productive public services, endogenous growth, and ‘keeping up with the Jones’. The authors show that the addition of the news channel and an extended, endogenous government spending fiscal policy rule all significantly improve model fit to data. The researchers then simulate the effects of monetary and fiscal policy and particularly the role of the Keynesian vs. Neoclassical aspects of the model in driving the results.

¹²³ initially presented and available on-line as Perendia and Tsoukis (2012) Dynare conference paper but it has been updated since that early version and some additional information not presented there is included here.

The paper synthesise the three theoretical strands of analysis of fiscal policy: the Keynesian multiplier, increases the return to private capital and the rate of growth, proactive and countercyclical endogenous public sector and endogenous labour supply.

7.2.1 The model

The model is as in Smets and Wouters (2007) (henceforth SW07) and Drautzburg-Uhlig (2010, henceforth DU10) extended with an involuntary unemployment/labour shift, the news based multiplier and the novel fiscal policy rule.

7.2.1.1 Involuntary unemployment

In those starting models, unemployment is entirely voluntary. In equilibrium, the variables, including labour hours, completely clear markets and are fully consistent with individual (and firm) optimisation. That is, unemployment is like (forced) leisure, but with full utility remuneration. This has implications for the marginal rate of substitution between consumption and labour/leisure, and therefore for the real wage and hence of the rest of the system.

On one hand, the NK Phillips curve used in standard NK DSGE models like SW07 replaces unemployment u from the original Phillips curve with output y . On the other hand, the Taylor rule, which in past was sometimes used with the unemployment (or employment) gap from “natural rate” as its target, has been nowadays consistently used with the output gap as the target so that the (involuntary) (un-)employment gap does not figure in most monetary policy oriented DSGE models.

7.2.1.2 The multiplier and the news:

The Keynesian multiplier is absent within the logic of the Smets and Wouters (2007) model because consumption in the standard Euler equation is driven just by the real

interest rate (see their eq. 2 which is a linearised Euler equation). The key problem is that the standard Euler equation is insensitive to how consumption responds to changes in lifetime resources. On the other hand, in wider context, government is expected to play budget constraint balancing (the so called “passive” as in Leeper 1991) role (or a role of or close to an exogenous shock) and only monetary authority is given an endogenous, unconstrained, (I.e. “active”) role.

To re-instate the multiplier, the researchers introduce the effect of news driven expectation change on consumption. To do so, the authors adopt a variant of the ‘permanent income theory of consumption’, following Obstfeld and Rogoff (1996, Ch. 2) among others¹²⁴. Accordingly, the authors write the consumption at time t as follows:

$$C_t = \frac{\tilde{r} - \gamma}{1 + \tilde{r} - \gamma} \left[A_t + (1 - \tau) E_t \sum_{s=0}^{\infty} X_{t+s} / R_t^s \right] \quad (7.2.1.2.1)$$

Where

$$R_t^s \equiv \prod_{v=1}^s (1 + \tilde{r}_{t+v}), \quad R_t^t = 1 \quad (7.2.1.2.2)$$

It is the inverse of the discount factor. A_t is financial wealth at the beginning of time t . X_t is labour earnings plus monopoly profits, (i.e. those profits that do not include the competitive rate of return to capital, net of taxes). The variable $\tilde{r} \equiv (1 - \tau)r$ is the net-of-tax steady state real interest rate r , approximately 3%, and γ the trend real growth rate. τ is a flat tax rate applicable to all incomes, labour or capital-related.

As taxation is not the authors’ focus, this tax rate will be assumed constant throughout, hence it will drop out of the linearisations that follow and, as in SW07, this tax rate plays no role in the subsequent analysis.

Fiscal policy will be assumed to take the form of variations in expenditure only. However, those variations in spending are not of a balanced-budget; they are assumed

¹²⁴ See in particular their equation (2.16).

to be financed by government bonds, which are not part of the private sector's net wealth (in line with Ricardian equivalence).

As the linearised system reflects cyclical variations along the trend, the budget deficit will also be cyclical. Thus, the government debt is assumed not to be accumulated because of the cyclical deficits and sufficits around the (balanced-budget), particularly when considered in a discounted sense and its trend will average to zero asymptotically. Therefore, the fiscal multiplier that will be considered below is assumed a bond-financed one, but in such a way, that does not jeopardise government solvency.

(Please refer to the Perendia and Tsoukis (2012) paper for details of model derivation and its linearisation).

After some transformations and subtraction (i.e. if one multiply (2') by $(1+\tilde{r}-\gamma)$ and (by subtracting from 4, see in the original paper), one can then get:

$$\Delta c_t = \frac{X}{C} \frac{\tilde{r} - \gamma}{1 + \tilde{r} - \gamma} \left[\frac{A}{X} (1 - \tau) r_t + \sum_{s=0}^{\infty} \frac{(E_t - E_{t-1})(1 - \tau) x_{t+s}}{(1 + \tilde{r} - \gamma)^s} - \frac{(1 - \tau) r_t / (1 + \tilde{r}) - \Delta y_t / (1 + \gamma)}{1 + \tilde{r} - \gamma} - \right. \\ \left. - (E_t - E_{t-1}) \sum_{s=0}^{\infty} \frac{(1 - \tau) r_{t+s+1} / (1 + \tilde{r}) - \Delta y_{t+s+1} / (1 + \gamma)}{(1 + \tilde{r} - \gamma)^s} \right] \quad (7.2.1.2.3)$$

where $(E_t - E_{t-1})x_{t+s} \equiv E_t x_{t+s} - E_{t-1} x_{t+s}$, and similarly with all the other variables. In other words, the evolution of consumption is attributed to 'news', i.e. revisions of expectations due to the shocks hitting the system. This equation involves taking expectations at different times, so it cannot be deduced from the aggregate resource constraint minus the government budget's constraint.

The relation to the multiplier is that when output changes, so will (monopoly) profits and labour earnings and this will create 'news' of higher future earnings, which will

affect current consumption, thus raising output further, and so on. To close the model, the researchers need a budget constraint which, in the linearised form is:

$$x_t = y_t + lshare(w_t + l_t) + \mu_t^p \quad (7.2.1.2.4)$$

where *lshare* (labour share) is parameter – commonly thought to be around 0.65. Thus, increases in total output, wages and employment coupled with the monopolistic power (fuelling supernormal profits) will have an impact on today's profits. The latter idea is the essence of the neo-Keynesian multiplier of the late 1980s Government spending and a fiscal policy rule

SW07 allow government spending to be endogenised so that its AR(1) process is affected by technology shocks in addition to exogenous government spending shocks. It can be however observed from comparing data series that the US government fiscal policy shows consistent, unemployment related pro-cyclical (i.e. employment counter-cyclical) spending policies.

Following Dixit and Lambertini (2001), (2003a) and (2003b)), the authors of this research let the government pursue an activist stabilisation policy via its spending, which is informed by the state of the economic cycle and the future outlook. The authors therefore extend the S&W model of the government spending AR(1) process with two additional elements: the news channel wcp_t and the expected unemployment change. This forms a new rule for government spending similarly to the monetary policy interest rate rule of Taylor (1993).

7.2.1.3 Government Spending Rule

In case of government spending g_t having a Taylor type policy rule augmenting simple (exogenous) AR(1) process with the news and forward-looking unemployment jump the generic form of this fiscal rule is:

$$g_t = \rho_g g_{t-1} + g_u x_t + g_w (E_t - E_{t-1}) \Omega_t + g_y \varepsilon_{yt} + \varepsilon_{gt} \quad (7.2.1.3.1)$$

where x_t is a labour market-related indicator of the state of the business cycle, to be defined below, whilst ε_{yt} and ε_{gt} are respectively government part of the consumption (e.g. technology) and the exogenous government spending shocks.

In empirical implementation, the authors investigated a number of variants, depending on the exact definition of x_t ; specifically, whether the level of unemployment (u_t), or a forward- or backward-looking change in unemployment or in the hours supplied (l_t) enters:

$$x_t \equiv u_t \quad (7.2.1.3.1a)$$

$$x_t \equiv E_t u_{t+1} - u_t \quad (7.2.1.3.1b)$$

$$x_t \equiv u_t - u_{t-1} \quad (7.2.1.3.1c)$$

$$x_t \equiv E_t l_{t+1} - l_t \quad (7.2.1.3.1d)$$

$$x_t \equiv l_t - l_{t-1} \quad (7.2.1.3.1e)$$

where $g_t = \log(G_t/G)$ and unemployment (u) is defined as a ratio (log difference) of employment (i.e. hours worked) in the flexible and sticky-price economy:

$$u_t = (l_t^f - l_t) + \varepsilon_u \quad (7.2.1.3.2)$$

The authors find that the estimated parameters indicate that government spending is characterised by a Taylor type counter-cyclical policy rule that is augmenting initially a simple (exogenous) AR(1) process. Government spending rises with a positive technology shock, expectations of an unemployment rise (or the employment drop) and, with a decrease in the news-driven expectations of higher future output or employment. It thus behaves in an endogenous fashion, at least partially, rather than as a random, exogenous shock as it has been usually modelled so far.

A few brief comments are in order on this rule, which is a novelty of this paper. It is, sometimes, claimed that there is no equilibrium for a situation when both fiscal and monetary policy are active (e.g. Leeper 1991, Bhattarai S. et al. 2012). In this research model, however, there is a separation of domains of responsibility and reaction: whilst monetary policy continues to react to inflation and possibly the output gap, the counter-cyclical fiscal policy focuses mainly on reactions to expected changes in spending behaviour and employment of the consuming households. Thus, there appears to be a scope for a complementarity in stabilisation, especially when if monetary policy is restricted by the zero lower bound on the interest rate policy instrument¹²⁵. However, accounting for zero-bound interest rate is beyond the scope of this research.

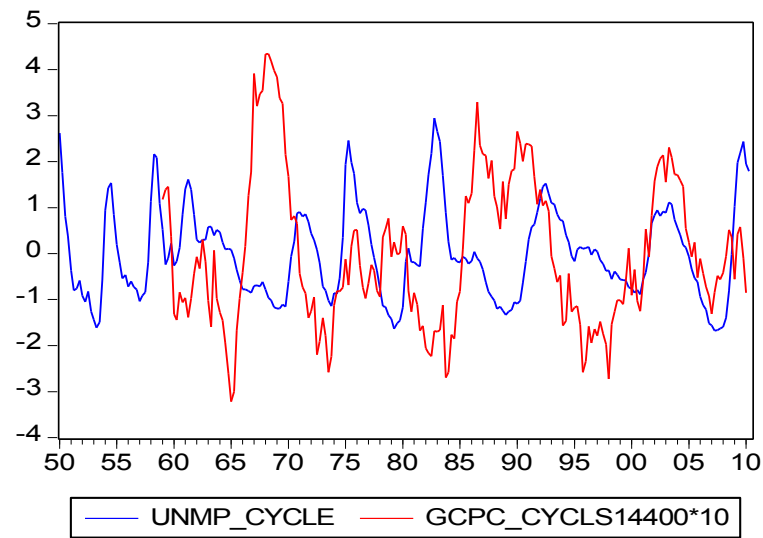
7.2.2 Estimation Data and Results

7.2.2.1 Preliminary data analysis

A preliminary analysis of US data, quarterly for period 1950 to 2010 and monthly, for the period of so-called great moderation, 1980-2007 related to employment, unemployment and government spending is presented.

¹²⁵ A similar approach to balanced fiscal and monetary activity has been, more recently also taken-up by Bhattarai K. and Trzeciakiewicz (2017).

Figure 7.2.2.1.1: HP filter de-trended US Government per-capita spending GCPC (renormalized by 10) and unemployment UNMP cyclical components.



In the above figure 7.2.2.1.1, one can see large surges of government spending, coinciding with the periods of high unemployment and its reductions: 1964-70, 1985-90, early 1990s, the crisis in 2001, and a further spending increase jump (and unemployment drop) starting in early 2003.

Table 7.2.2.1.1: Correlation coefficients of the US government per-capita spending, unemployment and employment-hours quarterly data for period 1959-2010

	EMP	UNEMPLM NT	GC_PC
EMP	1.000000	0.042186	0.946181
UNEMPLM NT	0.042186	1.000000	-0.032602
GC_PC	0.946181	-0.032602	1.000000

Table 7.2.2.1.2: Correlation coefficients of the US government per-capita spending, unemployment and employment-hours monthly data for period 1980-2007

	GCPC	UNEMPLM NT	EMP
GCPC	1.000000	-0.693074	0.885256
UNEMPLM NT	-0.693074	1.000000	-0.806671
EMP	0.885256	-0.806671	1.000000

The above tables of correlation coefficients of government per capita spending and unemployment, quarterly for period Jan. 1959- Aug 2010 and monthly data for period 1980-2007, shows negative values

Those correlation coefficients during sample period Jan. 1959- Aug 2010 using quarterly data is rather more polarised: it cannot be regarded significant, though similarly negative, at -0.03260 for government spending correlation to the unemployment but is very high and significant at 0.946 for the employment.

Table 7.2.2.1.2 is showing correlation coefficients of the US government per-capita spending, unemployment and employment-hours monthly data for period 1980-2007 with the former having coefficient at 0.693, thus, below the usually assumed significant level of +/-0.8 that can explain 64% changes. This negative correlation to unemployment indicates therefore that a higher gov. per capita spending correlates to a reduced unemployment and vice-versa, a higher unemployment relates to a lower gov. per capita spending. Opposite, and more significant at level of 0.885, is the case of the correlation coefficient between government spending and employment hours over the same period. However, taken together, they appear consistent with pro-cyclical rather than counter-cyclical government spending.

Cross-correlation correlograms between the government spending (GCPC) and unemployment monthly data for period 1980-2007, also shows consistent negative correlation, becoming less significant on leads than lags after 24 periods (2 years),

indicating that unemployment more causes government spending than other way around. It is in a way again opposite for employment, which is positive correlation and stays significant over more than 60 lags (5 years) however, fading-out less slowly and so more on the leads, indicating, that government spending may be causing employment but its effects may be taking effect over a longer time-period.

Table 7.2.2.1.3: Granger causality tests of the hypothesis that the US government per-capita spending is not Granger-causing unemployment using quarterly data for two periods 1960-2011 and 1980-2011

Table: Pairwise Granger Causality Tests			
Period: 1960-2011 (quarterly)			
Null Hypothesis:	Obs	F-Statistic	Probability
GCPC does not Granger Cause UNMP	201	0.48387	0.74757
UNMP does not Granger Cause GCPC		2.53113	0.04184
Period: 1980-2011			
Null Hypothesis:		F-Statistic	Probability
GCPC does not Granger Cause UNMP		0.45760	0.76683
UNMP does not Granger Cause GCPC		5.19637	0.00045

The above table 7.2.2.1.3 depicts Eviews results for Granger causality tests of the hypothesis that the US government per-capita spending is not Granger-causing unemployment over two recent periods in US history and vice versa. (Data used are HP filter de-trended US Government per-capita spending GCPC and unemployment UNMP cyclical components).

Table 7.2.2.1.4: Granger causality tests of the hypothesis that the US government per-capita spending is not Granger-causing unemployment using monthly data for period 1980-2007 and vice-versa and 18 lags:

Pairwise Granger Causality Tests			
Date: 19/02/18 Time: 18:44			
Sample: 1980M11 2007M02			
Lags: 18			
Null Hypothesis:	Obs	F-Statistic	Probability
EMP does not Granger Cause GCPC	298	1.28678	0.19593
GCPC does not Granger Cause EMP		1.33128	0.16791
UNEMPLMNT does not Granger Cause GCPC	298	2.09600	0.00646
GCPC does not Granger Cause UNEMPLMNT		1.15155	0.30274
UNEMPLMNT does not Granger Cause EMP	298	1.39925	0.13136
EMP does not Granger Cause UNEMPLMNT		4.40020	2.8E-08

The above table 7.2.2.1.4 similarly depicts Eviews results for Granger causality tests of the hypothesis that the US government per-capita spending is not Granger-causing unemployment over the recent period of “great moderation” in US history at lag 18 (Data used are in levels US Government per-capita spending GCPC, employment EMP and unemployment UNEMPLMNT). The Granger causality is however inconclusive at most of other lags and present only closely around 18. For lags closely around 11.the situation is rather different, with Granger causality going both directions as can be seen in the table 7.2.2.1.5 below:

Table 7.2.2.1.5: Granger causality tests of the hypothesis that the US government per-capita spending is not Granger-causing unemployment using monthly data for period 1980-2007 and vice-versa and 11 lags:

Pairwise Granger Causality Tests			
Date: 19/02/18 Time: 18:39			
Sample: 1980M11 2007M02			
Lags: 11			
Null Hypothesis:	Obs	F-Statistic	Probability
EMP does not Granger Cause GCPC	305	0.67149	0.76524
GCPC does not Granger Cause EMP		0.84321	0.59692
UNEMPLMNT does not Granger Cause GCPC	305	1.84084	0.04724
GCPC does not Granger Cause UNEMPLMNT		2.36530	0.00829
UNEMPLMNT does not Granger Cause EMP	305	1.99488	0.02886
EMP does not Granger Cause UNEMPLMNT		7.95339	4.7E-12

Also, at lags 8-10, it is only the last $h:0$ that can be rejected, implying government spending leading ahead of unemployment.

Whilst correlation does not indicate causality or its direction, the above Granger causality tests indicates that one cannot reject the $h:0$ hypothesis in most cases, the one that government per-capita spending (GCPC) is not causing unemployment (UNMP) can be rejected only in very small number of leg-length cases. On the other hand, it is at least at several loner lag lengths that one can reject that unemployment is not causing government spending implying possibility of some, though very delayed government activity being caused by rise in unemployment. Despite their consistent negative correlation, it is therefore still not possible to infer that government per-capita spending is consistently Granger caused by unemployment nor that the US government has been consistently following countercyclical, reactive spending policy to counter the

unemployment levels other than by exception and, judging by empirical assessment, this probably more so in the later, post 1990s years. A more detailed empirical research required in this area is, however, beyond the scope of this project.

7.2.2.2 Estimation Data

The data the authors used for the estimation is the same as that used by Smets and Wouters (2007), and was supplied together with their Dynare model file from the internet. These are seven time series:

1. real GDP output y ,
2. real wages w ,
3. investment i ,
4. consumption c ,
5. inflation π ,
6. short- term Federal reserve base interest rate i ,
7. work-force hours worked

(For more details, see the SW07 Data Appendix)

7.2.2.3 Testing the starting model without extensions

The estimated results for the Dynare SW07 model, without any extensions, are close to the results in the Table 1 of the SW07 AER paper. (See Appendix 6: Results for full set of results and estimation of parameters). Note that, though the parameter estimates results are similar, there are two marginal likelihood values reported in by SW07 outlined below:

1. SW07 Table 4: Testing the empirical importance of the nominal and real frictions in the DSGE model reports that the Base Marginal likelihood is -923 , whilst,

2. Table 7.2.2.3.1.1 below: Comparison of the marginal likelihood of alternative VAR models and the DSGE model the marginal log likelihood reported by SW07 report is -905.8.
3. The second result is much higher than what this research obtains for their original model, -924.9 (see below), or what their base one is. They, however, stated also that for the VAR vs DSGE comparison in Table 2 they used period 1956:1 – 1965:4 as a training sample, which this research did not.

Though this research did not succeed to replicate in full the original SW07 results, this research compares results without training and focuses on the relative improvements to their original model with the two novel extensions, the news driven expectation change and the fiscal policy rule.

Table 7.2.2.3.1: Two different MCMC Log Likelihood posterior results reported in SW07, one with the other without training (i.e “warming-up”) of Kalamn Filter estimation process.

Model	MCMC LL	Note
SW07 Tab 2	-905.8	With training
SW07 Tab 4	-923	Without training

7.2.2.4 Estimating extended models

After experimenting with the models and data in the “linear space” experimental laboratory of Dynare (2011) DSGE models estimation and simulation toolkit, this research found that the model specified by the authors of this research behaves in a comparable manner to SW07. As it has a sizeably higher likelihood, the authors’ model in fact provides a better fit to data than SW07.

The benchmark model estimated by Dynare, which the authors denote M0, is the SW07

model devoid of any news extensions. The results are close, but not identical, to the results in Table 1 of SW07.¹²⁶ In terms of the additional features that concern us here, SW07 M0 model has an Euler (8) without news and a fiscal rule (10) without any news term pertaining to the labour market-related variable. Its log-likelihood when estimated by Dynare is -925.088 and this forms a natural benchmark as the M0 model estimated by Dynare underpins all other models. The authors thus compare their results to this benchmark and the focus in the discussion that follows is a comparison of the results of models that incorporate news driven expectation change and the fiscal policy rule with the benchmark M0 model.

The empirical performance of the models is shown by the –Log-Likelihood (LL or –Log Data Density, LDD) shown in Table 1. (More detailed parameter estimates and Impulse Response Functions – IRFs – are shown in Appendix 6. The models with news generally perform better than similar models without news. This is obvious in the comparison between the pairs of M0 and M6, M1 and M7, and M5 and M8, where the latter member of the pair involves news in the fiscal rule. However, comparison between models M3 and M4 (the latter with a news-augmented Euler equation 8') shows the improvements realised by augmenting the Euler equation by a news term. Overall, however, it is fair to say that the improvement in the fit comes mainly from the incorporation of news in the fiscal rule rather than the consumption part of the model. In addition, estimating with partial information assumptions provided even better fit to data (see the top row in the table below).

¹²⁶ The benchmark ll value against which the authors measure the performance of the models they estimate is -924.956, obtained by estimating the SW07/M0 model by Dynare. Tables B.2.1 and C.2.2 in Appendix of the original Perendia and Tsoukis (2012) paper show the results from estimation based posterior maximisation, respectively, of M0.

Table 7.2.2.4.1: Summary of estimated DSGE models with full and partial (the top row) information assumptions

Rank	Model	Features of consumption	Features of the fiscal rule	$\beta\beta$	g_w	g_u	LL	MCMC 10,000 Draws
1a	M12 Part Info	Euler augmented by news (8')	News; (11e)	0.1398	-0.26	-0.1775	-909.916	
1b	M12	Euler augmented by news (8')	News; (11e)	0.1463	-0.26	-0.1732	-910.513	-910.213
2	M11	Euler augmented by news (8')	News; (11a)	0.1634	-0.298	0.0265	-911.493	
3	M9	Euler augmented by news (8')	News; (11b)	0.151	-0.281	0.164	-911.918	
4	M7	Euler (8)	News and (11c)		-0.259	0.1592	-911.926	
5	M8	Euler augmented by news (8')	Only news; ($g_u=0$)	0.1569	-0.295		-912.057	
6	M6	Euler (8)	Only news; ($g_u=0$)		-0.316		-912.079	
7	M10	Euler (8) augmented by news	News; (11c)	0.1544	-0.265	0.1154	-912.331	
8	M4	Hybrid Euler (8) with news and bk-looking (9a) with news	News and (11a)	0.269	-0.261	0.0257	-912.352	
9	M13	Euler eq. (8)	No news ($g_w=0$); (11e)			-0.4711	-913.115	-917.586 (10,000 draws)
10	M3	Hybrid Euler (8) and bk-looking (9a) & news	News and (11a)	0.4602	-0.318	0.0218	-915.805	
11	M1	Euler eq. (8)	No news ($g_w=0$); (11c)			0.4802	-917.623	-921.946 (10,000 draws)
12	M0	SW07 estimated by Euler eq. (8)	No news ($g_w=0$); $g_u=0$				-924.956	-925.115
13	M5	Euler augmented by news (8')	No news ($g_w=0$); $g_u=0$	-0.024			-929.619	
14	M2	Bk-looking (9a) with news	Only news ($g_u=0$)				Fails BK (1980)	

LL is Log data density (or the Laplace approximation of marginal log likelihood unless stated otherwise) of the estimation stage of the Dynare estimation and MCMC (where applicable) is a 10000 sample replication based on Metropolis-Hastings Monte Carlo Markov Chain algorithm estimation stage.

7.2.3 Discussion

7.2.3.1 Estimated parameters

Our preferred model is M12, in terms of empirical fit. It involves news both in an augmented Euler equation (8') and in the fiscal rule and a backward-looking labour difference in the latter. It behaves in a comparable manner to SW07 (as shown by the IRFs of Appendix 6). However, with a sizeably higher likelihood, this research model provides a much-improved fit to data than SW07: LDD=−910.513, to be contrasted with an SW07 LDD of −924.956 and its (short) MCMC Log data density of −929.037. In addition, a marginally better fit was that for model M12 when estimated with Partial Information, PCL86 method and assumptions, giving LDD=909.91.

Whilst the table comparing all the parameters estimated by this research using the original SW07 and this research's best-fit model 12 are in Appendix 6, the following table highlights some of the main differences:

Table 7.2.3.1.1: The main differences between SW07 M0 and best-fit M12 models with full and partial information assumption

	Estimated parameter description	SW07 M0 full info. est.	M12 Estim. Full info.	M12 Estim. partial info.
ρ_b	Consumption shock AR1 process parameter	0.1623	0.4760	0.5030
σ_l	Labour substitution risk aversion	1.6706	1.1582	1.1493
Ψ	elasticity of the capital utilisation	0.4687	0.3994	0.3956
Φ/Y_0	1+fixed costs relative to steady state output in intermediate goods output	1.7054	1.5279	1.5275
H	Habit	0.739	0.7889	0.7914
	Constant (long-term) labour engagement	0.2284	0.3773	0.3925
g_v	Tech shock effect on gov. spend	0.6045	0.7363	0.7431
η_b	Std err. Of consumption shock	0.2469	0.0833	0.0894

In a bit more detail, in comparison with the standard estimates of SW07, the news and unemployment rule extended model estimates show a much higher persistence, e.g. of the consumption shock, 0.476 vs. 0.162 (and even higher for partial information at 0.5).

In addition, related to that, are also lower labour risk aversion (1.16 vs. 1.17), a higher habit (lifestyle rigidity) level (0.79 vs. 0.74), lower elasticity of the capital utilisation z , and even more interestingly, much higher levels of long-term labour engagement. The authors also observe a much lower standard error for the consumption shock, which means that the news effect can explain most of the apparent consumption disturbances that are estimated when no endogenous news is present in consumption. E.g. even the best-fit model without news, model M13, has the standard error for the consumption shock η_b closely as high as that of the estimated SW07 above: 0.2456.

Lower fixed costs relative to steady state production output for intermediate goods $\Phi/Y_o \sim 1.5$ in our models vs. 1.7 in SW07 estimation seem consistent with the presence of a government spending rule based on either, or both, unemployment and/or the news channel rule. (I.e. Φ/Y_o is lower whenever the model has an extended fiscal rule, either with or without news in c).

It seems that the estimated higher constant levels of long term labour employment (0.38 vs. 0.23) for the given (i.e. measured) consumer consumption (c) and total output (y) but with counter-cyclical government spending driven by the new fiscal rule requires a **lower relative** share of the fixed costs (i.e. mainly capital investment) in relation to the total output. This means that stabilising effects of the fiscal rule increase both labour and fixed capital utilisations (e.g. lower elasticity of capital utilisation Ψ : 0.47 for SW07 vs 0.4 for M12). These effects also help to reduce the overall relative level of capital requirements by improving the efficiency and lowering relative cost of labour in the given intermediate goods production and hence, lower the share of the required fixed cost relative to the total output.

The Student t-statistics of the new parameters seems strong. In addition, the labour market-related parameter in the fiscal rule (g_u) is negative indicating counter-cyclical nature of the rule. It however shows somewhat weaker t-statistics in models when estimated in conjunction with the news effect (e.g. 1.9 in model M12) but appears

rather more significant when estimated without the news effect, e.g. 4.5 in model M11 (these estimates are available on request).

The effect of news on government spending in the context of the fiscal rule (g_w) is also negative and significant (t-stat = -3.89). Thus, both the change in employment and the news term cushion the government spending effect of the exogenous spending shock, so that only about 61% of the initial spending shock manifests itself into an actual change of government spending. This is also evidenced in an IRF of g of about 0.33 out of a shock of about 0.56 (equal to its standard error); IRFs will be discussed shortly. This cushioning is to be contrasted with an IRF of the spending shock on government spending of about 0.52 in M0/SW07, roughly equal to the shock; so the shock translates almost one-to-one into a change in government spending in that model. The interpretation of this cushioning effect in M12 is that the spending shock elicits a change in the state of the cycle and expectations about the overall future outlook. Such developments then reduce the impact of the exogenous shock on actual government spending. This may be for various reasons, e.g. because of a direct endogenous effect on the fiscal rule (i.e. adjusting spending to the state of the economy). Alternatively, this may appear for a range of political-economic reasons: a calculating government may realise that it will probably not need to spend the full amount of the exogenous stimulus in order to achieve a certain effect, but may retain the remaining funds for other use.

In terms of other parameters, estimates show a much higher persistence of the consumption shock (0.476 vs. 0.162) and, the related, lower labour risk aversion (1.16 vs. 1.17), a higher habit level (0.79 vs. 0.74), relatively lower fixed costs per output Φ/Y , and interestingly a much higher level of long term labour utilisation. The higher habit level is also significant as it implies a greater weight on lagged consumption in relation to that of the future (see parameter θ in M12 and other models in Appendix 6).

In addition, as can be seen from the right column in the above table, this research also shows similar but higher persistence of a few of the parameters when estimated in

partial information framework than those for the standard full information (even comparing with the extensions outlined above). These parameters are consumption, habit and employment related and this is fully in line with the earlier discussed results of e.g. Pearlman and Perendia (2006), and, Levine, Pearlman, Perendia and Yang (2008-2012).

7.2.3.2 IRF Simulations

This section reviews the Impulse Response Functions (IRFs) for M12 (see Figures C.1 in Appendix 6). As previously mentioned, the overall outlook of the IRFs is quite similar to that of M0/SW07. Notable differences concern the effects of the exogenous spending shock ($\varepsilon_{g,t}$) on consumption, which is positive here and remains so for a number of quarters. This is in sharp contrast to the original M0/SW07 IRFs. Moreover, the same shock has a smaller contemporaneous effect on total government spending here, (about 0.45 vs. about 0.5 in M0/SW07) as it is cushioned by other variables (news and the employment change). The effect of the news is shown in Table C.1.b. Positive news affects consumption, investment and wages in a positive way, but reduces overall government spending. As a result, the total effect on output is negative and remains so rather persistently. This somewhat counter-intuitive result is due to the strong and overriding effect of news on government spending.

The overall results could then be indicating that providing for the countercyclical government spending increases both, the utilisation of now relatively longer-employed labour, allows for higher level of consumption continuity (habit), increases labour employability and lowers relative cost of capital by improving its utilisation.

7.3 The rationale for the government spending rule(s)

Rogoff (e.g. Reinhart and Rogoff (2010)), have been widely criticised by quite a few authors for arguing their case against the prevailing benefits of government intervention

and emphasising dangers of quantitative easing policies in curing the recent Great recession. This criticism came mainly from the NK standpoint mainly for their economic models (e.g. Nersisyan and Wray (2010)). However, more recently it has been shown that their data preparation had several numerical and coding errors that have systematically lead the authors to incorrect estimations and their conclusion about the dangers of high debt/GDP ratio on the future of growth (Herndon, Ash and Pollin (2013)).

As mentioned earlier, despite their monetarist position, a few authors show that, in some cases increased debt may be beneficial for growth. Traum and Yang (2009) and Traum and Yang (2011-13) go beyond the common position of non-productive government spending and in their NK, SW07 derived DSGE model, and show that government spending may be beneficial for growth if used for investment or tax-cutting.

However, Leeper's notional division between so called active and passive government policy, somehow crude and rooted in his early paper, Leeper (1991), provided a legacy of restricted and a bit ambiguous predicament and enforced the tradition of a relatively narrow vision of the government role for future research. For him the "active" policy refers to active engagement on controlling control variable or spending "as it sees fit" and independently of the budget constraints. On the other hand, the "passive" policy is spending without the "freedom" of the active control, thus adjusting of the budget management in "response to" exogenous shocks and/or active management by other bodies and within budget constraints. It however, looks like that one could say that the passive policy is then better referred to as "constrained reactive (adjustment) policy" instead just "passive" whilst the "active" should be "unconstrained active" policy. This is in part so to reduce possibly ambiguity because in some other literature active and passive distinction is also used to differentiate between authority taking or not taking reactive adjustment action to, mainly, exogenous but also, endogenous shocks, as, for example, Ricardian equivalence, if fully applicable, would render any active (fiscal) policy almost inefficient.

Influenced by the strong warnings of the negative effect of government debt on growth (e.g. Reinhart and Rogoff (2010)), and after years of focusing on monetary policy as the main economic driver, there is now a growing literature on government spending rules that are mainly concerned with government policies aimed at restricting its deficit and build-up of the sovereign debt.

Those more recent articles tackling the issue of government spending rules (e.g. Leeper and Bi (2010), Bi (2010), Leeper, Plante, and Traum (2010)) focus on budget constraints not a business cycle tackling policy. In addition, Fernandez-Villaverde, Guerron-Quintana, Kuester and Rubio-Ramirez (2011) also tackle the idea of a government spending rule and measure the variance contribution of unemployment on government spending, however, this is not inside the model.

Zubairy (2013) creates a small DSGE model with a government budget and consumption, and points out that if monetary policy is less stringent in reacting to output, the fiscal multiplier may be higher and more effective. Zubairy (2013) extends the government spending AR (1) rule (the law of motion) with a lagged output gap as a form of automatic stabiliser and allows its parameter to be normally distributed to allow for either a counter or procyclical effect on government spending and estimates it to be negative. In Zubairy's model, those automatic stabilisers capture the countercyclical spending on unemployment benefit transfers but do not indicate a significant countercyclical effect of government policy.

In the preparatory ("laboratory") experiments we, also used the same output gap based government rule extension with a normally distributed parameter before introducing unemployment as the sole main driver. We then obtained a much better fit to data when using only unemployment. Comparing impulse response functions for increases in government spending, we (the researchers) noticed similarities in relatively short-lived increases in output, labour hours and consumption and a small reduction in investment.

In both Zubairy's and this research model, the output multiplier effect of government consumption is higher than 1, though lower in the long term. Zubairy also measures the effects of tax reductions and finds their multipliers' effects to be lower than 1 although they have a positive effect on output. However, whilst in Zubairy's model output yields 1.07 dollar for a dollar of government spending, the short-term multiplier in the authors' model is much higher resulting in 1.4 dollars output increase. Also, whilst the effects on the increase of inflation and interest rates in this research model are a quick steep rises and have a tendency to converge towards a lower level long term increase, in Zubairy's model they are, unexpectedly, slower to rise but then result in rather higher long term increase.

In view of this research, it is probably wrong to apply a relatively restrictive active fiscal policy following the terms of Leeper (1991) and to expect cycle smoothing to be achieved by assuming deep, strong habits in government consumption demand in conjunction to its continuous aim to maximise its consumption midst budget constraint. This, deeply habitual government consumption behaviour model is, as the author explicitly states, very much alike that of households. This reflects an inert behaviour that does not seek to counter the effects of economic downturns by changing government consumption and is hence opposed to an engaging, endogenously driven fiscal spending policy, adjusted to countering business cycle which the researchers model. Zubairy has a model of a labour taxation effect on government spending but not a model of an unemployment effect such as this research develop.

None of those afore-mentioned reports, however, allow for a more consensual approach or understanding of how a pro-active government policy, aiming to tackle the economic dynamics other than to just reactively mend the wounds of the business cycle's downturns through unemployment benefit transfers. For example, they do not consider that an activist fiscal policy can be endogenously driven by a rule that aims to counter the business cycle downturns and any resulting unemployment. Consequently, none is including unemployment as a part of the government policy in its spending consideration, but only in the household's utility equation.

The rule this researchers introduces is not imposed but, like the (Vasicek-)Taylor one, it is a statistical expectation implied from estimations as an optimising control mechanism. It is a departure from the pure rational expectations and discretionary, opaque, fiscal policy of governments spending. It is also a departure from the world of economic models where government spending is deemed adequately described by no more than a random, exogenous shock, a perturbation that could easily lead to a non-optimal state.

The author of this research would therefore like to name this counter-cyclically active policy a pro-active policy and the limited unemployment benefit remedy transfer a remedial re-active policy, as opposed to the active and the passive policies in Leeper (1991) sense.

7.3.1 Is fiscal policy dead -Evidence of fiscal spending and its varied success

Debate continues to surround the desirability and effectiveness of fiscal policy and the controversy surrounding the ‘Obama stimulus plan’, the ARRA 2009 (i.e. American Recovery and Reinvestment Act, 2009), particularly the government spending, In a discussion following a presentation at a 2012 macroeconomic conference, a leading monetary and central banking economist proclaimed active fiscal policy dead.

However, the authors’ estimates above and the relative fluctuations of g in relation to y indicate much larger relative fluctuations than those that would have resulted just from direct transfers. On the other hand, the government spending may take less orthodox means other than, and, in addition to more traditional means of government spending for public purchases and work commissions,. Recent decades showed high increases of foreign aid packages conditioned by the services and/or goods being bought from, or supplied by, the donor country based business.

A large portion of the foreign aid money may actually not part the donor country at all due to a frequently stipulated clause that the donated aid can be used only for services and goods purchased from the donor country. This is effectively functioning as a domestic government financed expansionary spending aimed at improving exports. This may be for services work done by the donor country companies, e.g. consulting or transport, and, the goods exported and supplied to the aid-receiving foreign country. In addition, this government co-funded work is then producing additional tax revenues as a partial return to the donor governments. (An OECD 2009 study¹²⁷ points-out that even when aid is not formally and contractually tied to supply by the donor country, it is still often supplied by it).

There is emerging evidence in the literature of some even more unorthodox fiscal intervention shocks that resulted with more or less successful growth increase effects. As an example, R. Barro (Barro 2010), among others, recently referred to fiscal interventions in the form of defence spending (and for a military intervention related non-military logistics spending), pointing to the overall GDP output rise at the start of wars and to its decline amid raised taxation in their aftermath¹²⁸.

Whilst C. Romer (1992) points out that those deciding factors for the US' recovery from the Great Depression were fiscal spending and foreign financial inflow transfers in the wake and during WWII, a few other more recent publications claim a substantial and sustained rise of GDP in various military interventions. A rise of nearly 7% during the Korean war sustained and contributed to a continuous, though smaller, GDP growth in the years following the war, or just in intensive preparations for them (e.g. preparation for Iranian invasion in 1980s contributed to GDP boost in time of 1980s recession), and contributing to recoveries from preceding recessions. Although active fiscal spending intervention may not be dead, accounting for its sources and targets and

¹²⁷ Jepma, C.,: "Tying Aid", OECD, 1991 and "Aid untying: is it working? Thematic Study On The Developmental Effectiveness Of Untied Aid: Evaluation Of The Implementation Of The Paris Declaration And Of The 2001 DAC, Recommendation On Untying ODA To The LDCS", OECD 2009

¹²⁸ see: <http://online.wsj.com/article/SB10001424052748704751304575079260144504040.html>

then taking all the fiscal spending intervention data measures into the authors' model would have required near forensic research into foreign aid and those un-orthodox fiscal interventions. (e.g. see Ramey and Shapiro (1998), Laidler (2009), Romer (1992) and, Labonte and Levitt (2010) and discussion in Appendix 9).

7.3.2 Monetary-fiscal cooperation

A number of authors claim that there is no equilibrium for a situation when both fiscal and monetary policies are active. For example Leeper (1991) or a recent work by Bhattarai S. et al. (2012) has similar findings but they use similar target functions for both the simultaneous monetary and fiscal policies. This creates a conflict of responsibility domain and disrupts equilibrium. In addition, Kirsanova, Leith and Wren-Lewis (2009) conclude that the prevailing consensus in the recent literature is that monetary policy should work together with fiscal, but with limited effect. They hence also believe the former should be focusing on, and dominating, business cycle control and the latter, the government deficit and debt control.

On the contrary, in our model there is a separation but also co-operation and complementarity of domains of responsibility and reaction. Whilst monetary policy continues to react to inflation (and possibly the output gap), the countercyclical fiscal policy focuses mainly on reactions to expected changes in spending behaviour and the employment of the consuming households. Though they both attack an extended Phillips curve model from their respective domains, there is scope for complementarity and co-operation in a joint effort in resolving the problems especially when monetary policy is restricted by a zero lower bound on the interest rate policy instrument.

This is probably just one example of possible co-operative monetary-fiscal interventions where two agencies, the central bank and the state, act towards fulfilling their respective utility functions. They thus act in line with their obligations to improve the utility of their respective stakeholders: the business sector and the household electorate.

Worell (2000) shows that, although the independence of a central bank from the government works well in its drive of monetary policy in large economies, in smaller, open economies it is better that they cooperate and coordinate their respective monetary and fiscal policies. Lowest inflation is observed in small open economies where central bank's monetary policy is devised in a very tight coordination with government treasury.

In addition, several authors show active but discretionary simultaneous monetary and fiscal policies may lead to in-determination or suboptimal Nash equilibria if they are not fully coordinated and agreed by both sides (Dixit and Lambertini 2003a, Dixit and Lambertini 2003b and Lambertini 2004). Though most of those authors analyse monetary-fiscal cooperation (or the lack of it) within EMU, it is not therefore surprising that the fiscal rule extended SW07 model and the estimated US data indicate a presence of such dual policy activity in the US too.

What may appear surprising is that economists, in their publications, nevertheless model government spending as an exogenous shock. This opens up the question whether it is simply aimed to simulate fully discretionary and opaque fiscal policy, or possibly also, as a part of a prudential policy to minimise the risk of potential investors' fear from rising taxes when the fiscal policy is shown to be active. Along those lines, Davig and Leeper (2009) use a Markov switching DSGE model to show that regime switching between active and passive fiscal and monetary policy regimes may explain well the recent decades in the US economy movements whilst showing positive fiscal spending multipliers when if an active fiscal policy is in place.

Such policy mixtures, based either on simultaneous actions driven by commonly agreed optimal goals (Dixit and Lambertini (2003a) and (2003b), and Lambertini (2004)) or on alternating between periods of active and passive regimes (Davig and Leeper (2009)), indicate a need for a better cooperation if not even coordination between the fiscal and the monetary authorities. One can therefore question the need for their separation and

argue for their simultaneous or, even cooperative activity¹²⁹.

7.3.3 Government debt and cost of fiscal intervention.

It has been frequently pointed out that government spending crowds out investment due to the fear of future taxation of either the businesses directly, or by reducing demand for their product through taxation of the consumers or households. In contrast there seem to be much less of a concern in the literature for a crowding out of capital amidst households maintaining their spending through rising debt which they will have even more certain obligation to repay.

Similarly, whilst the government budget is sought to be constrained, there does not seem to be a limiting constraint on to how much the central bank can spend towards inflation targeting costs, nor how that is going to be funded. Whilst foreign exchange targeting may be self-financing, that is, sell high to dampen or buy low to appreciate, the timing may be adverse.

On the other hand, this research model of endogenising government spending shows that the feedback effect from the news effect actually reduces the government spending. This including that of unemployment lowering incited by the shock and that not the full amount of the initial spending shock is passed through into the actual rise of government spending (i.e. varying around 55% only. See the outputs of IRFs for g on ε_g shock and the standard error of the shock of around 0.55).

This bears different interpretations. It may be perceived that the government is spending the shock-money inefficiently by retaining 45% for itself, e.g. administrative expenses. Another plausible interpretation (but similar) is based on the observed phenomena that although a government may announce a high expansionary intervention policy move of e.g. 100 Mill, but knowing (or possibly hoping) that it will

¹²⁹ A similar approach to balanced fiscal and monetary activity has been, more recently also taken-up by Bhattarai K. and Trzeciakiewicz (2017)

not need to spend it all. I.e., the resulting good news will have its accelerating effect so that the government will probably not need to spend the full amount announced but only a part, e.g. 50 Mil. to achieve the desired demand and output rise stimulus effect. It may then act intentionally slowly in the spending the budget, and, if the target was at least partially achieved with less, it may retain the remaining budget for other use. It is thus acting as a rational agent, optimising its spending in the short and maximising its utility function – improving welfare of the electorate in return for re-election - in the long term.

NOTE: For more details from this paper in relation to its analysis of the fiscal multipliers, please refer to the original paper.

It is however worth re-iterating that the models with news in the Euler equation consistently show higher responses of both consumption and output to the fiscal shock. In the models without news in consumption, though the output rises with fiscal expansion, the consumption decreases (see compare models M12 and M13 that are identical except that the former incorporates news in the Euler equation and the fiscal rule whereas the latter does not). In addition, the researchers get output multipliers higher than 1 that last at least for a year, whereas without the news, the consumption response is less than 1 or negative. This repudates the key neoclassical criticism of the fiscal multiplier that it crowds out private consumption and that fiscal spending is therefore ‘expensive’ from the welfare point of view.

7.3.4 Conclusions

Understanding the effects of fiscal policy on aggregate output is increasingly important in an era of business cycle instability, when the stabilisation potential of monetary policy appears rather limited for a variety of reasons. This paper has sought to enhance the understanding of the aggregate effects of government spending and the nature of the associated multiplier. It does so by building and estimating a medium-sized DSGE

model which incorporates ‘news’ (the news based expectation change) and the formulation of fiscal policy, particularly spending, as following a rule akin to the Taylor (1993) rule for monetary policy. The former, the news based expectation change, is motivated as a way of better understanding the fiscal multiplier, which the Euler equation of dynamic models is not in a good position to capture for the reasons explained in Section 2. The fiscal rule concerns spending on goods and services (the ‘G’ of elementary macroeconomics) and is motivated as a way of formalising the stabilisation role of fiscal policy and linking it to the nature of the business cycle; in view of its potential, such government spending is unlikely to follow a pattern entirely unrelated to the state of the economy. Furthermore, the authors (Perendia and Tsoukis (2012)) combine these two feature enhancements and extend the fiscal rule with the “news” as an additional term in it. These features are innovations of this paper; the rest is a standard NK DSGE model such as the SW07 model that is rapidly achieving ‘canonical’ status in this literature (and to which reference should be made for further details).

The authors show that adding the news channel and an extended, endogenous government spending fiscal policy rule framework both significantly improve the model fit to data and its forecasting quality. Both of the novel features, the “news” channel and the unemployment driven fiscal rule, seem well supported by the data. It is however, deemed fair to say that much of the improvement in the model fitness comes from the “news” and unemployment channel in the context of the fiscal rule, more so than the news channel in consumption. A better fit to data after adding such a rule strongly suggests therefore that endogenising government spending and assuming its countercyclical nature would be a rather more realistic assumption rather than assuming it is a random, exogenous shock.

Finally, this framework has abstracted various important aspects of the real world such as interactions between fiscal and monetary policy (as alluded to in the Introduction), consumer heterogeneity (e.g. adding the parallel co-existence of non-Ricardian consumers a la Drautzburg and Uhlig, 2010) and the effects of budget constraints,

government deficits and debt. Incorporation of these features is on the agenda for future research work, as are the inclusions of optimistic and pessimistic ('animal spirits'-driven) agents along the lines of DeGrauwe (2009) and the imperfect (partial) information solution framework with the adaptive behaving agents along the lines of Levine, Pearlman, Perendia and Yang (2009-2012).

8 Conclusion, Achievements and Future Work

8.1 Conclusion

The primary focus of this research has been on informational issues in macroeconomic modelling, particularly in Dynamic Stochastic General Equilibrium (DSGE) models used by macroeconomic planning bodies such as central banks. For start, it provided an overview of contemporary dynamic macroeconomic analysis and forecasting models used by such institutions and of the main issues and critiques, which were discussed, and many refuted earlier in this text. Many of the critiques have been responded to as being out-dated since DSGE models evolved in their capabilities (and, in part thanks to this project), surpassing, thus, many of the older limitations that have been raised in most of those critiques.

Some of the criticisms that are still very valid are that they are complex to implement, difficult to use and require much more preparation and skills than e.g. VAR or panel data models. Another is that they require more time and computational power to run even small, parsimonious models used by academics, but these remarks are not, however, disqualifying DSGE models for their power of predicting and optimising economy. And, this power can be improved, as we have shown, by going beyond single representative rational agent and adding heterogeneous, imperfectly informed, non-fully rationally behaved agents

Most of other valid remarks are generic for economic modelling in general and not specific to DSGE so that they cannot be directly blamed for the 2007/8 crisis. One of most controversial such issues being the existence of multiple possible global equilibria rather than the single one (e.g. Benhabib and Farmer 1999 and Farmer et al. 2015), the other being what should central banks do and target, especially in time of zero (or even negative) interest rate as we have been seeing since 2008 crisis.

This is followed by a discussion of some of the insufficiencies in modern economic

modelling theory and practice that may have contributed to the development of the latest, 2007-08 economic crisis. Economic models based on a single representative or on rational agents with full information are considered as insufficient, and some of their respective alternatives such as using heterogeneous and irrational agents acting in models of imperfect information conditions have been presented and analysed as potential improvement.

A chapter was dedicated to revisit issue of rationality, a fundamental presumption in at least two of its main models, that of rational preferences and the other, rational expectations and it was shown that there is, one could say, a common underlying and partially, sub-conscious mechanism connecting the two models as analysed within the relatively new domain of neuroeconomics.

It was also shown that there are additional, major implications of imperfect, incomplete or limited information and of the limited, information processing capacity being available to individuals or smaller organisations to process that information. Instead, these limitations on resources are driving towards heuristics based decision making within bounded rationality or rational inattention conditions. This is, then explaining why it is that only larger teams or organisations can be considered to have basic conditions needed for forming fully rational expectations. Saying so, it does not necessarily mean that they follow it , thus, indicating that a major issue in the traditional and more recent macro-economic modelling theory has been making assumption of full sufficiency of a single representative agent forming fully rational expectations based on fully set of needed information.

8.2 Summary of the Achievements

This study provided some improvements to macroeconomic theory, the modelling and introduced several enhancements to the DSGE method by implementing several innovations within the now standard Smets and Wouters 2007 DSGE model:

1. On a more theoretical side, in ch. 3, some major criticisms of DSGE models have been addressed and responded to. In addition, in ch. 4, this research provides two contributions, one in terms of providing an explanation of a dichotomy of two major types of rationalities, the “instinctive” utility maximiser and full information rational expectation formation. It is deemed that this dichotomy is having its possible roots in the brain structure and its function-specialised segments as shown by neuroeconomics research. The other was to propose a preliminary, hypothetical model of economic agents based on distributed parallel processing and entropy, a theoretical model needing future development.
2. The first two major innovations concern a joint research work with professors J. Pearlman and P. Levine and the implementation of the solution for partial information modelling developed by Pearlman, Currie and Levine (1986) that corrects the traditional DSGE models’ inappropriate asymmetric information assumptions (ch. 5)¹³⁰. This inconsistency is bound to lead to less realistic parameter estimates than a more realistic scenario in which there is symmetry with regard to partial (imperfect) information, which is being modelled and analysed throughout a good part of this research. It has been shown to produce superior estimations and IRF simulations to some of the contemporary standard (e.g. Smets and Wouters (2007)) DSGE models and that decision of agents differ with different information being available at the time. That research work also showed the benefits of introducing heterogeneous agents by the inclusion of a second group of adaptive economic agents alongside the rational ones.
3. The second major contribution was made to analysis of causes of both the 1930s Great Depression and the recent 2007 crisis (so called “Great Recession”) and identification of influence of a, so far overlooked factor that this research

¹³⁰ I.e. They assume that all economic agents have full access to all relevant, needed measurements of economic shocks, whereas the econometricians have no access to all that information.

introduces and denotes “*recessionary debt accelerator*” (see Ch. 6). This (novel) factor, explained in this research, may affect the economy either in conjunction or independently of other recessionary accelerators (“decelerators”) such as Fisher’s debt-deflator and its effect is analysed in context of liquidity shortage shock, this possibly caused by monetary tightening through a sustained, long term interest rate rise shock (trend).

4. The third group of innovations of this research involved the extension of the standard Smets and Wouters 2007 DSGE model to assess the effects of two new factors as explained in ch. 7. Firstly news and the resulting changes in consumers' rational expectations, and secondly, an a new endogenised fiscal policy Taylor-like rule based on unemployment and the news- related expectation changes on consumption and growth. The resulting work improves the models' fit to data and their forecasting capacity and precision, and outlines potential directions for facilitating an economy out of a recession or a crisis by means of combined fiscal and monetary policies with some but not conclusive indicators that mutual coordination can also be beneficial.

8.3 Recommendations

As this research has shown, even small conceptual differences may lead to major differences in the output estimates. Hence, to reduce the effect of errors and improve estimation precision, the major institutions need to improve further their economic models and use a combination of several macro-models, of which some need to be large DSGE models augmented with the VAR techniques. They then need to create their estimates usually on a basis of a combination of informal and formal heuristics and the weighted average of the results obtained from different models. However, the informal bias may have major implications as this work shows in the example of the development of Great Recession of 2007/2008.

8.4 Future Work

Though this research proved the benefits of a partial (imperfect) symmetric information solution, adding heterogeneous agents to the economic models showed even higher improvements in the models' fit to data. It is therefore logical to expect that partial information models with asymmetric information distributed across heterogeneous agents should provide additional substantial improvements, but that should be the subject for a further study.

On the modelling side, it is expected that non-linear models, which incorporate household debt and additional financial market variables with heterogeneous agents models based in neuroeconomics characteristics, would be much better at predicting the 2007 crisis. It is hence a conclusion of this research that model enhancements in these directions should probably be given a much higher priority over other features.

Some other major next steps could be:

1. modelling and inclusion of the recessionary debt accelerator as introduced and described in this research ,
2. the inclusion of better IFRS like accounting models for the financial derivatives that draw-in vast sums of corporate profits and household income used for investment with no direct effect on the real economy,
3. investigating and possibly confirming, whether the technological developments and related practices of recent years, such as internet shopping, market monitoring and monitor electronic pricing, could have led to substantially lower price rigidities.
4. As per ch. 5.8, one can than take into further analysis whether it is the differences between fast (“procedural”) and “slow” (declarative) thinking that may be facilitating the perceived higher stability of, e.g., a large corporation or a

parliamentarian democracy acting in fully, communicatively rational manner. Or, on the other hand, can the procedural, individual decision making drive faster adaptive response and higher dynamics in systems led by a somehow authoritarian CEO or presidential with prerogative of high powers of authority, where such system can be exposed to higher danger of an inadequate personal bias and/or potentially higher volatility of its policies.

Appendix 1: PCL Method for Solving Partial Information Rational Expectations

Note: This section closely replicates Appendix 1 and, in part, Appendix 2 in Perendia (2006)¹³¹ and cover implementation of the PCL86 partial information DSGE models' solution and estimation method¹³² within the BayesDSGE software package (details in Appendix 1.6 below). For details on PCL86 implementation in Dynare, please refer to Pearlman 2009, Perendia 2010d, and, Levine and Pearlman 2011 as well as Dynare users' manual and material related to partial information.

PCL (1986) provided both a DSGE model solution a sub-space, time-domain recursive Kalman filter and Riccati equation based estimation method for partial information Rational Expectations models based on, and enhancing the solution given initially by Blanchard and Kahn (1980).

In Pearlman et al. (1986) extension of Blanchard and Kahn model, it is assumed that measurements of currently observable variables are denoted as w_t and the state-space equations written as

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad w_t = [K_1 \quad K_2] \begin{bmatrix} z_t \\ x_t \end{bmatrix} + v_t \quad (\text{A1.1})$$

where K_1 and K_2 define relationship between the p currently observed variables in the w_t and the model state-space variables. The assumed information set available at time t is:

$$I_t = \{w_t, A_{ij}, K_1, K_2, U, V\}, \quad i,j=1,2 \quad (\text{A1.2})$$

where $U = \text{cov}(u_t)$ and $V = \text{cov}(v_t)$. The partial information situation still allows that a

¹³¹ The text below is close reproduction of the notes by Prof. J Pearlman.

¹³² The PCL86 provides generic method for solving and estimating linear DSGE models that can be also used for models with partial information assumptions about the current values and shocks.

subset of the structural state-space, the non-predetermined (forward-looking and control) variables¹³³ x_t and the pre-determined (backward-looking and exogenous) variables z_t may still be observable at time t and mapped to w_t . This solution however, also allows the other, additional, non-structural, variables to be deemed observable and to constitute w_t . and thus, augment the estimation results like (See Appendix 2a).

¹³³ The (rational) control variables can be one or more of the non-predetermined state variables, usually one or more of (rational) choice variable that can be chosen by one or more of participating and decision making economic agents. The agent(s) need to make choice(s) optimally and effectively, in a manner so that can have a sufficient impact on the economic system behaviour and its direction to (an/)the optimal (steady) state. In the NK models, it is usually taken to be consumption and/or the some other choice variable(s) in the model that can be used to optimise model around its optimal goals. However, in most of modern the NK monetary policy models aimed at inflation targeting, it is the monetary policy interest rate that is most frequently used as the main or the only control variable, but money levels or target exchange rate may be used when alternative monetary policies are used. On the other hand, the system of equations describing the economic system, needs to be sufficiently “sensitive” (i.e. elastic, reactive or dependent) on that set of control variables so that the state-space representation can be controllable and directed by that set of the chosen control variables. In the follow-up to the 2008 crisis, it hence became evident that a single variable like policy interest rate is not sufficient to provide sufficient level of controllability of the economic (state-space) system and its return to its optimal growth. Mathematical models and issues of the rank of controllability gramian matrix of a state-space system are however beyond the scope of this research but more can be found in the state space literature, (e.g. see Aoki 1987/1990).

A1.1 Likelihood estimation with Partial Information – Non-RE Case

For a standard time series partial information model¹³⁴, one can express the system as:

$$z_{t+1} = Az_t + q_t \quad (A1.3)$$

with observations:

$$y_t = Cz_t + r_t \quad (A1.4)$$

and

$$\text{cov}(q_t) = Q; \text{cov}(r_t) = R \quad (A1.5)$$

The system updating equations (assuming q_t and r_t are independent) are given by

$$z_{t+1,t} = Az_{t,t-1} + AP_t C^T (CP_t C^T + R)^{-1} e_t \text{ with } e_t = y_t - Cz_{t,t-1} \quad (A1.6)$$

$$P_{t+1} = AP_t A^T - AP_t C^T (CP_t C^T + R)^{-1} CP_t A^T + Q \quad (A1.7)$$

where

$$z_{1,0} = 0; P_{1,0} = AP_0 A^T + Q \quad (A1.8)$$

and the log-likelihood is given by

$$2 \ln L = -T \cdot nn \cdot \log(2 \cdot \pi) - \sum \ln \det(CP_t C^T + R) - \sum e_t^T (CP_t C^T + R)^{-1} e_t \quad (A1.9)$$

where the researchers note that $CP_t C^T + R = \text{cov}(e_t)$, T – length size of the data sample and nn - number of observed variables in the sample

¹³⁴ I.e. one that assumes that all variables are expressed in an adaptive expectation (V)AR(n) form that does not distinguish between the non-predetermined, forward-looking rational expectations variables and, the predetermined and backward-looking variables, and where eigen vectors of the state-space gain matrix are stable (that is, all its eigen values $\Lambda_i < 1$). For “proper” PCL86 solution reduced state-space (“VAR”) form, see A1.4 below, eq. A1.13a&b, and, for its Dynare system timing-adjusted reduced form, the equation (A1.26) in the following section Timing Issues. For more general discussion on “VAR” (or VARMA) representation of DSGE please refer to e.g. Aoki (1987, 1996), Fernández-Villaverde et al. (2007) or Giacomini (2013).

A1.2 RE with Asymmetric information

Define z_t =backward looking and exogenous variables, and, x_t =forward-looking (non-predetermined) and control variables. There is not an enormous amount of difference in the likelihood calculation, except that for the observations the researchers have all of the predetermined variables assumed observed, plus some extra non-predetermined variables, so that the observations are given by

$$w_t = \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} 0 \\ r_{2,t} \end{bmatrix} = \begin{bmatrix} I \\ C_2 \end{bmatrix} z_t + \begin{bmatrix} 0 \\ r_{2,t} \end{bmatrix} \quad (\text{A1.10})$$

where the $r_{2,t}$ may well depend on the q_t . This is technically an irritation for the filtering problem, but is easily dealt with. The likelihood is dealt with in a related way. Note that the researchers still have a non-zero innovations process $\{e_t\}$ even for the fully observed predetermined variables, because the updating equations are $x_{t+1,t} = Ax_t$, so that in general x_{t+1} and $x_{t+1,t}$ will not match. Since this situation is rarely encountered, the authors provide no further details.

A1.3 Incorrect Partial Information Likelihood estimation

The following is the setup used in Dynare, and all other implementations of DSGE of which the authors are aware. Assume the model is given by

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (\text{A1.11})$$

With a subset of the structural state-space, the non-predetermined (forward-looking and control variable) being x_t and the pre-determined and backward-looking variables being z_t , and then reduced to:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1} \end{bmatrix} = \begin{bmatrix} C & 0 \\ -NC & 0 \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \text{terms in } u_{1t}, u_{2t}, u_{2,t+1} \quad (\text{A1.12})$$

A1.4 Correct Partial Information setup

This time the researchers take into account the effect that partial information has on the reduced form solution, as in Pearlman et al. (1986). The researchers assume that measurements are denoted as w_t and write the equations as¹³⁵:

$$\begin{bmatrix} z_{t+1} \\ x_{t+1,t} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + \begin{bmatrix} u_{1t} \\ u_{2t} \end{bmatrix} \quad (\text{A1.13a})$$

$$w_t = \begin{bmatrix} K_1 & K_2 \end{bmatrix} \begin{bmatrix} z_t \\ x_t \end{bmatrix} + v_t \quad (\text{A1.13b})$$

Then from Pearlman et al. (1986) the researchers have the following results:

Firstly define the saddlepath relationship between expectations of z and x by

$$N z_{t+1,t} + x_{t+1,t} = 0 \quad (\text{A1.14a})$$

where

$$\begin{bmatrix} N & I \end{bmatrix} \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} = \Lambda \begin{bmatrix} N & I \end{bmatrix} \quad (\text{A1.14b})$$

and Λ is a square matrix essentially containing the unstable eigenvalues. Define the following matrices:

$$\begin{aligned} C &= A_{11} - A_{12}N & A &= A_{11} - A_{12}A_{22}^{-1}A_{21} & B &= A_{12}A_{22}^{-1} \\ D &= K_1 - K_2A_{22}^{-1}A_{21} & F &= K_2A_{22}^{-1} & E &= K_1 - K_2N \end{aligned} \quad (\text{A1.15})$$

NB: There is no need to calculate Λ because it can be written (from above) as

$$\Lambda = N A_{11} + A_{22}$$

The Kalman filtering equation is then given by:

¹³⁵ I.e. this is PCL86 solution for reduced form state-space representation, sometimes referred to as VAR-representation of DSGE. With its non-predetermined (forward-looking and control) variables x_t and the pre-determined (an backward-looking) variables z_t and with the Blanchard and Kahn (1980) condition satisfied with the number of forward-looking x_t variables being equal to the number of the unstable eigen vectors of the state-space gain matrix (that is, equals the number of unstable eigen values $\Lambda_i > 1$).

$$z_{t+1;t} = Cz_{t;t-1} + (CP_t D^T + A_{12} \Lambda^{-1} U_{22} F^T)(EP_t D^T + V + K_2 \Lambda^{-1} U_{22} F^T)^{-1} e_t \quad (A1.16)$$

$$e_t = (w_t - Ez_{t;t-1}) \quad (A1.17)$$

$$P_{t+1} = AP_t A^T + BU_{22} B^T + U_{11} - (AP_t D^T + BU_{22} F^T)(DP_t D^T + FU_{22} F^T + V)^{-1}(DP_t A^T + FU_{22} B^T) \quad (A1.18)$$

the latter being a Ricatti equation.

The likelihood function can be evaluated in much the same way as in Section 1 above:

$$2\ln L = -T * nn * \log(2 * \pi) - \sum \ln \det(cov(e_i)) - \sum e_i^T (cov(e_i))^{-1} e_i \quad (A1.19)$$

where the researchers note that T is length size of the data sample and nn - number of observed variables in the sample

$$cov(e_t) = (EP_t D^T + V + K_2 \Lambda^{-1} U_{22} F^T)(DP_t D^T + FU_{22} F^T + V)^{-1}(DP_t E^T + FU_{22} \Lambda^{-T} K_2^T + V) \quad (A1.20)$$

Following Pearlman et al, this is initialised at

$$Z_{1;0} = 0 \quad P_1 = P + M \quad (A1.21)$$

where P is the steady state of the Riccati equation, and M is the solution of the Lyapunov equation

$$M = CMC^T + (CPD^T + A_{12} \Lambda^{-1} U_{22} F^T)(DPD^T + FU_{22} F^T + V)^{-1}(DPC^T + FU_{22} \Lambda^{-T} A_{12}^T) \quad (A1.22)$$

Timing issues

However, modern models and tools (including Dynare) apply generalised solution that locates z_t and $E_t x_{t+1}$ on the left hand side of the equation:

$$\begin{bmatrix} W & X \\ Y & Z \end{bmatrix} \begin{bmatrix} z_t \\ E_t x_{t+1} \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} z_{t-1} \\ x_t \end{bmatrix} \begin{bmatrix} e_t \\ 0 \end{bmatrix} \quad (\text{A1.23})$$

Our implementation uses a special case of reorganisation of this generalised model so that all AR1 processes are grouped in the top rows:

$$\begin{bmatrix} I & 0 & 0 \\ W_1 & W_2 & X \\ Y_1 & Y_2 & Z \end{bmatrix} \begin{bmatrix} u_t \\ z_t \\ E_t x_{t+1} \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & A_1 & B_1 \\ 0 & C_1 & D \end{bmatrix} \begin{bmatrix} u_{t-1} \\ z_{t-1} \\ x_t \end{bmatrix} + \begin{bmatrix} e_t \\ 0 \\ 0 \end{bmatrix} \quad (\text{A1.24})$$

or, in a form more suitable for application of the Pearlman et al. 1986 solution:

$$\begin{bmatrix} I & 0 & 0 \\ W_1 & W_2 & X \\ Y_1 & Y_2 & Z \end{bmatrix} \begin{bmatrix} u_t \\ z_t \\ E_t x_{t+1} \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & A_1 & B_1 \\ 0 & C_1 & D \end{bmatrix} \begin{bmatrix} u_{t-1} \\ z_{t-1} \\ x_t \end{bmatrix} + \begin{bmatrix} e_t \\ 0 \\ 0 \end{bmatrix} \quad (\text{A1.25})$$

After multiplying both sides by the inverted matrix on the LHS, the researchers obtain the following equation in reduced PCL86 form:

$$\begin{bmatrix} u_{t+1} \\ z_t \\ E_t x_{t+1} \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ -V_2 & A_2 & B_2 \\ -U_2 & C_2 & D_2 \end{bmatrix} \begin{bmatrix} u_t \\ z_{t-1} \\ x_t \end{bmatrix} + \begin{bmatrix} e_{t+1} \\ 0 \\ 0 \end{bmatrix} \quad (\text{A1.26})$$

and the observation set may then also be expressed in PCL '86 format as:

$$w_t = \begin{bmatrix} 0 & 0 & L_2 \\ -L_1 V_2 & L_1 A_2 & L_1 B_2 \end{bmatrix} \begin{bmatrix} u_t \\ z_{t-1} \\ x_t \end{bmatrix} \quad (\text{A1.27})$$

Where L_1 and L_2 are selection matrices, or , more precisely, in this implementation

$$w_t = L [u_t z_t x_t]^T = \begin{bmatrix} L_1 \\ L_2 \end{bmatrix} [u_t z_t x_t]^T = \begin{bmatrix} L_1 G \\ L_2 \end{bmatrix} \begin{bmatrix} u_{,t} \\ z_{t-1} \\ x_t \end{bmatrix} \quad (\text{A1.28a})$$

$$= \begin{bmatrix} L_{12} & 0 \\ 0 & L_{23} \end{bmatrix} \begin{bmatrix} -[V_2] [A_2] [B_2] \\ [0] [0] [1] \end{bmatrix} \begin{bmatrix} u_{,t} \\ z_{t-1} \\ x_t \end{bmatrix} = \mathbf{K} \begin{bmatrix} u_{,t} \\ z_{t-1} \\ x_t \end{bmatrix} = [\mathbf{K}_1 \mathbf{K}_2] \begin{bmatrix} u_{,t} \\ z_{t-1} \\ x_t \end{bmatrix} \quad (\text{A1.28b})$$

Where \mathbf{L}_1 and \mathbf{L}_2 are appropriately sized selection matrices of 1s and 0s in system matrix \mathbf{S}_t matching \mathbf{z}_t and \mathbf{x}_t respectively such that $\mathbf{L} = [\mathbf{L}_1 \mathbf{L}_2]^T$ and \mathbf{G} represents matrix multiplying the state vector in (A1.28a) above and:

$$\begin{aligned} \mathbf{L}_1 &= [\mathbf{L}_{11} \mathbf{L}_{12} \mathbf{L}_{13}] = [\mathbf{0} \mathbf{L}_{12} \mathbf{0}] & \text{and} & \quad \mathbf{L}_1 \mathbf{G} = [-\mathbf{L}_{12} \mathbf{V}_2 \quad \mathbf{L}_{12} \mathbf{A}_2 \quad \mathbf{L}_{12} \mathbf{B}_2] \\ \mathbf{L}_2 &= [\mathbf{L}_{21} \mathbf{L}_{22} \mathbf{L}_{23}] = [\mathbf{0} \mathbf{0} \mathbf{L}_{23}] & \text{and} & \quad [\mathbf{L}_1 \mathbf{G} \quad \mathbf{L}_2]^T = [\mathbf{K}_1 \mathbf{K}_2] = \mathbf{K} \end{aligned} \quad (\text{A1.29})$$

Then, in time adjusted setup:

$$N\mathbf{z}_{t;t} + \mathbf{x}_{t+1,t} = \mathbf{0} \quad (\text{A1.30})$$

A1.5 Solving Riccati Equation¹³⁶

Iterative Solution

Having a linear relation

$$\mathbf{p}(t) = \mathbf{P}(t) \mathbf{x}(t) \quad (\text{A 2.31})$$

Ricatti matrix differential equation has only final conditions and can be solved with backward iterative recursion and numerical integration based on Euler's approximation:

$$\mathbf{P}(t-T) = \mathbf{P}(t) = T\mathbf{P}'(t) \quad (\text{A1.32})$$

Assuming starting value $\mathbf{P}(T) = \mathbf{P}(0) = \mathbf{0}$ (or $T=0$),

A1.5.1 Fast-Iterative Solution

When Riccati has to be solved outside Kalman or similar recursive loop, a fast iterative solution based on period doubling algorithm is used.

¹³⁶ Based on Aoki (1987/1990) pp 78-82

A1.5.2 Non-Iterative Solution¹³⁷

Most frequently used non-iterative solution is based on construction of the real Shur triangular decomposition form. Assume $n \times n$ matrix Riccati equation $\mathbf{X} = \mathbf{A}\mathbf{X}\mathbf{A}' + \mathbf{f}(\mathbf{X})$ where

$$\mathbf{f}(\mathbf{X}) = (\mathbf{M} - \mathbf{A}\mathbf{X}\mathbf{C}')(\mathbf{\Lambda} - \mathbf{C}\mathbf{X}\mathbf{C}')^{-1}(\mathbf{M} - \mathbf{A}\mathbf{X}\mathbf{C}')' \quad (\text{A1.33})$$

The researchers can define three auxiliary $n \times n$ matrices as:

$$\mathbf{\Psi} = \mathbf{A}' - \mathbf{C}' \mathbf{\Lambda}^{-1} \mathbf{M}'; \quad \mathbf{Q} = \mathbf{C}' \mathbf{\Lambda}^{-1} \mathbf{C} \quad \text{and} \quad \mathbf{D} = \mathbf{M} \mathbf{\Lambda}^{-1} \mathbf{M}' \quad (\text{A1.34})$$

then a $2n \times 2n$ matrix $\mathbf{\Phi}$ can be defined as:

$$\mathbf{\Phi} = \begin{bmatrix} \mathbf{\Psi} - \mathbf{Q}\mathbf{\Psi}''\mathbf{D} & \mathbf{Q}\mathbf{\Psi}'' \\ -\mathbf{\Psi}''\mathbf{D} & \mathbf{\Psi}'' \end{bmatrix} \quad (\text{A1.35})$$

where “ $''$ ” denotes inverse transpose of a matrix. If one construct the real Shur triangular decomposition form $\mathbf{W}'\mathbf{\Phi}\mathbf{W}$ of the matrix $\mathbf{\Phi}$:

$$\mathbf{W}'\mathbf{\Phi}\mathbf{W} = \begin{bmatrix} \phi_{11} & \phi_{12} \\ 0 & \phi_{22} \end{bmatrix} \quad (\text{A1.36})$$

where each ϕ_{12} is also a triangular, $n \times n$, matrix, then matrix $\mathbf{X} = \mathbf{W}_{21}\mathbf{W}_{11}^{-1}$ solves the above Riccati equation where \mathbf{W}_{21} and \mathbf{W}_{11} are $n \times n$ submatrices of \mathbf{W} .

¹³⁷ Based on Aoki (1987/1990) pp 78-82

A1.6 Method and Tools: BayesDSGE system design and its modifications

A.1.6.1 PCL Implementation in BayesDSGE

This PCL86 solution and estimation method for DSGE models was initially implemented as a modification and an extension to BayesDSGE, a generic, small DSGE estimation and IRF simulation software package, a system of Matlab routines that was developed by A. Justiniano. BayesDSGE was built around C. Sims' functions gensys and csminwel (See Sims 2002a). It had to be modified in the course of implementing the PCL1986 method as described in detail in Perendia (2006), and then used in Pearlman and Perendia (2006) and Perendia (2008) research work.

The BayesDSGE system is a two stage solution variant of the standard MCMC DSGE tool and is based on the recursive state-space Kalman-Filter MLE (stage 1), and Bayesian MCMC Random-Walk Metropolis-Hastings algorithm (stage 2) methodologies.

The system has been modified and extended with:

1. the modified, part information general solution method outlined in the Timing Issues section of and implemented in the new module PI_gensys, which replaces C. Sims (2002a)' gensys, but continues to utilise his QZdiv and QZswitch routines for real Shur triangular decomposition and ordering matrix elements by eigenvalues respectively (see above schema).
2. The existing Gensyslikel and Gensyspost modules needed to be modified to handle the changes to the system.
3. the new, computationally more complex set of functions for the new partial (but symmetric) information assumption of the Kalman filter (PT_ KF in the above

schema) based on the solution provided in Pearlman, Currie and Levine 1986 and its data rich generalisation and (as outlined earlier in the text and presented in detail earlier in Appendix 1) which replaces the asymmetric information Kalman filter (KF in the schema):

- the modified Kalman filter shell routine which completes the PCL86 system equation solution method before calling the new, part-info Kalman filter functions (pt_info_kf_shell.m),
- Fast discrete Riccati equation solver called by the new “shell”.
- A new Part info Kalman filter (pt_info_kf.m)

A.1.6.2 General PCL Usage Notes

Both, BayesDSGE developed by A. Justiniano and Dynare are generic tools for solving and estimating numerically DSGE models built in Matlab programming language (with Dynare having some technical extension in other languages too). In both cases, economic DSGE models are specified in generic manner, without needing particular characteristics for PCL86 partial information solution and estimation. They are then passed through the system for either their standard, “full-info” solution and estimation, or, using a simple system specific command, directed through a variant of the PCL86 based, however, to specific system adjusted solver and Kalman filter.

In either of the two package implementations, a generic DSGE model can be, without modifications, passed through either the package's, system specific standard, “full-info”, or, the PCL86 based part-info solver and estimation pipelines with its appropriate specific Kalman filter. However, users would see a difference in the results only when their DSGE economic model has more shocks than observable variables, otherwise results should be equal.

A.1.6.3 Notes on Accessing PCL86 Matlab Implementations

Because both, BayesDSGE developed by A. Justiniano and Dynare are generic tools for solving and estimating numerically DSGE models built in Matlab programming language, PCL implementation was also generic.

However, reproducing PCL86 code for BayesDSGE within a PhD publication would not be appropriate for two main reasons. This is primarily due to its large size, but also, because it is part of a proprietary package system initially developed by A. Justiniano and that it would not be much helpful to users without having seen and having access to the whole proprietary package the new code it is part of.

Readers interested in analysing the relevant Matlab code developed specifically for PCL86 based DSGE model solution, its Kalman filter estimation and IRF simulation are, therefore, advised to access and download the relevant code from the Dynare web-site, (www.dynare.org), where it is available as a part of a free, public domain DSGE toolkit.

For technical details on PCL86 implementation in Dynare, please refer to Pearlman 2009, Perendia 2010d, and, Levine and Pearlman 2011 as well as Dynare users' manual and material related to partial information.

Appendix 2a: Factor Augmented VAR (FAVAR)

Note: This section replicates section from Perendia (2006) describing an extension to PCL86 used in Pearlman and Perendia (2006), Levine Pearlman and Perendia (2007) and in Perendia (2008).

Here we briefly explain Factor Augmented VAR, a variant of which was used for estimation of our initial model in Levine, Pearlman and Perendia (2007) and in Perendia (2008) in conjunction with PCL86 solver described earlier.

To overcome some of the remaining limitations of VAR, B-VAR and Structural VAR (SVAR) models, such as relatively small number of variables and time-series they can handle¹³⁸ leading to “price puzzle”¹³⁹, and, building on the work by Stock and Watson (1999)¹⁴⁰, several papers by Bernanke, (Bernanke and Boivin (2003) and, Bernanke et al. (2004/2005)) describe and use new, Factor-Augmented VAR (FAVAR) method.

In general, FAVAR works by nesting two VARs into the one VAR estimation process: one for a small number of observations directly related to (or representing) the variables of the model of interest \mathbf{Y}_t , another made of a number of inherently non-observable variables that augment the SVAR estimation – factors \mathbf{F}_t , and additional vector of noisy indicator observations \mathbf{X}_t that are, driven by both \mathbf{F}_t and \mathbf{Y}_t via the matrix $\mathbf{\Lambda}=[\mathbf{\Lambda}_F \mathbf{\Lambda}_Y]$ of estimated relational parameters so that:

$$\mathbf{X}_t = \mathbf{\Lambda}_F \mathbf{F}_t + \mathbf{\Lambda}_Y \mathbf{Y}_t + \boldsymbol{\varepsilon}_t = [\mathbf{\Lambda}_F \mathbf{\Lambda}_Y] \begin{bmatrix} \mathbf{F}_t \\ \mathbf{Y}_t \end{bmatrix} + \boldsymbol{\varepsilon}_t = \mathbf{\Lambda} \boldsymbol{\Phi}(\mathbf{L}_n) \begin{bmatrix} \mathbf{F}_{t-1} \\ \mathbf{Y}_{t-1} \end{bmatrix} + \boldsymbol{\varepsilon}_t \quad (\text{A2a.1})$$

¹³⁸ Inclusion of additional variables in standard VARs is severely limited by degrees-of-freedom problems.

¹³⁹ The conventional finding in the VAR literature that a contractionary monetary policy shock is followed by an increase in the price level, rather than a decrease as standard economic theory would predict.

¹⁴⁰ For example, Bernanke & Boivin 2003 build upon the work of Stock and Watson (1999) who conclude that “the best-performing forecast for inflation is an augmented Phillips curve forecast that uses a new composite index of aggregate activity comprised of the 168 individual activity measures”.

Where $\Phi(L) \begin{bmatrix} F_{t-1} \\ Y_{t-1} \end{bmatrix} + \mathbf{u}_t$ defines dual VAR state equation with order n and lag polynomial operator L .

FAVAR has a dual form, one of which combines the SVAR analysis with the recent developments in non-parametric, principal component analysis based dimension reduction, and the other, which combines SVAR with Bayesian likelihood and Gibbs sampling based estimation of the parameters $[\mathbf{\Lambda}_F \mathbf{\Lambda}_Y]$ and factors \mathbf{F}_t from the set of noisy indicators. The latter form was used to extend PCL86 solution method, the reduced state space (i.e. VAR) form of the transformed model with, noisy observations linear equations as factors augmenting estimation of the current estimates of the current variables $z_{t,t}$ using \mathbf{L}_1 and \mathbf{L}_2 appropriately sized selection matrices in equations A.1.28 and A.1.29 above). The non-pre-calibrated additional parameters were then also included into the estimation.

NOTE: due to alternations to implementation of PCL86 into Dynare and complexity of Dynare system FAVAR-like extension was not ported and implemented in Dynare system.

Appendix 2b: Model and its Linearisation

Note: This section replicates model as described in detail in Perendia (2006) and used in Pearlman and Perendia (2006), Levine Pearlman and Perendia (2007) and Perendia (2008).

A2b.1 Households

For most contemporary economic models, the starting point is a constrained maximisation of the individual multi-generational household τ 's expected, inter-temporal utility function U over infinite time and for all future generations and based on contemporary expectations at time $t=0$. In its Euler type first degree discrete time interval approximation it is usually expressed as:

$$E_0\left[\sum_{t=0}^{\infty} \beta^t U_t^{\tau}\right] \quad (\text{A2b.1.1})$$

Where β is a future discount coefficient, usually assumed to be constrained $0 < \beta < 1$ and, for simplicity, assumed to be time and household invariant¹⁴¹.

The instantaneous utility function (Felicity function) is expressed as a “balancing act” optimisation function of consumption C and leisure $(1-N)$ where N is time (number of hours) spent in work (assumed not to be source of pleasure). Definition of the felicity function varies slightly, however, between authors¹⁴². SW02 and Batini et al. (05a) define the household's τ objective felicity function as:

$$U_t^{\tau} = \varepsilon_{C,t} \left[\frac{(C_t(\tau) - H_{C,t})^{1-\sigma}}{1-\sigma} \right] + \varepsilon_{M,t} \frac{(M_t(\tau) / P_t)^{1-\phi}}{1-\phi} - \varepsilon_{N,t} \frac{(N_t(\tau) - H_{N,t})^{1+\phi}}{1+\phi} + u(G_t) \quad (\text{A2b.1.2})$$

¹⁴¹ Usually approximated as $1/(1+r^*)$ where r^* is real interest rate, though, in reality, this is not the case in relation to an individual person and the phase of his/her life.

¹⁴² and even between two papers by the same authors (e.g. SW02 and SW03)

Where $H_{C,t}$ and $H_{N,t}$ are consumption and labour supply¹⁴³ habits based on past time behaviour, life-style rigidity and a wish not to differ from the rest of the community. The consumption risk factor is σ (i.e. inverse of the inter-temporal elasticity of consumption) and ϕ is the inverse Frisch (disutility) of labour supply, i.e. inverse of labour supply substitution elasticity¹⁴⁴. $M_t(\tau)/P_t$ is the real cash balance at the end of period and φ is in SW02 denoted as σ_m and defined as the “inverse of elasticity of money holding in respect to interest rate”¹⁴⁵. $\varepsilon_{C,t}$, $\varepsilon_{M,t}$ and $\varepsilon_{N,t}$ are the general consumption, the money demand and labour supply preference shocks respectively.¹⁴⁶ They are assumed to follow an AR1 random walk stochastic process with their respective IID normal errors $\eta_{X,t}$ (where X is one of M, C or N). $H_{N,t}$ and $H_{C,t}$ are labour and consumption life-style rigidities (or habits) defined as shock-less AR1 process in proportion to past labour supply and consumption: $H_{C,t} = h_C C_{t-1}$ and $H_{N,t} = h_N N_{t-1}$ respectively¹⁴⁷. The $u(G_t)$ is the utility of exogenous government spending at time t .

Households are expected to respect an inter-temporal budget constraint which may be expressed in a variety of ways. Essentially¹⁴⁸, in a differential equation form, a simple budget constraint equation can be defined as:

$$A'_t = W_t N_t + r_t A_t - C_t - T_t \quad (\text{A2b.1.3})$$

where W_t is wage, A_t is the risk-free equivalent value of an income bearing portfolio of assets and state contingent claims (i.e. normalised to its risk-free value), r_t the real interest rate and T taxes. It is assumed that any income residuals from period t are re-

¹⁴³ SW02 and SW03 do not take into account labour supply habits.

¹⁴⁴ In B&G and S&W - also appearing as σ_L -inverse elasticity of labour supply in relation to wage i.e. coef. of relative inter-temporal labour supply substitution (labour supply "risk aversion")

¹⁴⁵ However, it may be considered as an instance of investment risk-aversion coefficient.

¹⁴⁶ In SW02 word “preference” attributes only $\varepsilon_{C,t}$ and does not play part in definition of the other two, and, hence, it is unclear whether the other two are “endogenous” to household or not.

¹⁴⁷ Although a certain level of smoothing-up the past through aggregation, averaging or indexation is often assumed rather than relying on the imminent, first lag only.

¹⁴⁸ Based on Heijdra & Van Der Plong 2002

invested in additional assets¹⁴⁹. Multiplying sides with $e^{-R(t,\tau)}$ where $R(t,\tau) = \int_t^\tau r(s)ds$, integrating both sides and solving by partial differentiation, the resulting equation leads to:

$$A(t) = \int_t^\infty [C(\tau) - W(\tau)N(\tau) + T(\tau)] e^{-R(t,\tau)} d\tau + [\lim_{\tau \rightarrow \infty} A(\tau) e^{-R(t,\tau)}] \quad (A2b.1.4)$$

Each household has, however, also had to adhere to a so called “No Ponzi game” lifestyle constraint which restrains households from holding any debts or any savings at the ultimate “end of time”¹⁵⁰, thus,

$$\lim_{\tau \rightarrow \infty} A(\tau) e^{-R(t,\tau)} = 0 \quad (A2b.1.5)$$

and

$$A(t) = \int_t^\infty [C(\tau) - W(\tau)N(\tau) + T(\tau)] e^{-(t,\tau)} d\tau \quad (A2b.1.6)$$

Or, in a discrete time Euler approximation:

$$A_{t+1} = W_t N_t + (1+r_t)A_t - C_t - T_t \quad (A2b.1.7)$$

-with a “No Ponzi game” lifestyle constraint:

$$\lim_{t \rightarrow \infty} A(t) e^{-R(t)} = 0 \quad \text{where } e^{-R(t)} \sim \prod_{i=1 \dots t} (1 + r_{t,i})^{-1} \quad (A2b.1.8)$$

the inter-temporal budget is then:

$$A(t) = \sum_t [(W_t N_t + (1+r_t)A_t - C_t - T_t) e^{-R(t)}] \quad (A2b..1.9)$$

For example, the budget constrain in SW02 (with small notational differences) is

¹⁴⁹ It may have been allowed that A is negative representing a borrowing that needs to be repaid.

¹⁵⁰ In some earlier instances, this was considered to be the end of an individual's lifecycle but inter-temporal, multi-generational households are now considered to last to “the end of time”.

defined as:

$$\frac{M_t}{P_t} + b_t \frac{B_t}{P_t} = \frac{M_{t-1}}{P_{t-1}} + \frac{B_{t-1}}{P_t} + Y_t - C_t - I_t \quad (\text{A2b.1.10})$$

where B_t/P_t is bond income and b_t its price¹⁵¹. Their definition of household income can be simplified to $Y_t = (W_t N_t + A_t)$ but they extended it with the difference between the return on the real capital stock ($r_{k,t} z_t K_{t-1}$) and the cost of its utilisation z_t variation ($\Psi(z_t) K_{t-1}$) and dividend income Div, hence:

$$Y_t = (W_t N_t + A_t) + (r_{k,t} z_t K_{t-1} - \Psi(z_t) K_{t-1}) + \text{Div} \quad (\text{A2b.1.11})$$

In the authors' initial model, household τ 's budget constraint is expressed as:

$$P_t C_t(\tau) + A_t(\tau) + M_t(\tau) = W_t(\tau)(1 - T_t)N_t(\tau) + (1 + R_{t-1})A_{t-1}(\tau) + M_{t-1}(\tau) + \Gamma_t(\tau) \quad (\text{A2b.1.12})$$

Where P is price index, $A_t(\tau)$ is household τ 's aggregate end-of-period deposits and/or riskless investments assets (e.g. government bonds), $W_t(\tau)$ – wage and $\Gamma_t(\tau)$ dividend income net of taxes and T – labour wage income taxes.

A2b.2 Consumption

Maximising the household's instantaneous utility, a felicity objective function in respect to consumption and asset holdings (i.e. bonds in case of SW02) and having a budget constraint defined as above, Smets and Wouters derive first order conditions in form:

$$E\left[\beta \frac{\lambda_{t+1} R_t P_t}{\lambda_t P_{t+1}}\right] = 1 \quad (\text{A2b.2.1})$$

Where R_t is the gross nominal rate of return on bonds ($R_t = 1 + r_t = 1/b_t$) and λ_t is the marginal utility of consumption:

¹⁵¹ The real cash balances $M_t(r)/P_t$ may be ignored if cash is not assumed to be held over between the periods but tax T_t may be added to the balance sheet too as Batini et al. (05a) do.

$$\lambda_t = \varepsilon_t(C_t - H_t)^{-\sigma_c} \quad (\text{A2b.2.2})$$

Similarly, demand for cash is given by

$$\varepsilon_{M,t} \left(\frac{M_t}{P_t} \right)^{-\sigma_m} = (C_t - H_t)^{-\sigma_c} - 1/(1+r_t) \quad (\text{A2b.2.3})$$

A2b.3 Labour supply and wages

According to the SW02 model, households fully re-optimize their wages at time t with probability $1-\xi_w$ for a long time ahead (where ξ_w is wage stickiness or a wage rigidity factor). Household τ aims to optimize their wages so as to maximize their utility objective function subject to constraints such as the demand for labour defined as:

$$N_{\tau,t} = \left(\frac{W_{\tau,t}}{W_t} \right)^{-(1+\lambda_{w,t})/\lambda_{w,t}} N_t \quad (\text{A2b.3.1})$$

Where $\lambda_{w,t}$ is mark-up shock¹⁵² at time t and λ_w is mean from IID driven wage mark-up shock $\lambda_{w,t} = \lambda_w + \eta_{w,t}$ and, N_t and W_t are the aggregate labour demand and (average) nominal wage respectively aggregated across all households¹⁵³ defined in Dixit-Stiglitz form¹⁵⁴ as:

$$N_t = \left(\int_0^1 N_{\tau,t}^{1/(1+\lambda_{w,t})} d\tau \right)^{1+\lambda_{w,t}} \quad \text{and} \quad W_t = \left(\int_0^1 W_{\tau,t}^{-1/\lambda_{w,t}} d\tau \right)^{-\lambda_{w,t}} \quad (\text{A2b.3.2})$$

The households that do not receive re-optimisation approval signal and cannot re-optimize. They may be able to adjust by past inflation rate as:

¹⁵² Batini et al. (2005a) instead $(1+\lambda_{w,t})/\lambda_{w,t}$ use η - a (time invariant) demand elasticity for specialised labour.

¹⁵³ SW02 make an unrealistic abstraction that all households can supply the full range of differentiated labour. Such an assumption can lead to unrealistically low estimates for λ_w .

¹⁵⁴ Batini et al. (2005a) use discrete sum instead of averaging

$$W_{\tau,t} = \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w} W_{\tau,t-1} \quad (\text{A2b.3.3})$$

depending on whether their wage indexation factor γ_w is different from zero¹⁵⁵. For those who do, the household utility maximisation leads to a wage re-optimisation mark-up first order condition in the form:

$$\frac{\tilde{W}_t}{P_t} E_t \sum_{i=0}^{\infty} \beta^i \xi_w^i \left[\frac{P_t / P_{t-1}}{P_{t+i} / P_{t+i-1}} \right]^{\gamma_w} \frac{l_{\tau,t+i} U_{c,t+i}}{1 + \lambda_{w,t+i}} = E_t \sum_{i=0}^{\infty} \beta^i \xi_w^i l_{\tau,t+i} U_{L,t+i} \quad (\text{A2b.3.4})$$

where \tilde{W}_t is the new nominal wage and U_C and U_L are the marginal utility of consumption and disutility of labour respectively. Given the above relations, the aggregate wage dynamics is then driven by:

$$W_t^{-\lambda_{w,t}} = \xi [W_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_w}]^{-\lambda_{w,t}} + (1 - \xi) \tilde{W}_t^{-\lambda_{w,t}} \quad (\text{A2b.3.5})$$

A2b.4 Firms and producers

In line with Batini et al. 05a, an output driven by a CES model results in an individual firm f 's output¹⁵⁶:

$$Y_{f,t} = A_t \left(\left(\frac{1}{v} \right)^{\lambda_{w,t}/(1+\lambda_{w,t})} \sum_{\tau=1}^v N_{f\tau,t}^{1/(1+\lambda_{w,t})} \right)^{1+\lambda_{w,t}} = A_t N_{f,t} \quad (\text{A2b.4.1})$$

where A_t , $N_{f\tau,t}$ and $N_{f,t}$ are the exogenous productivity shock, the firm's demand for labour of type τ and the firm's aggregate demand for labour respectively. τ is the labour type and v – the total number of hours. The firm's marginal cost (without considering capital or investment and as estimated in this research) is then defined as wage cost per

¹⁵⁵ For simplification it can be expected that $\gamma_w, \lambda_w = [0, 1]$ and that they are time invariant but it is worth investigating whether they can fall outside that range and be time variant.

¹⁵⁶ In their formulation Batini et al. use η instead of λ_w as noted earlier

unit of output relative to the producer's price¹⁵⁷ and given by:

$$MC_t = \frac{W_t}{A_t P_t} = \frac{U_t (1 + \lambda_w)}{A_t (1 - T)} \left(\frac{Y_t}{A_t v} - h \frac{Y_{t-1}}{A_{t-1} v} \right)^\phi (C_t - h_c C_{t-1})^\sigma \frac{P_t}{P_{t+1}} \quad (A2b.4.2)$$

SW02 define output in a Cobb-Douglas form and, with capital investment, the firm's marginal cost is, in a similar way, given by:

$$MC_t = (1/\varepsilon_{a,t}) W_t^{1-\alpha} r_{k,t}^\alpha (\alpha^{-\alpha} (1-\alpha)^{-(1-\alpha)}) \quad (A2b.4.3)$$

Where $\varepsilon_{a,t}$ is a productivity shock at time t and α , the Cobb-Douglas proportion factor. They then declare the final output as an aggregate of different intermediate products of type j as:

$$Y_t = \left(\int_0^1 y_{j,t}^{1/(1+\lambda_{p,t})} dj \right)^{1+\lambda_{p,t}} \quad (A2b.4.4)$$

Where $\lambda_{p,t}$ is defined (in a similar way to $\lambda_{w,t}$) as a stochastic time-variant price mark-up shock driven by IID disturbances and its shocks are passed on as inflation shocks.

Similarly, output of product j may be defined as constant return CES function

$$Y_t = \left(\int_0^1 y_{j,t}^{(\zeta-1)/\zeta} dj \right)^{\zeta/(\zeta-1)} \quad (A2b.4.5)$$

where ζ is the elasticity of substitution. Consequently, in a perfect competitive market, the price of final good P is an aggregate of prices of the intermediate products p_j :

$$P_t = \left(\int_0^1 p_{j,t}^{-1/\lambda_{p,t}} dj \right)^{-\lambda_{p,t}} \quad (A2b.4.6)$$

¹⁵⁷ “The marginal cost of an additional unit of output is the cost of the additional inputs needed to produce that output. More formally, the marginal cost is the derivative of total production costs with respect to the level of output. Marginal cost and average cost can differ greatly. For example, suppose it costs \$1000 to produce 100 units and \$1020 to produce 101 units. The average cost per unit is \$10, but the marginal cost of the 101st unit is \$20” (quoted from <http://www.econmodel.com/classic/terms/mc.htm>)

Similarly to wage setting, micro level firms can also re-optimize their prices only on random signal event and those that do not receive the signal, follow a general price inflation indexation adjustment. The first order condition for profit optimisation is:

$$E_t \sum_{i=0}^{\infty} \beta^i \xi_p^i \lambda_{p,t+i} Y_{j,t+i} \left[\frac{\tilde{P}_{j,t-1}}{P_t} \left[\frac{P_{t-1+i} / P_{t-1}}{P_{t+i} / P_t} \right]^{\gamma_p} - (1 + \lambda_{p,t+i}) mc_{t+i} \right] = 0 \quad (\text{A2b.4.7})$$

And their price dynamics as:

$$P_t^{-1/\lambda_{p,t}} = \xi_p [P_{t-1} \left(\frac{P_{t-1}}{P_{t-2}} \right)^{\gamma_p}]^{-1/\lambda_{w,t}} + (1 - \xi_p) \tilde{P}_t^{-1/\lambda_{p,t}} \quad (\text{A2b.4.8})$$

A2b.5 Investment and capital rental¹⁵⁸

As mentioned earlier, in the SW02 model, the households rent their real capital stock K_t (e.g. savings) to the production sector¹⁵⁹ at rate $r_{k,t}$. They can increase the capital supply by investing (I_t) in future periods or by increasing the utilisation z_t of the already existing capital at the cost of its utilisation variation $\Psi(z_t)K_{t-1}$. Both options, however lead to a consumption reduction in the current period t . In a rather simplified¹⁶⁰ form, capital investment is driven by:

$$K_{t+1} = K_t(1 - \tau) + (1 + \varepsilon_{i,t})I_t \quad (\text{A2b.5.1})$$

Where τ and $\varepsilon_{i,t}$ are capital depreciation rate and investment efficiency shocks and first order conditions from the optimisation of the household's budget leads to the equations giving a real value to capital and of its utilisation:

¹⁵⁸ To be able to discuss their equilibrium equation, a necessary subset of investment related equations is represented here too.

¹⁵⁹ A rather useful extension for modelling the increasing number of households involved in a small real-estate rental business, either domestic or business.

¹⁶⁰ BW02 introduces another factor which is not being considered for this study.

$$Q = E\left[\beta \frac{1 + \lambda_{t+1}}{\lambda_t} (Q_{t+1}(1-\tau) + r_{k,t+1}z_{t+1} - \Psi(z_{t+1}))\right] \quad (\text{A2b.5.2})$$

where $r_{k,t} = \Psi'(z_t)$

A2b.6 Equilibrium

In a closed economy defined by SW02, the goods market (steady state) equilibrium is defined by an equation stating that output is equal to the sum of consumption, government spending, investment and unlike most other equilibrium models, the capital utilisation costs $\Psi(z_t)K_{t-1}$, has a complementary par to investment demand:

$$Y_t = C_t + G_t + I_t + \Psi(z_t)K_{t-1} \quad (\text{A2b.6.1})$$

The capital rental market equilibrium is an equilibrium where demand for capital by the intermediate goods producers is equal to the supply by households and the labour when offered matches demand, for given wage level.

Appendix A2c: Initial Model Linearisation

In its structural, log-linearised form, the full model consists of twelve equations in total. It has five equations for some of the main economic, potentially measurable variables: inflation, consumption, wage, output and the interest rate. It also has three equations for non-observable variables, namely, marginal cost, natural (i.e. steady state) production and, similarly, natural consumption. The, additional four auxiliary equations are for the shocks: monetary, preference, technology and government expenditure, the latter three being AR1 random walk processes. .

The model is log-linearised around its steady state. The core part of its log-linearised form (based on the model used in Batini et al. 2005 b), has eleven equations:

$$\pi_t = \frac{\beta}{1+\beta\gamma} \varepsilon_t \pi_{t+1} + \frac{\gamma}{1+\beta\gamma} \pi_{t-1} + \frac{(1-\beta\xi)(1-\xi)}{(1+\beta\gamma)\xi} mc_t \quad (1)$$

$$mc_t = wr_t - a_t \quad (2)$$

$$c_t = \frac{h}{1+h} c_{t-1} + \frac{1}{1+h} \varepsilon_t c_{t+1} - \frac{1-h}{(1+h)\sigma} (i_t - \varepsilon_t \pi_{t+1} + (\rho_{presf} - 1) pref_t) \quad (3)$$

$$wr_t = \frac{\beta}{1+\beta} E_t wr_{t+1} + \frac{1}{1+\beta} wr_{t-1} + \frac{\beta}{1+\beta} E_t \pi_{t+1} + \frac{1+\beta\gamma W}{1+\beta} \pi_t + \frac{\gamma W}{1+\beta} \pi_{t-1} \\ + \frac{(1-\beta\xi W)(1-\xi W)}{(1+\beta)\xi W(1+\eta\Phi)} \left(\frac{\sigma}{1-h} (c_t - hc_{t-1}) + \Phi(y_t - a_t) - wr_t \right) \quad (4)$$

$$y_t = \frac{C}{Y} c_t + \frac{G}{Y} g_t \quad (5)$$

$$i_t = \rho i_{t-1} + (1-\rho) [\theta_\pi \pi_t + \theta_y (y_t - y_t^{nat})] + mp_t \quad (6)$$

$$g_t = \rho_g g_{t-1} + \epsilon_{gt} \quad (7)$$

$$a_t = \rho_{tsch} a_{t-1} + \epsilon_{at} \quad (8)$$

$$pref_t = \rho_{presf} pref_t + \epsilon_{presf,t} \quad (9)$$

$$\Phi y_t^{nat} + \frac{\sigma}{1-h} c_t^{nat} = \frac{\sigma h}{1-h} c_{t-1}^{nat} + (1+\Phi) a_t \quad (10)$$

$$y_t^{nat} = \frac{C}{Y} c_t^{nat} + \frac{G}{Y} g_t \quad (11)$$

(A2c.1)

Where:

C, G and Y represent steady state values for consumption, government spending and the total (GDP) output respectively.

Equation 1 is a RE forward-looking Philips curve relation for inflation π_t . It is defined as a function of past and future expectations of inflation, price indexation to past inflation γ , a future discount coefficient β ¹⁶¹, a Calvo price stickiness (price rigidity) factor ξ and the marginal cost itself defined in Eq 2. With $\gamma=0$, this becomes simple forward-looking inflation equation. With $\xi=0$, the prices in the system become fully flexible and the system fully reacts to any marginal cost change. The inflation π_t in this equation and the authors' estimation model, is a deviation from the steady state target inflation which is, in turn, estimated in the model as a parameter π_t^* , hence the difference between this and the equivalent equation in SW03.

Eq.2 defines marginal cost as a difference of wage w_t (defined in 4) and technological shock a_t . Another inter-temporal, both backward and forward looking RE determined variable is aggregate consumption c_t in Eq. 3 expressed as a function of its future expectation and past values, a habit (or lifestyle rigidity) factor h , preference shock $pref_t$, expected inflation deviation π_t and the consumption risk factor σ (i.e. inverse of inter-temporal elasticity of consumption).

Inter-temporally optimised RE also determine the combined, forward- and backward- looking real wage equation (4) where η is the demand elasticity for specialised labour as in Batini et al. (2005b) (expressed in Boivin and Giannoni (2005) and Smets and Wouters (2002) and (2003) as $(1 + \lambda_w)/\lambda_w$ where λ_w is the mean from the IID wage mark-up shock $\lambda_{w,t} = \lambda_w + \eta w_t$ in Smets and Wouters (2002) and (2003)).

¹⁶¹ Smets & Wouters (2003) and Boivin & Giannoni (2005) estimate (annual) $\beta = 1/(1 - \tau + r^k)$ where τ is depreciation, r^k – capital cost, whilst Batini et al. (2005b) use $\beta = 1/(1 + rr^*)$ where rr^* – real interest rate. This formula is closely related to ρ used as a subjective future discount (i.e. the “current time preference”) rate appearing in the literature so that the above β is an order of magnitude of $1/(1 + \rho)$. There is however another, closely related factor βt used in literature as a future discount, this arising from the risk (or, subjective estimate of the risk, i.e. the fear) of death at time t (or in its very near future) leading to lifetime uncertainty so that the future discount becomes $\beta t + \rho$ rather than just ρ (both factors order of 0.01) as in the Blanchard-Yaari model (Heijdra & Van Der Plong 2002).

Eq. 5 is a simplified aggregate demand IS curve which drives production y_t as a function of private and government consumption (shocks). It also represents the goods equilibrium equation.

Eq. 6 is a Taylor rule for the optimisation of the interest rate i_t as a function of past interest and current inflation rates, the production gap and monetary policy shocks.

The three AR1 shock processes: Government, technology and preference shocks are AR1 random walk processes driven by their ρ ($0 < \rho < 1$) and IID disturbances ε_t and defined in Eq.7, 8 and 9 respectively.

Eq. 10 and 11 define natural rates of consumption and output respectively and define the natural equilibrium as a reference for estimating consumption and output gaps respectively. In the initial test the researchers assume that there is no government spending and, $C/Y=1$ and $G/Y=0$ (i.e. $y=c$ and $y_{nat}=c_{nat}$) Later the researchers assume 22% of consumption and spending is from government budget, so $C/Y=0.78$ and $G/Y=0.22$.

Eq. 12 missing above is a simplified monetary policy shock equation:

$$mp_t = \varepsilon_{mpt} \quad (A2c.2)$$

where all ε_{xx} are IID with a zero mean (e.g. $\varepsilon_{mpt} \sim N(0, \sigma_{mpt})$):

Appendix 3: Data and Priors for the Initial PCL Estimation

Note: This section replicates model as described in detail in Perendia (2006) and also used in Pearlman and Perendia (2006) and Perendia (2008).

A 3.1 Priors

Estimated Parameter	Description	Density Distrib.	Prior Mean	Prior SD
ρ	Taylor rule inflation smoothing parameter.	B **)	0.85	0.15
$\Theta\pi^{*})$	IFB Taylor Rule Inflation Feed-Back weight	G	2	0.5
$\Theta_Y^{*})$	IFB Taylor Rule Production Output Feed-Back weight	N	0.5	0.25
γ_c	Price indexation to lagged inflation and target π^*	B	0.5	0.15
γ_w	Wage indexation to lagged inflation and target π^*	B	0.5	0.15
ξ_c	Calvo price stickiness - a proportion of firms that do not re-optimize prices every interval (a form of price rigidity)	B	0.75	0.15
ξ_w	Calvo wage stickiness - a proportion of firms that do not re-optimize wages every interval (a form of wage rigidity)	B	0.75	0.15
4. (or σ_L)	Inverse Frisch (disutility) of labor supply: In B&G and S&W also appearing as σ_L - coef. of relative intertemporal Labour supply substitution "risk aversion" - i.e. inv. of labour supply substitution elasticity θ_L	N	2	1.5
σ_c	Coef. Of relative intertemporal consumption substitution "risk aversion" (or curvature of consumption utility function) - inverse of consumption substitution elasticity θ_c	N	1	0.375
Habit	Habit formation (lifestyle rigidity) weight	B	0.7	0.15
ρ_{tech}	AR1 coefficient for technology shock	B	0.85	0.15
ρ_{pref}	AR1 coefficient for consumer preference shock	B	0.85	0.15

π^* (%)	π^* - Mean Inflation (Inflation Target) in (%)	N	2.5	0.7
Rr^* (%)	Real interest Rate in (%)	N	2.5	0.7
λ_w	$\eta=(1+\lambda_w)/\lambda_w$ is demand elasticity for specialized (i.e. differentiated) labour supply where $(1+\lambda_w)$ is the mean (steady state) part of IID wage mark-up shock.	N	0.2	0.15
ρ_g	AR1 coefficient for Government spending	B	0.85	0.15
σ_{pref}	SD of preference shock	I	0.25	1.5
σ_{tech}	SD of technology shock	I	0.25	1.5
σ_{gg}	SD of monetary shock	I	0.25	1.5
σ_{mp}	SD of government spending shock	I	0.25	1.5
Derived Parameters:				
β	Future discount factor derived as $\beta=1/(1+rr^*)$, or, for quarterly data in (%) as: $\beta=1/(1+rr^*(\%)/100)^{0.25}$			
η	demand elasticity for specialized (differentiated) labour supply: $\eta=(1+\lambda_w)/\lambda_w$			

*¹) Taken from Batini et al. 05b.

**¹) B= Beta; G=Gamma; I=Inv. Gamma; N=Normal

A 3.2 Data

Although Boivin and Giannoni (2005) are covering the period 1965-2002 and Smets and Wouters (2003) are starting back in 1957, all tests in this research were done on quarterly US data covering period 1981Q1 – 2004Q4 to analyse the later period in US economy during which the stricter interest rate controls were introduced by the US Fed.

The initial tests were performed primarily to establish the existence of and identify the differences between estimations with asymmetric (but full information for the agents) and the symmetric but all partial information assumptions. The initial estimation on the three series: y_t , i_t and π_t , was done with data from Datastream. The interest rate was based on the Treasury Bill interest rate, and inflation rates calculated as the first difference of the logs of the GDP deflator.

Initially, the logarithm of GDP had a Hodrick-Prescott filter in Eviews is applied to smooth this data. The smoothed $\ln(\text{GDP})$ is then subtracted from the original $\ln(\text{GDP})$.¹⁶² Instead of demeaning inflation and interest rate data, following Batini et al. (2005b) the early research used un-transformed inflation and interest rate data expressed in percentages to estimate the mean, real inflation and unobserved real interest rates. These are used later in the calculation of the quarterly, future discount coefficient β as $\beta = 1/(1+r^*/100)^{1/4}$ where r^* is the unobserved, estimated real rate of interest expressed as a percentage giving β a figure roughly around 0.995 (See note ¹⁶³).

In the second group of estimates, the researchers adopt the approach of Boivin and Giannoni (2005). They de-trend all the series and express them as (%) deviation from

¹⁶² Though there are some considerations whether an HP filter is well suited as it may lead to spurious cross-correlations between de-trended series (see Harvey & Jaeger 1993) and Smets & Wouters (2003) use an alternative solution, HP filter is being widely used for RBC analysis and data smoothing, e.g. in Juillard et al. (2004) and Batini et al. (2005b).

¹⁶³ Smets & Wouters (2003) and Boivin & Giannoni (2005) imply that the (annual) $\beta = 1/(1-\tau + r^k)$ where τ is depreciation, r^k – capital cost and impose its value in the estimation process rather than estimate it.

the trend. Again, the first estimates are on the three series: $\log(y_t)$, i_t and π_t based on, or derived from GDP, the Treasury Bill rate and the first difference of the GDP deflator data taken from Datastream as earlier. The researchers used a Hodrick-Prescott filter in Eviews (with $\lambda=1600$) to de-trend all the series as a difference between the non-smoothed and the HP filter smoothed data series (i.e. the cycle series output from Eviews HP Filter function).

Additional data series for data-rich estimation on the lines of Boivin and Giannoni (2005) were found in Datastream and IFS databases (see Appendix 3). For most of the series, where appropriate, the logs, logs of the deflated - or of the 1st differences of the series were used instead of their level data before de-trending them using an HP filter. Unlike BG05, the series were not expressed in % of their deviation from their trends.

Data series are quarterly covering 96 quarters: Q1 1982 – Q4 2004

Data Series:	Source	Detrended	Log	Deflated	1st Diff.	Extra-/intra-polated
Initial Case A:						
r = TREASURY BILL RATE	TDS					
π =Dlog(GDP Deflator)	TDS		yes	Deflator series	yes	
y = GDP in volume	TDS	HP	yes			
Additional Five Series For Cases C And D			yes			
CPI Based Inflation	TDS	HP	yes		yes	
Private Domestic Fixed Investment	TDS	HP	yes	Yes		
Unemployment Rate	IFS	HP				
Wages: Hourly Earnings in Manufacturing	TDS	HP	yes	Yes		
Personal Consumption Expenditures (Quarterly Series)	TDS	HP	yes	Yes		
Additional Twelve Series For case E			yes			
Sales Of New One family Houses vol.	TDS	HP	yes			

New Passenger Cars - Total Registrations Vol.	TDS	HP	yes			
Us Personal Saving As % Of Disposable Personal Income S.Adj	TDS	HP	yes			
Consumer Confidence Index S.Adj	TDS	HP	yes			
Gov Consumption and Investment	TDS	HP	yes	Yes		
Industrial Production Manufacturing	TDS	HP	yes		Yes	
Gold Price	TDS	HP	yes	Yes		
Crude Brent Oil Price	BP+ TDS	HP	yes	See note ¹⁶⁴		partial ¹⁶⁵
Crude Petroleum Production (vol)	IFS	HP	yes			
Goldman Sachs Commodity Index – Price Index	TDS	HP	yes			
Consumption Of Fixed Capital, Lag 1	IFS	HP	yes	Yes		
The Conference Board Leading Economic Indicators Index	TDS	HP	yes		Yes	

¹⁶⁴ It was deemed unnecessary since HP filter performs well the deflation using GDP deflator and the two outputs were identical.

¹⁶⁵ For period 1981Q1- 1982Q2 not covered by TDS data are converted annual price sourced from BP

Appendix 4: Results of initial PCL estimation: Additional Relations

Estimated Parameters:	Asym. Info 15KMCMC draws	Asym. info Max. Likelihood hoodest.	Prior density	Prior Mean	Prior SD
rhoPiCG	0.756	0.760	I	0.850	0.150
rhoCcp	0.331	0.333	I	0.650	0.150
rhoWwh	0.023	0.020	I	0.050	0.150
rhoUy	0.827	0.744	I	0.800	0.150
rhoInvi	0.006	0.006	I	0.050	0.150
rhoCpiC	0.875	0.583	I	0.650	0.150
rhoWcp	0.328	0.308	I	0.650	0.150
rhoYwh	0.284	0.279	I	0.650	0.150
rhoWuu	0.616	0.580	I	0.650	0.150
rhoPiuu	0.381	0.361	I	0.650	0.150
rhoIuu	0.283	0.272	I	0.650	0.150
rhoYInv	3.374	3.362	I	0.650	0.150
rhoSAVEy	0.705	0.581	I	0.650	0.150
rhoSAVEii	0.196	0.208	I	0.650	0.150
rhoCHOUSEy	0.616	0.540	I	0.650	0.150
rhoCHOUSEcc	69.133	66.288	I	0.650	0.150
rhoCHOUSEii	0.404	0.446	I	0.650	0.150
rhoCHOUSEipi	0.268	0.251	I	0.650	0.150
rhoCCARy	0.626	0.670	I	0.650	0.150
rhoCCARcc	0.594	0.592	I	0.650	0.150
rhoCGOVgg	0.581	0.582	I	0.650	0.150
rhoCCONFXy	0.746	0.656	I	0.650	0.150
rhoCCONFXcc	90.221	83.701	I	0.650	0.150
rhoCCONFXii	0.564	0.597	I	0.650	0.150
rhoCCONFXipi	0.316	0.288	I	0.650	0.150
rhoKPTLy	0.570	0.518	I	0.650	0.150
rhoKPTLcc	25.760	23.139	I	0.650	0.150
rhoKPTLii	0.202	0.193	I	0.650	0.150
rhoYECOXy	0.395	0.339	I	0.650	0.150
rhoYMNFTy	0.434	0.406	I	0.650	0.150
rhoYOILy	0.529	0.430	I	0.650	0.150
rhoPOILcc	0.520	0.556	I	0.650	0.150
rhoPCMDTXy	0.587	0.583	I	0.650	0.150
rhoPCMDTXcc	0.603	0.531	I	0.650	0.150
rhoPGOLDcc	0.913	0.608	I	0.650	0.150

Appendix 5: Comparing Full and Partial Information Impulse response functions (IRF): Effect of incomplete (partial) information assumptions

Table A5. 1: shocks present in the model used in the tests and number of observed variables assumed in simulation and relevant graph(s):

Shock	Description	Full	3 ob.	2 ob.	1 ob.
eps_g	Gov. spending	5.4	5.5	5.6	
eps_a	Technology	5.1	5.2	5.3	
eps_ms	Price Markup Shock	5.13	5.14	5.15	
eps_r	Interest rate	5.7	5.8	5.9	
eps_c	Consumption	5.10	5.11	5.12	

Figure A5.1: : Dynare and full information PCL IRFs for eps_a technology shock

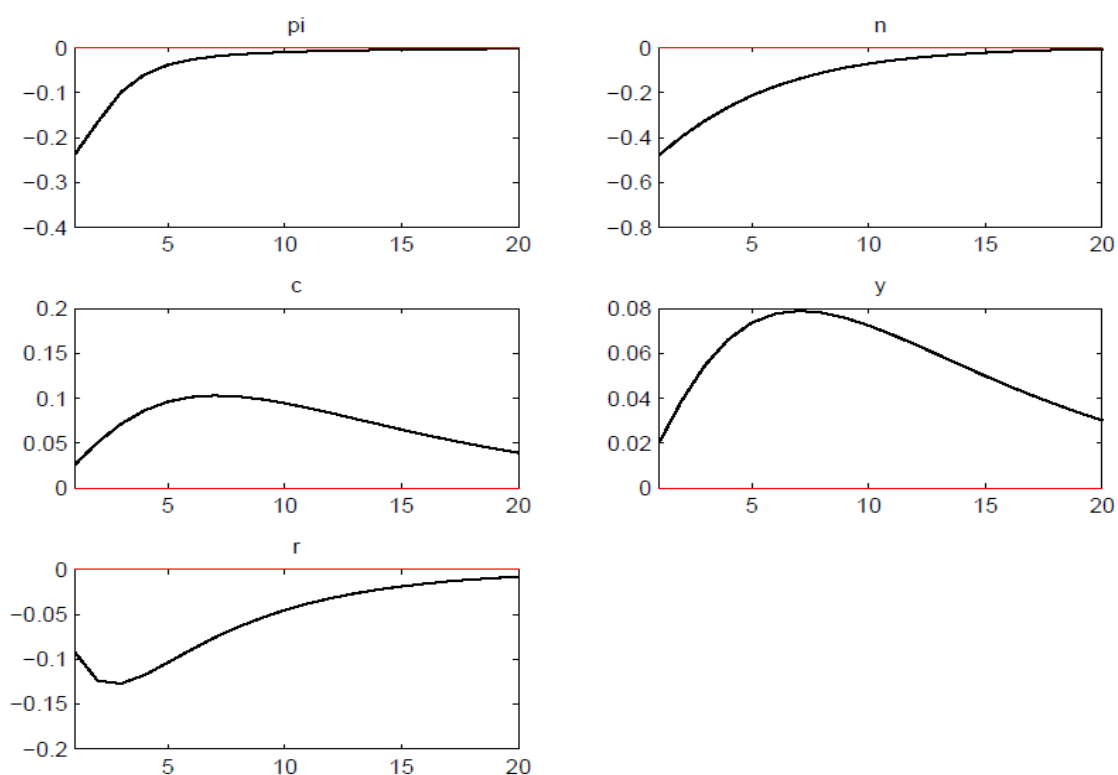


Figure A5.2: Part information PCL IRFs for eps_a technology shock and only pi, y and
r observed

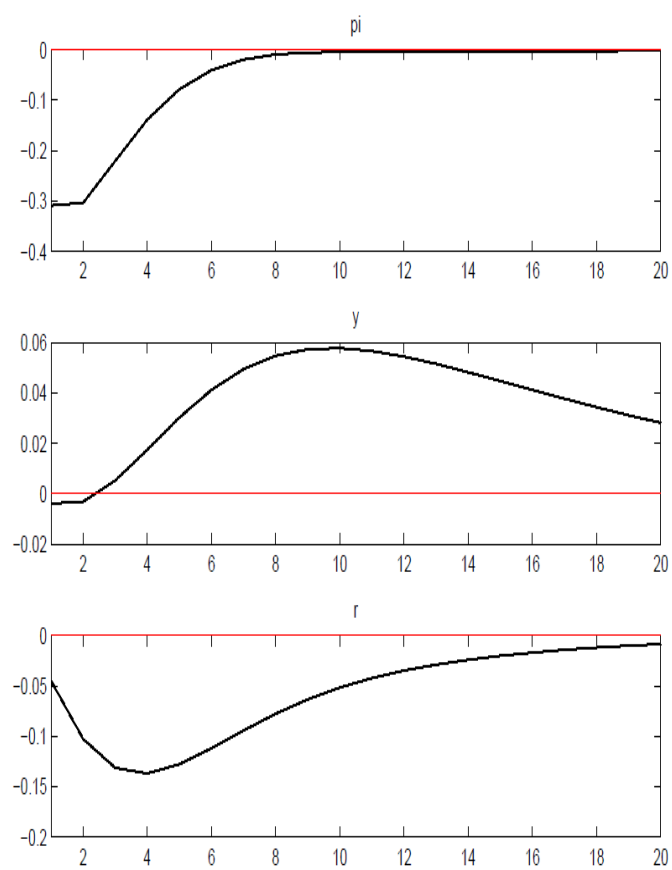


Figure A5.3: Part information PCL IRFs for eps_a technology shock and only pi and y (left) and pi and r (right) are observed

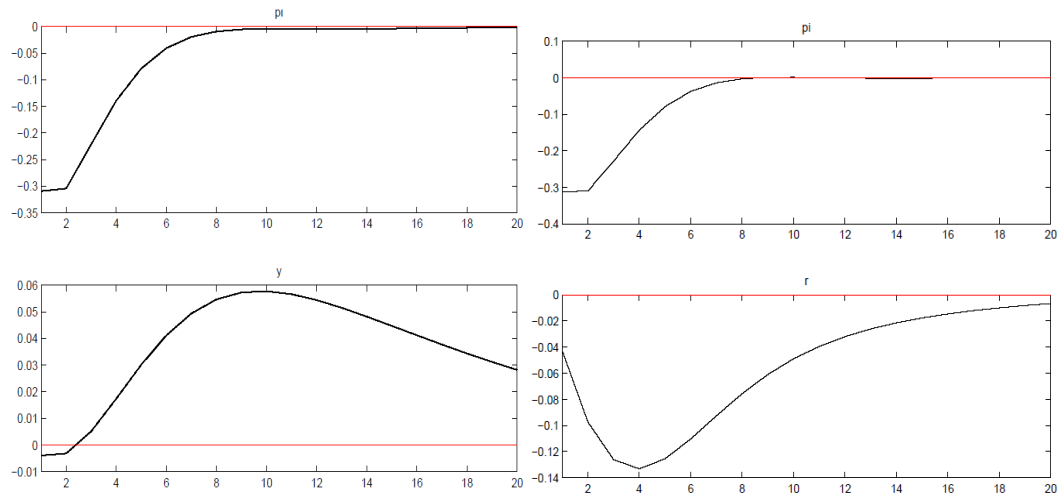


Figure A5.4: Dynare and full information PCL IRFs for eps_g shock

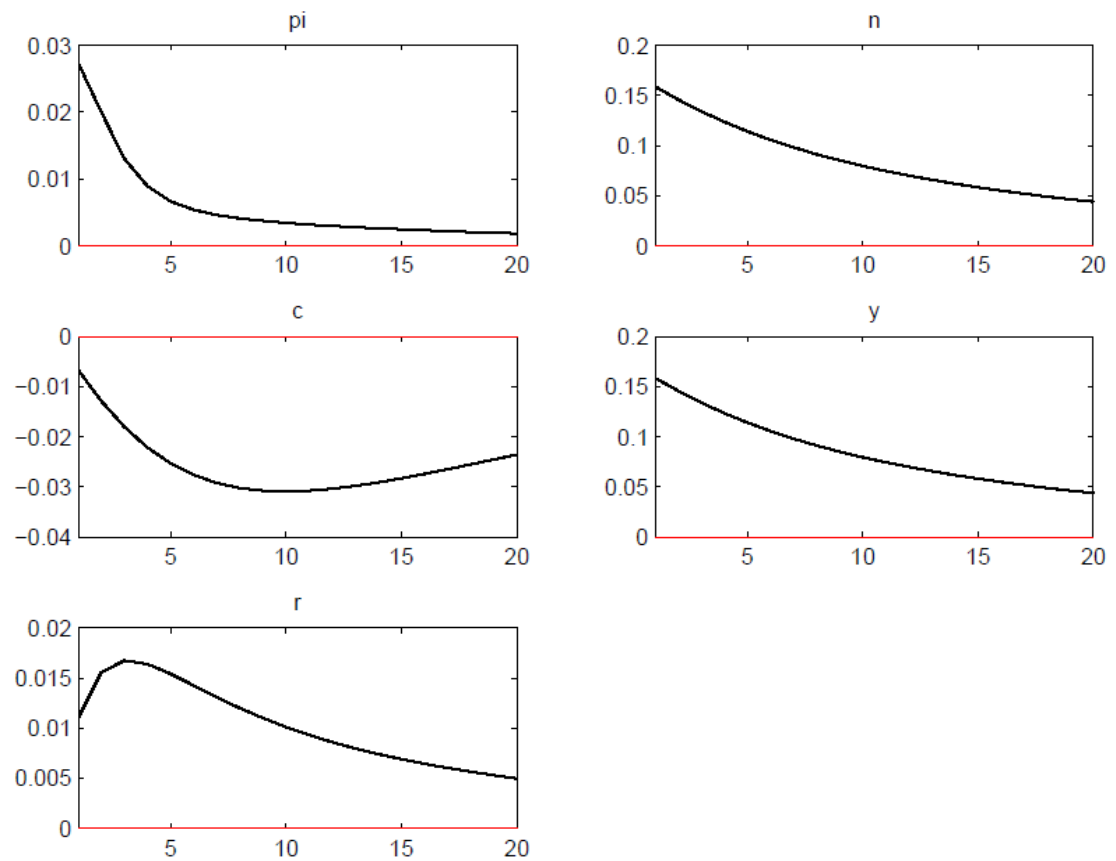


Figure A5.5: Part information PCL IRFs for eps_g gov. spending shock and only pi, y and r observed:

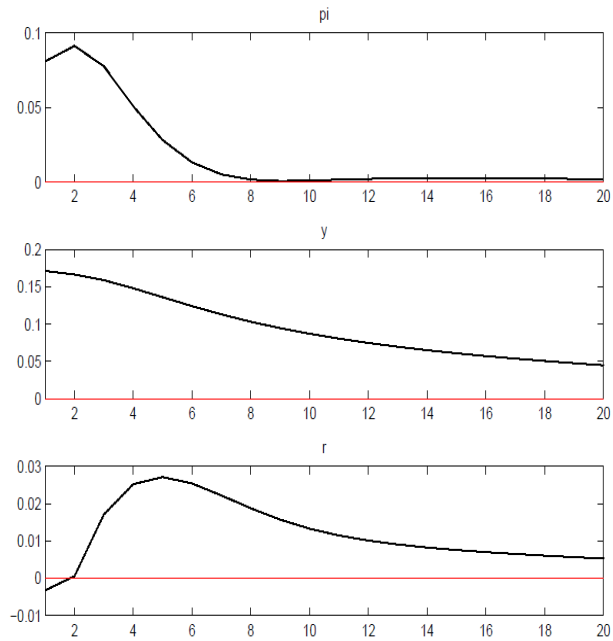


Figure A5.6: Part information PCL IRFs for eps_g shock and only pi and y (left) and pi and r (right) are observed

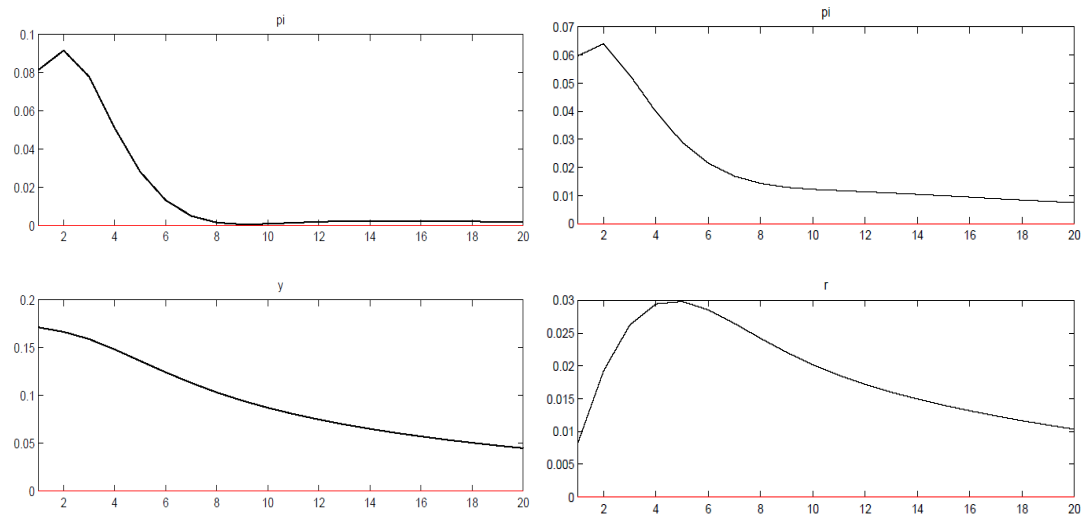


Figure A5.7: Dynare and full information PCL IRFs for eps_r interest rate shock.

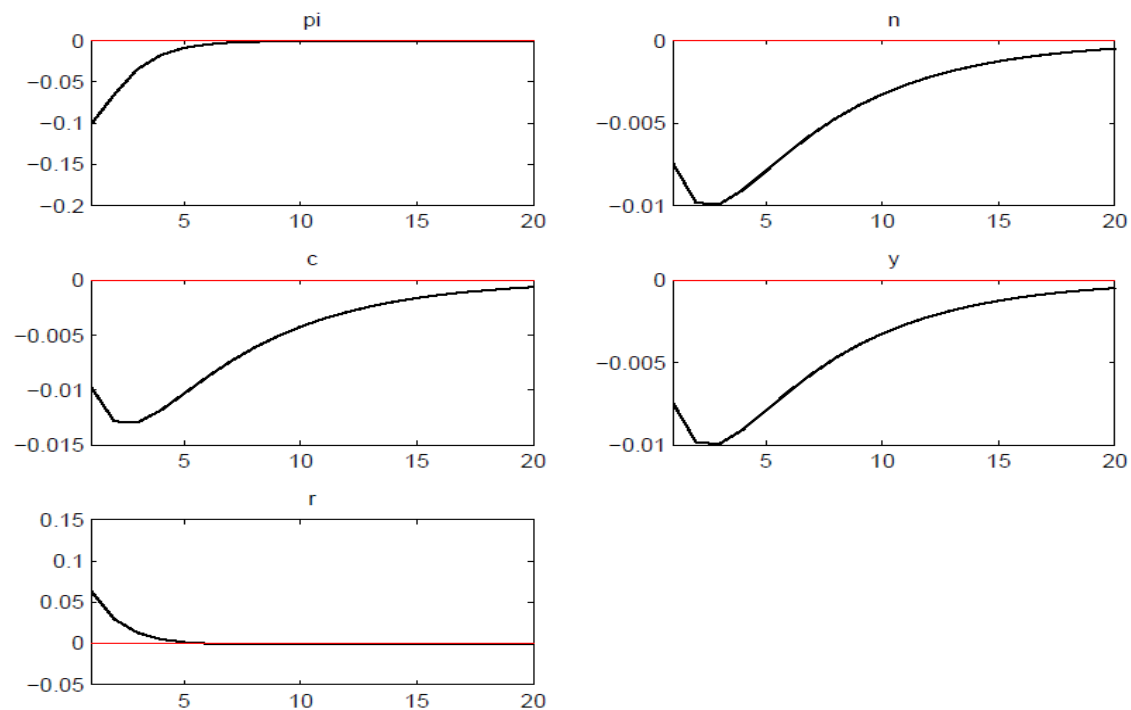


Figure A5.8: Part information PCL IRFs for eps_r interest rate shock and π , y and r observed:

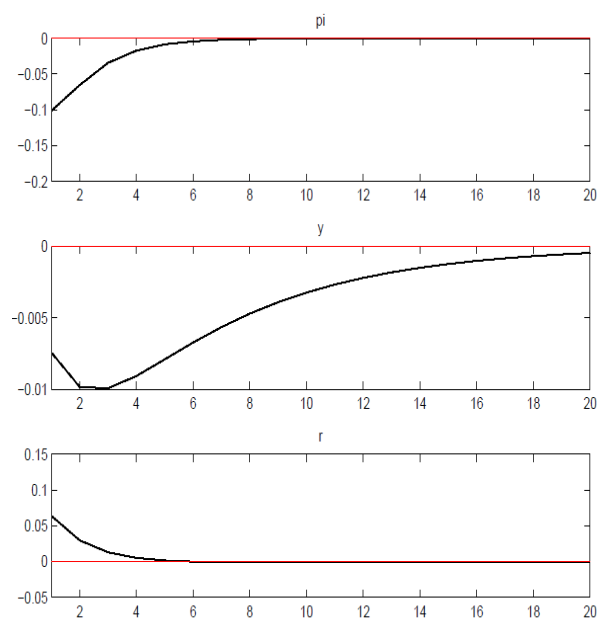


Figure A5.9: Part information PCL IRFs for eps_r shock and only pi and y (left) and pi and r (right) are observed

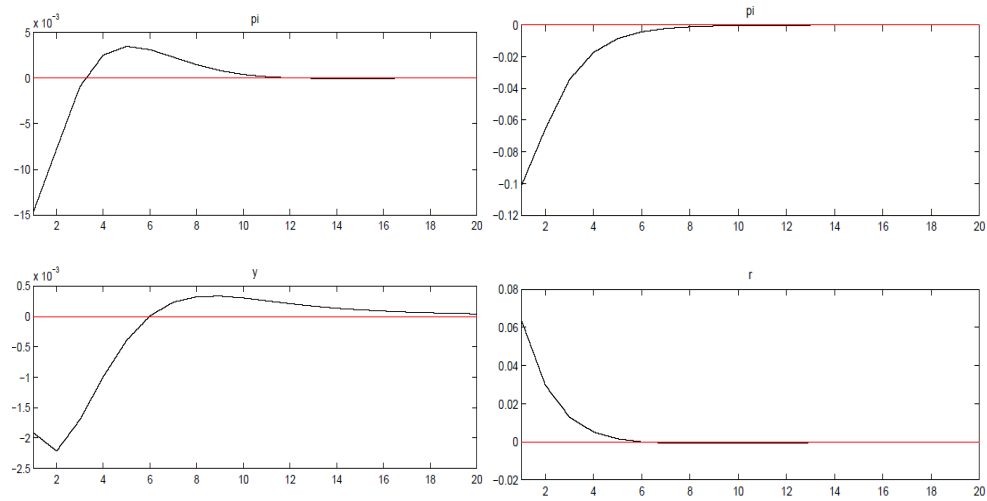


Fig A5.10: Dynare and full information PCL IRFs for eps_c consumption rate shock.

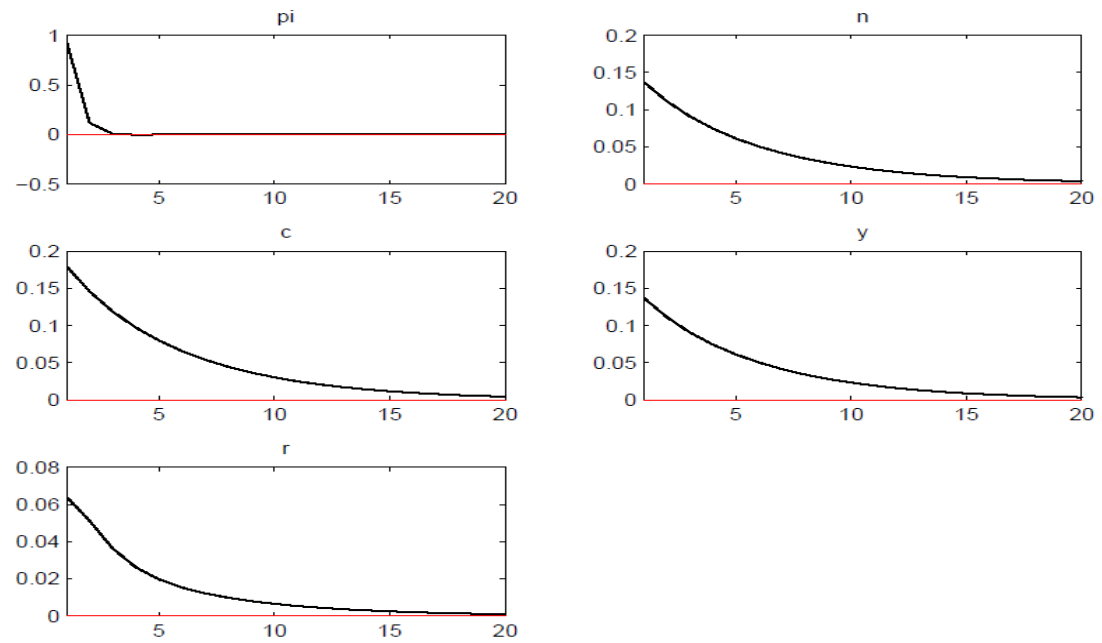


Fig. A5.11: Part information PCL IRFs for eps_c consumption shock and pi, y and r
observed:

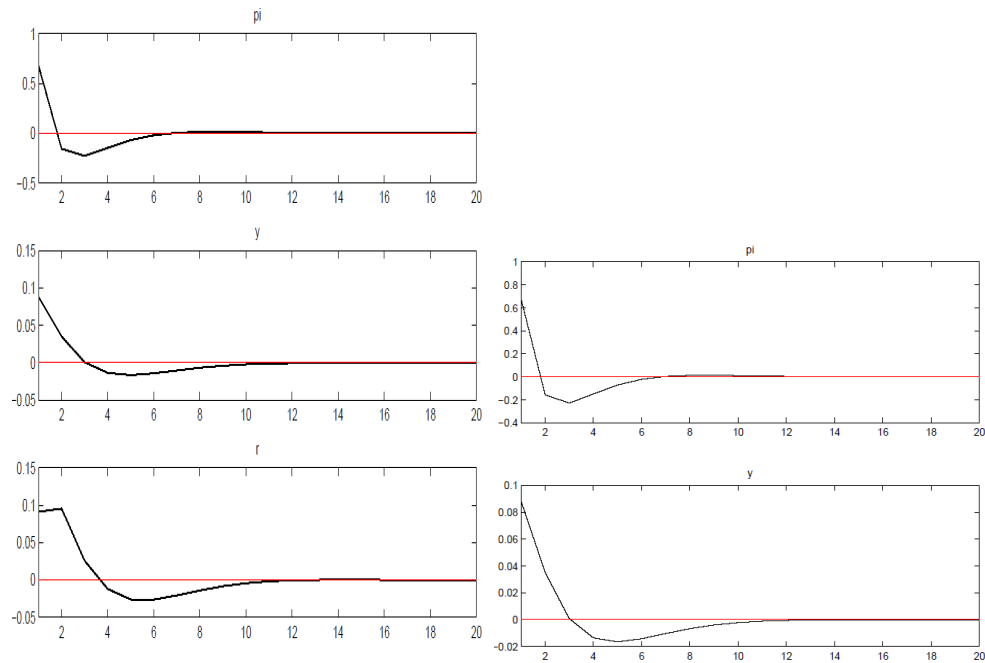


Fig A5.12: Part information PCL IRFs for eps_c shock and only pi and y (left) and pi
and r (right) are observed:

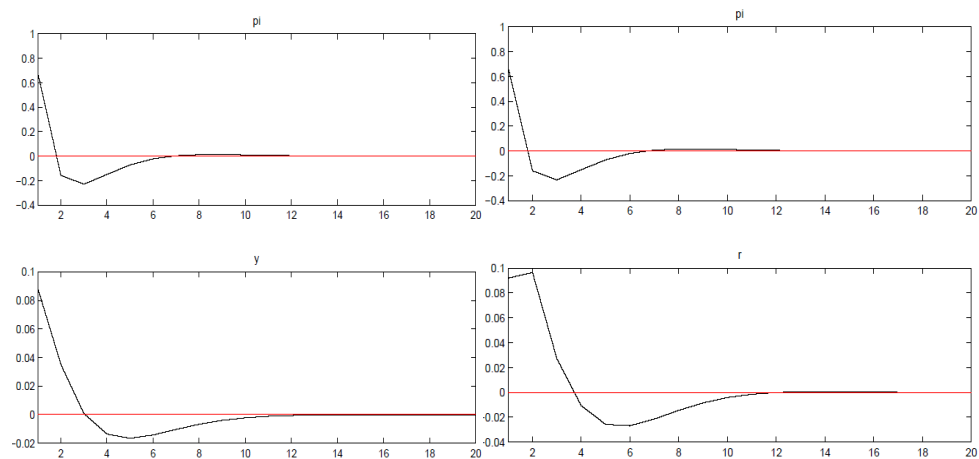


Fig A5.13: Dynare and full information PCL IRFs for eps_ms shock:

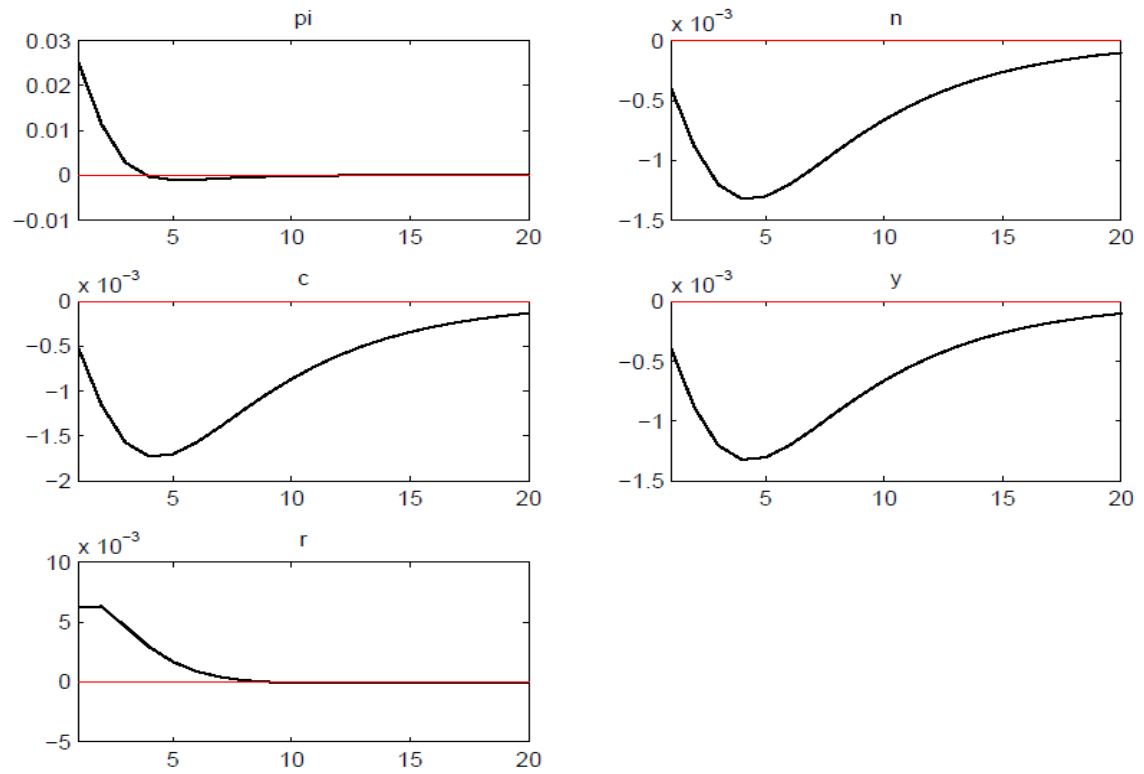


Fig. A5.14: Part information PCL IRFs for eps_ms shock and only π , y and r observed:

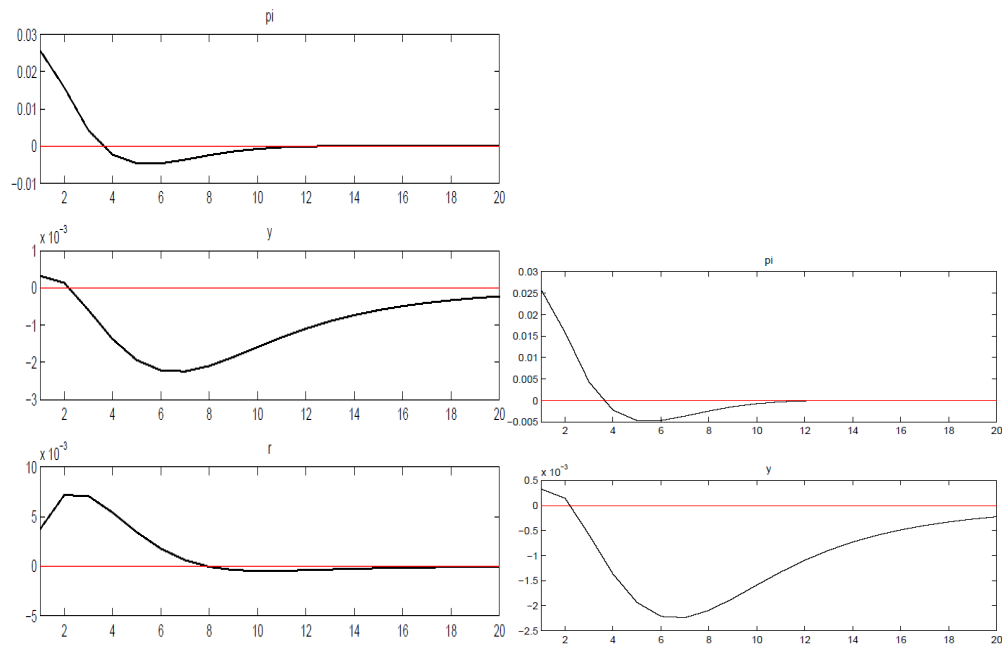
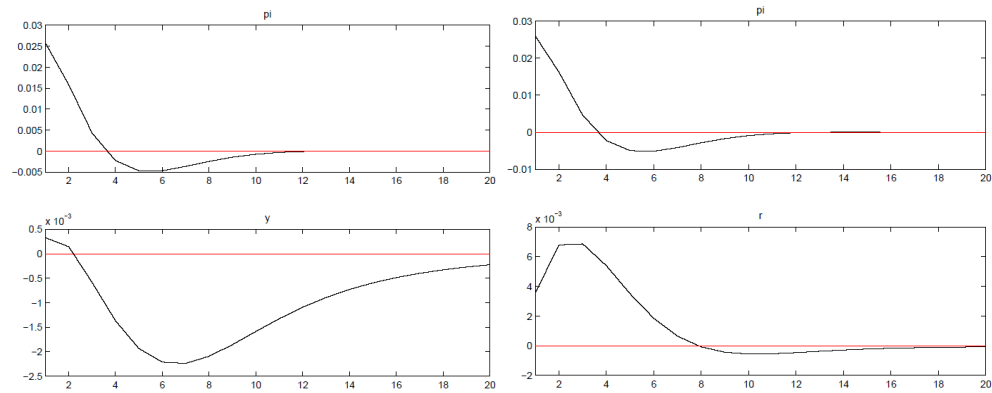


Fig A5.15: Part information PCL IRFs for eps_ms shock and only pi and y (left) and pi and r (right) are observed:



Appendix 6: Results for Fiscal Policy Rules

Table A6.1 Summary estimates of the parameters for model M12

Parameter		Point estimates		M12 estimates		
SW07 Label	Description	M0/ SW07	M12	Distribution	Mean	Std. error
ρ_a	Technology shock AR1 coefficient	0.9585	0.9426	BETA	0.5	0.20;
ρ_b	Consumption preference shock AR1 coefficient	0.1623	0.476	BETA	0.5	0.20;
ρ_g	Government spending shock AR1 coefficient	0.9688	0.9741	BETA	0.5	0.20;
ρ_i	Investment cost shock AR1 coefficient	0.7038	0.7122	BETA	0.5	0.20;
ρ_r	Interest rate shock AR1 coefficient	0.1311	0.1285	BETA	0.5	0.20;
ρ_p	Mark-up disturbance AR1 coefficient	0.9405	0.9351	BETA	0.5	0.20;
ρ_w	Wage shock AR1 coefficient	0.9771	0.9785	BETA	0.5	0.20;
μ_p	Price markup	0.7861	0.798	BETA	0.5	0.2;
μ_w	Wage markup	0.8683	0.878	BETA	0.5	0.2;
ϕ	Steady-state elasticity of the capital adjustment cost	5.3508	5.4984	NORMAL	4	1.5;
σ_c	Consumption risk aversion	1.3027	1.333	NORMAL	1.50	0.375;
H	Habit	0.739	0.7889	BETA	0.7	0.1;
ζ_w	Probability of wage adjustment in period	0.7002	0.7056	BETA	0.5	0.1;
σ_l	Labour risk aversion	1.6706	1.1582	NORMAL	2	0.75;
ζ_p	Probability of price adjustment in period	0.6225	0.6782	BETA	0.5	0.10;
i_w	Wage indexation	0.5894	0.5661	BETA	0.5	0.15;
i_p	Price indexation	0.2447	0.2497	BETA	0.5	0.15;
Z	Elasticity of the capital utilisation	0.4687	0.3994	BETA	0.5	0.15;
Φ/Y_0	Fixed cost in production relative to output	0.7054	1.5279	NORMAL	0.25	0.125;
r_π	Inflation coefficient in Taylor rule	2.0619	2.0298	NORMAL	1.5	0.25;
r_r	Interest rate coefficient in Taylor rule	0.8148	0.806	BETA	0.75	0.10;
r_y	Output coefficient in Taylor rule	0.0846	0.0842	NORMAL	0.125	0.05;
$r_{\Delta y}$	Lagged output difference coefficient in Taylor rule	0.2125	0.219	NORMAL	0.125	0.05;
	Long term inflation (constant)	0.6107	0.6155	GAMMA	0.625	0.1;
β	Discount factor	0.21	0.21	GAMMA	0.25	0.1;
	Long term labour	0.2284	0.3773	NORMAL	0.0	2.0;
γ	Growth Trend	0.4258	0.4217	NORMAL	0.4	0.10;
g_v	Technology shock effect on	0.6045	0.7363	NORMAL	0.5	0.25;

	government spending					
α	Capital weight production function	0.2957	0.3202	NORMAL	0.3	0.05;
g_u	Employment difference (11e) in the government spending rule	N/A	-0.1732	NORMAL	0.01	0.2;
β	News in consumption	N/A	0.1463	NORMAL	0.1	2.0;
g_w	News in the government spending rule	N/A	-0.26	NORMAL	0.01	0.2;
	Std. error of AR1 shocks:					
η_a	Technology shock	0.4239	0.4433	INV_GAMMA	0.1	2;
η_b	Consumption shock	0.2469	0.0833	INV_GAMMA	0.1	2;
η_g	Government spending shock	0.5349	0.5566	INV_GAMMA	0.1	2;
η_q	Investment shock	0.4597	0.4575	INV_GAMMA	0.1	2;
η_r	Monetary (interest rate) shock	0.2410	0.2442	INV_GAMMA	0.1	2;
η_π	Inflation shock	0.1372	0.1376	INV_GAMMA	0.1	2;
η_w	Wage shock	0.2469	0.24	INV_GAMMA	0.1	2;
	AR1 shock to consumption propensity - normal economy	N/A	1.463	INV_GAMMA	0.1	2;
	AR1 shock to consumption propensity - frictionless economy	N/A	0.046	INV_GAMMA	0.1	2;

Notes: The results are based on using Sims (2002a) ‘sclminwel’ algorithm; see the Table in the following section for more details.

Table A6.2: Posterior Maximization of the Original SW07 Model

<u>Parameter</u>	<u>prior mean</u>	<u>mode</u>	<u>s.d.</u>	<u>t-stat</u>	<u>prior</u>	<u>pstdev</u>
crhoa	0.500	0.9585	0.0106	90.2220	beta	0.2000
crhob	0.500	0.1623	0.0779	2.0839	beta	0.2000
crhog	0.500	0.9688	0.0092	105.6310	beta	0.2000
crhoqs	0.500	0.7038	0.0603	11.6642	beta	0.2000
crhoms	0.500	0.1311	0.0665	1.9737	beta	0.2000
crhopinf	0.500	0.9405	0.0380	24.7624	beta	0.2000
crhow	0.500	0.9771	0.0098	100.1353	beta	0.2000
cmap	0.500	0.7861	0.0869	9.0460	beta	0.2000
cmaw	0.500	0.8683	0.0674	12.8896	beta	0.2000
csadjcost	4.000	5.3508	1.0149	5.2724	norm	1.5000
csigma	1.500	1.3027	0.1331	9.7838	norm	0.3750
chabb	0.700	0.7390	0.0442	16.7268	beta	0.1000
cprobw	0.500	0.7002	0.0795	8.8038	beta	0.1000
csigl	2.000	1.6706	0.6229	2.6819	norm	0.7500
cprobp	0.500	0.6225	0.0576	10.8135	beta	0.1000
cindw	0.500	0.5894	0.1359	4.3373	beta	0.1500
cindp	0.500	0.2447	0.0959	2.5521	beta	0.1500
czcap	0.500	0.4687	0.1049	4.4676	beta	0.1500
cfc	1.250	1.7054	0.0762	22.3797	norm	0.1250
crpi	1.500	2.0619	0.1755	11.7454	norm	0.2500
crr	0.750	0.8148	0.0245	33.2613	beta	0.1000
cry	0.125	0.0846	0.0225	3.7636	norm	0.0500
crdy	0.125	0.2125	0.0270	7.8551	norm	0.0500
constepinf	0.625	0.6107	0.0667	9.1598	gamm	0.1000
constebeta	0.250	0.2100	0.0917	2.2913	gamm	0.1000
constelab	0.000	0.2284	1.0173	0.2245	norm	2.0000
ctrend	0.400	0.4258	0.0214	19.9343	norm	0.1000
cgy	0.500	0.6045	0.0970	6.2298	norm	0.2500
calfa	0.300	0.2957	0.0442	6.6882	norm	0.0500

Log data density [Laplace approximation] is -924.955511.

(for comparison, see table 1A in SW07)

Table A6.3: MCMC Estimation Results For The Original SW07

Parameter	prior mean	post. mean	conf. interval		prior	pstdev
crhoa	0.500	0.9560	0.9411	0.9741	beta	0.2000
crhob	0.500	0.1923	0.0605	0.3196	beta	0.2000
crhog	0.500	0.9683	0.9526	0.9859	beta	0.2000
crhoqs	0.500	0.7148	0.6219	0.8144	beta	0.2000
crhoms	0.500	0.1470	0.0470	0.2428	beta	0.2000
crhopinf	0.500	0.9201	0.8514	0.9924	beta	0.2000
crhow	0.500	0.9711	0.9487	0.9910	beta	0.2000
cmap	0.500	0.6806	0.4486	0.8997	beta	0.2000
cmaw	0.500	0.8243	0.7084	0.9284	beta	0.2000
csadjcost	4.000	5.4920	3.7946	7.0321	norm	1.5000
csigma	1.500	1.3106	1.1020	1.5251	norm	0.3750
chabb	0.700	0.7328	0.6621	0.8133	beta	0.1000
cprobw	0.500	0.6842	0.5735	0.7888	beta	0.1000
csigl	2.000	1.6460	0.6705	2.4433	norm	0.7500
cprobp	0.500	0.6199	0.5318	0.7017	beta	0.1000
cindw	0.500	0.5985	0.3974	0.8031	beta	0.1500
cindp	0.500	0.2344	0.0879	0.3710	beta	0.1500
czcap	0.500	0.4950	0.3381	0.6583	beta	0.1500
cfc	1.250	1.7028	1.5673	1.8233	norm	0.1250
crpi	1.500	2.0598	1.8167	2.3084	norm	0.2500
crr	0.750	0.8116	0.7743	0.8488	beta	0.1000
cry	0.125	0.0819	0.0476	0.1148	norm	0.0500
crdy	0.125	0.2149	0.1697	0.2624	norm	0.0500
constepinf	0.625	0.6366	0.5241	0.7693	gamm	0.1000
constebeta	0.250	0.2279	0.0819	0.3668	gamm	0.1000
constelab	0.000	-0.0970	-2.0788	1.6590	norm	2.0000
ctrend	0.400	0.4223	0.3874	0.4609	norm	0.1000
cgy	0.500	0.6038	0.4493	0.7605	norm	0.2500
calfa	0.300	0.2952	0.2226	0.3609	norm	0.0500

Log data density is -929.036863.

Table A6.4: Posterior maximization: extended model with news and rules

Parameter	prior	mean	mode	s.d.	t-stat	prior	pstdev
crhoa	0.500	0.9500	0.0149	63.5825	beta	0.2000	
crhob	0.500	0.4563	0.1751	2.6053	beta	0.2000	
crhog	0.500	0.9727	0.0099	98.7354	beta	0.2000	
crhoqs	0.500	0.7436	0.0616	12.0720	beta	0.2000	
crhoms	0.500	0.1069	0.0597	1.7895	beta	0.2000	
crhopinf	0.500	0.9516	0.0590	16.1327	beta	0.2000	
crhow	0.500	0.9737	0.0129	75.7312	beta	0.2000	
cmap	0.500	0.8602	0.1062	8.1023	beta	0.2000	
cmaw	0.500	0.8974	0.0423	21.2079	beta	0.2000	
csadjcost	4.000	4.8032	1.4321	3.3540	norm	1.5000	
csigma	1.500	1.3701	0.1399	9.7913	norm	0.3750	
chabb	0.700	0.7886	0.0432	18.2604	beta	0.1000	
cprobw	0.500	0.6572	0.0719	9.1458	beta	0.1000	
csigl	2.000	1.9094	0.6817	2.8010	norm	0.7500	
cprobp	0.500	0.7156	0.0627	11.4089	beta	0.1000	
cindw	0.500	0.5369	0.1429	3.7560	beta	0.1500	
cindp	0.500	0.2340	0.0908	2.5771	beta	0.1500	
czcap	0.500	0.3955	0.0917	4.3123	beta	0.1500	
cfc	1.250	1.5541	0.0839	18.5201	norm	0.1250	
crpi	1.500	1.9839	0.1824	10.8768	norm	0.2500	
crr	0.750	0.8170	0.0251	32.5844	beta	0.1000	
cry	0.125	0.0707	0.0266	2.6553	norm	0.0500	
crdy	0.125	0.2221	0.0274	8.0962	norm	0.0500	
constepinf	0.625	0.6275	0.0693	9.0514	gamm	0.1000	
constebeta	0.250	0.2100	0.0917	2.2913	gamm	0.1000	
constelab	0.000	0.2713	1.1661	0.2326	norm	2.0000	
ctrend	0.400	0.4236	0.0239	17.7490	norm	0.1000	
cgy	0.500	0.8238	0.1213	6.7884	norm	0.2500	
calfa	0.300	0.3231	0.0404	7.9938	norm	0.0500	
cgu	0.010	0.1728	0.1366	1.2647	norm	0.2000	
wrhoul	0.100	0.0201	0.0123	1.6323	norm	0.2000	
crhowcpf	1.000	-0.1868	0.0960	1.9455	norm	2.0000	
crhowcp	1.000	0.1309	0.0274	4.7854	norm	2.0000	
cgw	0.010	-0.2337	0.0585	3.9971	norm	0.2000	

Log data density [Laplace approximation] is -916.513551.

A.6.IRF Diagrams

Figure A.6.1 IRFs to a shock to unemployment:

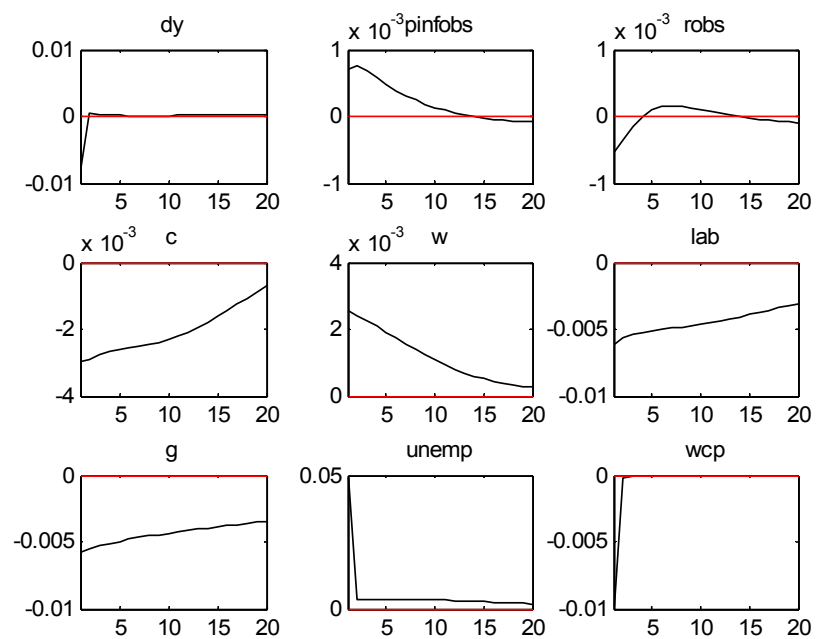


Figure A.6.2 IRFs to a shock to propensity to consume (the news)

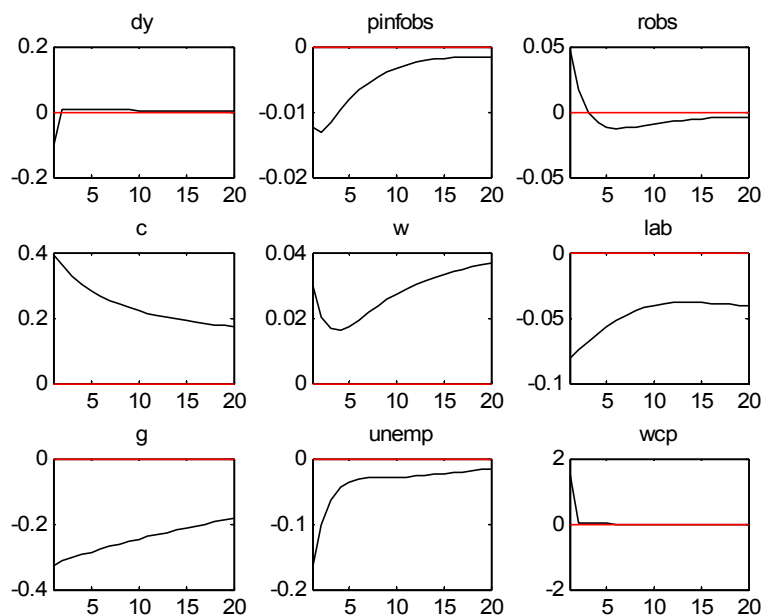


Figure A.6.3 IRFs to a shock to government spending

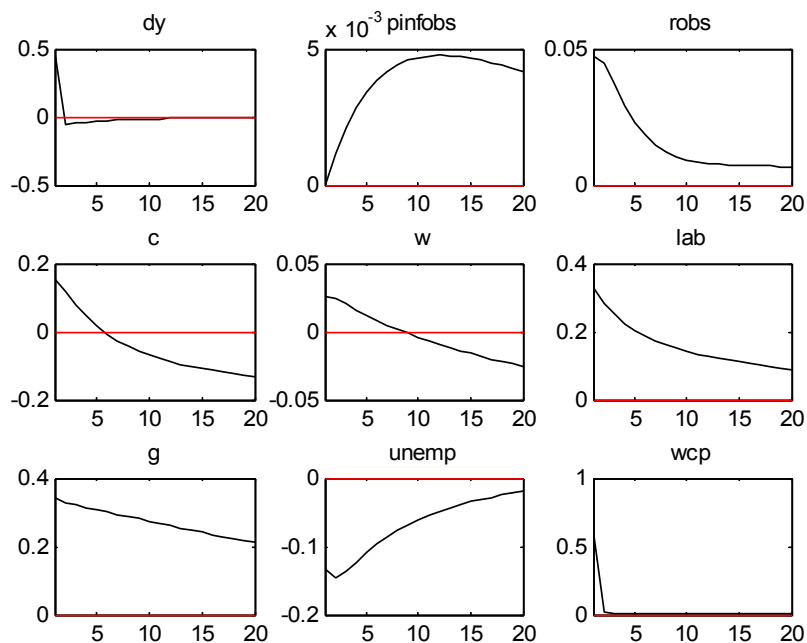


Figure A.6.4 IRFs to a shock to monetary policy rate r

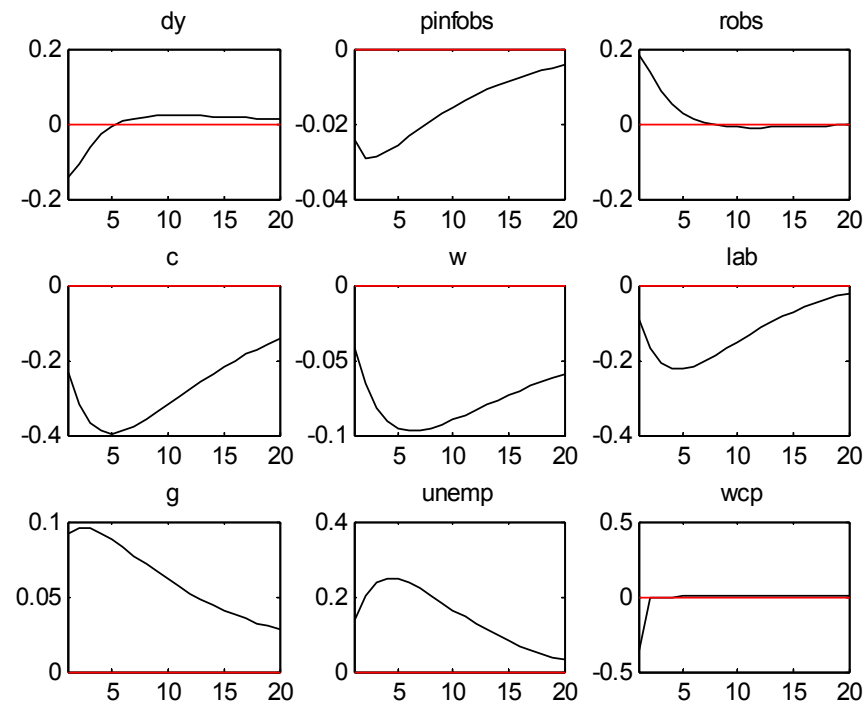


Figure A.6.5 IRFs to a shock to wage w

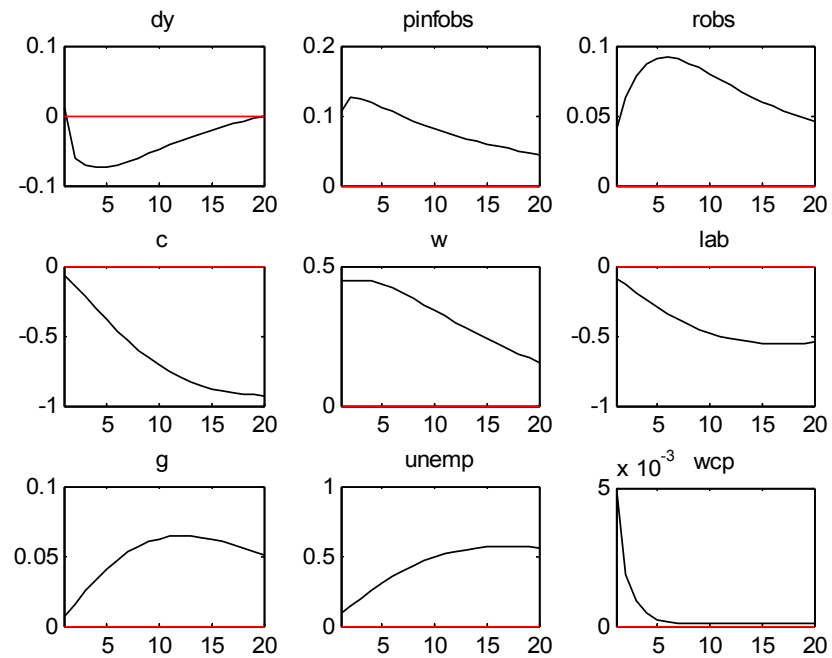


Figure A.6.6 IRFs to a shock to inflation

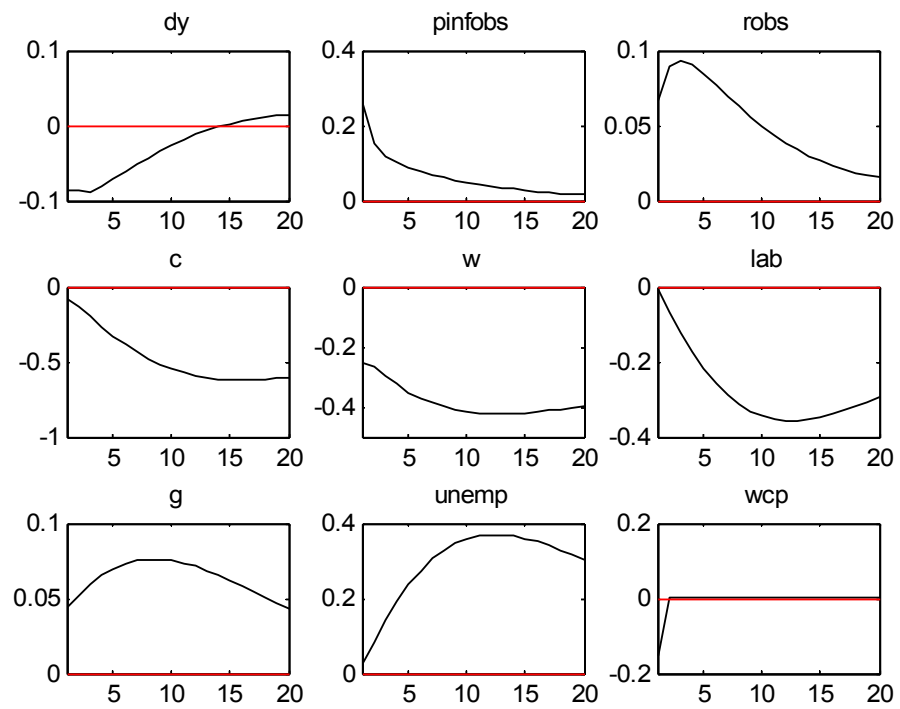
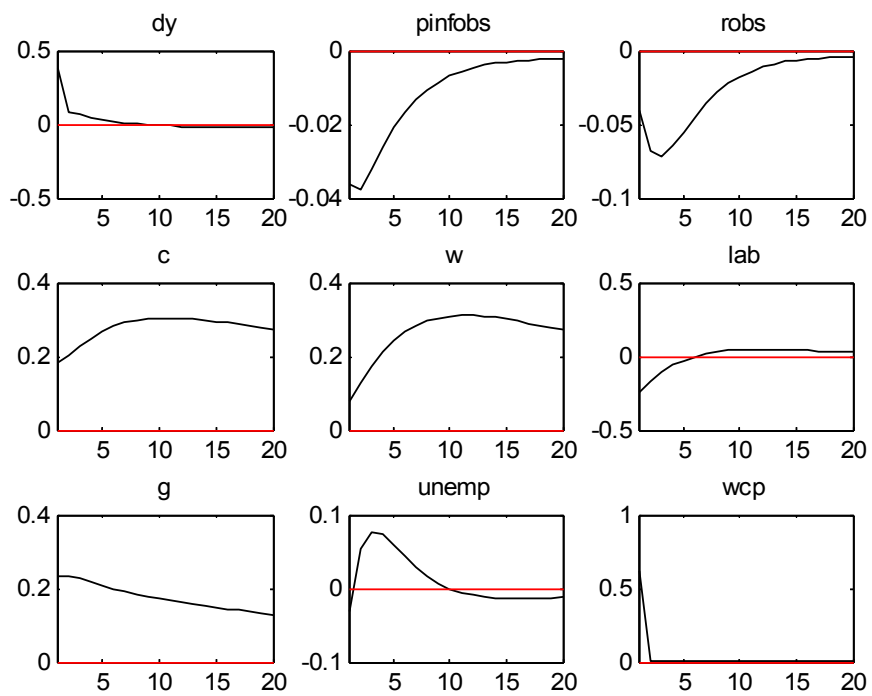


Figure A.6.7 IRFs to a shock to technology



Appendix 7: Yield Curve Estimation Results

A7.1 Estimation of the YC in the Initial Model with PC:86 and FAVAR

A.7.1.3 Results

	Basic		Simplified	2nd relation:	
Case:	Basic 7 and no extra observations		YC with Y-gap only	YC with Y-gap and Pi gap	
Likelihood:		-210.261	174.9249	259.9105	
Extra Parameter Estimates:					
			Simplified	2nd relation:	
			Y-gap only	Y-gap and Pi gap	
Y-gap:	b1y		0.018302	0.040045	
	b3y		0.1234	0.1064	
	b5y		0.18327	0.14951	
	b10y		0.24397	0.19151	
Pi gap	r1y		n/a	-0.06075	
	r3y		n/a	0.15287	
	r5y		n/a	0.25605	
	r10y		n/a	0.36936	

NOTE:

Throughout this estimation all of the a^N parameters to R_t have been set to 1.

A7.2 Estimation of the YC in the S&W07 Model with Fiscal Rule

This Appendix contains results of estimation of the S&W07 Model with news, fiscal rule (as used in Perendia and Tsoukis 2012). In this experiment, however, its observable dataset was augmented by one and five year Treasury bond in an additional Taylor rule like equation, based on the early work Perendia (2008) as briefly outlined earlier in Ch 5.4, but with the risk premium time-invariant constant RP added to the rule instead of using inflation, i.e.:

$$R_t^N = RP^N + a^N R_t + b_y^N (y_t - y_t^*) + \eta_t^N \quad (A7.2.1)$$

RESULTS FROM POSTERIOR MAXIMIZATION

parameters

	prior	mean	mode	s.d.	t-stat	prior	pstdev
crhoa	0.500	0.9557	0.0104	91.7015	beta	0.2000	
crhob	0.500	0.4026	0.0889	4.5298	beta	0.2000	
crhog	0.500	0.9610	0.0105	91.6865	beta	0.2000	
crhoqs	0.500	0.8134	0.0540	15.0682	beta	0.2000	
crhoms	0.500	0.0876	0.0517	1.6942	beta	0.2000	
crhopinf	0.500	0.9774	0.0179	54.5071	beta	0.2000	
crhow	0.500	0.9535	0.0142	66.9143	beta	0.2000	
cmap	0.500	0.9111	0.0436	20.8815	beta	0.2000	
cmaw	0.500	0.8070	0.0808	9.9857	beta	0.2000	
csadjcost	4.000	4.3732	1.1263	3.8826	norm	1.5000	
csigma	1.500	1.9497	0.2393	8.1473	norm	0.3750	
chabb	0.700	0.4959	0.0647	7.6652	beta	0.1000	
cprobw	0.500	0.6325	0.1070	5.9093	beta	0.1000	
csigl	2.000	0.3931	0.3306	1.1891	norm	0.7500	
cprobp	0.500	0.7414	0.0523	14.1773	beta	0.1000	
cindw	0.500	0.4934	0.1410	3.5003	beta	0.1500	
cindp	0.500	0.2019	0.0738	2.7377	beta	0.1500	
czcap	0.500	0.4214	0.0974	4.3248	beta	0.1500	

cfc	1.250	1.4704	0.0718	20.4670	norm	0.1250
crpi	1.500	1.9188	0.1699	11.2957	norm	0.2500
crr	0.750	0.8440	0.0235	35.9870	beta	0.1000
cry	0.125	0.0592	0.0161	3.6829	norm	0.0500
crdy	0.125	0.2555	0.0268	9.5409	norm	0.0500
constepinf	0.625	0.6322	0.0796	7.9407	gamm	0.1000
constebeta	0.250	0.2100	0.0916	2.2913	gamm	0.1000
constelab	0.000	-0.2671	1.2528	0.2132	norm	2.0000
ctrend	0.400	0.4661	0.0178	26.2114	norm	0.1000
cgy	0.500	0.3889	0.1137	3.4203	norm	0.2500
calfa	0.300	0.2763	0.0439	6.2869	norm	0.0500
cgu	0.010	-0.4933	0.0931	5.2983	norm	0.2000
RP1Y	0.000	0.0440	0.0283	1.5545	norm	0.5000
rhoR1Yr	1.000	0.9776	0.0502	19.4703	norm	0.0500
rhoSR1Y	1.000	1.0300	0.0227	45.3687	norm	0.0500

standard deviation of shocks

	prior mean	mode	s.d.	t-stat	prior	pstdev
ea	0.100	0.4613	0.0296	15.5855	invga	2.0000
eb	0.100	0.1996	0.0244	8.1735	invga	2.0000
eg	0.100	0.6450	0.0489	13.1862	invga	2.0000
eqs	0.100	0.4088	0.0376	10.8621	invga	2.0000
em	0.100	0.2446	0.0153	15.9925	invga	2.0000
epinf	0.100	0.1536	0.0165	9.3003	invga	2.0000
ew	0.100	0.2334	0.0240	9.7315	invga	2.0000
ewcp	0.100	0.0461	0.0188	2.4502	invga	2.0000
ewcpf	0.100	0.0461	0.0188	2.4502	invga	2.0000
EM_R1Y	0.100	0.1732	0.0112	15.4063	invga	2.0000

Log data density [Laplace approximation] is -892.566505

Appendix 8 Taylor Rule and Stochastic Interest Rate Forecasting

A 8.1 Taylor Rule

Along the lines of SW07, the macroeconomic model used in this research implements a set of Taylor type inflation targeting rules (Taylor 1993) in monetary policy reaction equations aimed at estimating the optimal real interest and inflation rates:

$$r = p + .5y + .5(p - 2) + 2(1) \quad (\text{A8.1.1})$$

where

r is the nominal base interest rate (e.g federal funds rate in the US),

P is the rate of inflation over the previous four quarters

Y is the percent deviation of real GDP from a target.

This simple, two-factor Taylor rule has gone a long way since its publication in 1993. A more comprehensive rule equation for optimisation of interest rate r_t as a function of past interest rate and, the current ($j=0$) or the expected future inflation rate ($j>0$)¹⁶⁶, the production gap¹⁶⁷ ($y_t - y_{nat,t}$), and the monetary policy shock $\varepsilon_{mpt,t}$, can be given by:

$$r_t = \rho r_{t-1} + (1-\rho)[\theta_\pi E \pi_{t,t+j} + \theta_y (y_t - y_{nat,t})] + \varepsilon_{mpt,t} \quad (\text{A8.1.2})$$

where ρ , θ_π and θ_y are inflation forecasting based (IFB) monetary policy reaction (i.e.

¹⁶⁶ Note: Following Batini et al. (2005b) i_t and π_t in this research equation are neither real nor nominal observations but deviations from the mean, difference between the observed data (when available, e.g. $\pi_{obs,t}$ in this case) and the unobserved means, r^* and π_t^* respectively. In addition, the authors estimate the mean, real inflation π_t^* and unobserved real interest rates r^* , and use the latter in the calculation of the (quarterly) future discount coefficient β as $\beta = 1/(1+r^*/100)^{1/4}$.

¹⁶⁷ The DSGE model identifies the production gap as a difference between production in the steady state economy and in the economy without frictions and rigidities (e.g. price and wage stickiness).

feedback control) rules' parameters that will be estimated, and $\varepsilon_{\pi t}$ is a simplified IID monetary policy shock .

After an inflation shock, the policy maker balances his options between a quick return and a smooth inflation path back to the target rate, and sets a nominal interest rate accordingly where parameter ρ defines the degree of interest rate smoothing – the higher it is, the lower the effect of inflation or production gaps is. The feedback parameters θ_y and θ_π define the speed of the correction: the higher they are, the higher the interest rate will be, and the quicker the economy will react to eliminate the gap between the expected (forecasted) and the target inflation rate or to reduce a high, positive output gap in an over-heated economy. Index j is policy horizon, a number of periods ahead that the policymaker is looking for the feedback from¹⁶⁸.

The model estimated in this research used a Taylor rule equation for the estimation of current interest rate r_t which feeds back on current inflation deviations from target inflation π^-_t and on the output gap. The latter is the difference between deviations from trend output and deviations from the flexible-price natural rate y^\wedge_t . (Eq 30 in LPP2007)

$$r_t = \rho_r r_{t-1} + \rho_\pi (\pi_t - \pi^-_t) + \rho_{\Delta\pi} \Delta(\pi_t - \pi^-_t) + \rho_y (y_t - y^\wedge_t) + \rho_{\Delta y} \Delta(y_t - y^\wedge_t) + \varepsilon_{R,t} \quad (\text{A8.1.3})$$

where $\varepsilon_{R,t} \sim N(0, \sigma_R)$ and inflation target π^-_t follows an AR(1) process.

$$\pi^-_{t+1} = \rho_\pi \pi^-_t + \varepsilon_{\pi,t+1} \quad (\text{A8.1.4})$$

In the research report presented at CFE 2008 (Perendia 2008), the author has shown that this Taylor rule can be rewritten as

$$r_t = r_{t-1} + (1-\rho_r) [[(\rho_\pi (\pi_t - \pi^-_t) + (\rho_{\Delta\pi} \Delta(\pi_t - \pi^-_t) + \rho_{\Delta y} \Delta(y_t - y^\wedge_t) + \rho_y (y_t - y^\wedge_t)] / (1-\rho_r) - r_{t-1}] + \varepsilon_{R,t} \quad (\text{A8.1.5})$$

¹⁶⁸ In this model $j=0$ and $E\pi_{t,t+j} = \pi_t$

A8.2 Stochastic Interest Rate Forecasting

One of the main differences between financial and economic modelling becomes apparent in a dichotomy between their respective approaches to model inputs and outputs. Along those lines, a few authors (e.g. Hull 2000, Choudhry 2004) distinguish between the arbitrage free and the equilibrium models of term structure. The former has future yield curves as input from observations aiming at fitting arbitrage free yield curve regardless of the wider economic context, and the latter, is an equilibrium-mean-reverting statistical projection which has its output yields calculated on economic principles.

For example, Vasicek's (1977) a mean-reverting stochastic process for deriving short-term interest rates which is based on the so-called Ornstein-Uhlenbeck process, which, for spot rate $r(t)$ is a normally distributed stationary Markov chain process with variance σ :

$$dr(t) = \alpha(b - r(t))dt + \sigma r(t)^\beta dz(t) \quad (\text{A8.2.1})$$

where α , β , σ and b are positive constants ($\alpha, \beta, \sigma, b > 0$), and $z(t)$ a Brownian motion (see Glasserman (2004)). In a specific, commonly used approximation, $\beta=0$ and the equation is tractable analytically.

Aiming to improve the fit of the future rate yield curve and bring interest rate determination and forecasting models closer to the needs of the efficient, arbitrage free financial markets, Hull and White(1990) introduce a time-variant extension of the above Vasicek's (1977) equilibrium model, but with a drift $\theta(t)$ and $\beta=0$:

$$dr(t) = [\theta(t) + \alpha(b(t) - r(t))]dt + \sigma(t) dz(t) \quad (\text{A8.2.2})$$

I.e., the above Hull and White (1990) model reduces to Vasicek's (1977) model for $\beta=0$

(i.e. $r(t)^{\beta}=1$), $b(t)\equiv b$ and $\sigma_t \equiv \sigma$ i.e. for b and σ being constant (equilibrium) values and drift $\theta(t)=0$.

The above, time-invariant/constant mean reversion factor Vasicek (1977) model is thought to belong to the equilibrium group of models, with b being the long-term equilibrium value. On the other hand, the time-variant, mean reversion factor $b(t)$ Hull and White's (1990) extension enables more exact fitting to the other market reference prices such as forward rates, and represents a step in the direction towards the well-fitted arbitrage-free models.

In the Hull and White's (1990) model, the drift term $b(t)$ is calculated so that $r(t)$'s drift can stochastically and asymptotically fit the drift of the forward rate and the arbitrage free expectations:

$$b(t) = F_t(0,t) + a * F(0,t) + \sigma^2/2a * (1-\exp(-2at)) \quad (\text{A8.2.3})$$

where $F(0,t)$ is the forward rate for time t at time 0, and $F_t(0,t)$ its 1st derivative over time t .

A8.3 Taylor Rule and Financial Stochastic Models Compared

The earlier form of the Taylor rule for estimation of the current spot short interest rate r_t can be seen as a macro-economic approximation of what is in financial business often used and known as a Hull and White's (1990) arbitrage-free model of interest rates:

In a discrete Euler approximation for one step ahead forecasting of r_{t+1} Hull and White's (1990) model of interest rate r can be expressed as

$$r(t_{i+1}) = r(t_i) + \alpha(b(t_i) - r(t_i)) (t_{i+1} - t_i) + \sigma_t (t_{i+1} - t_i)^{1/2} z(i+1) \quad (\text{A8.3.1})$$

and then its relation to the Taylor (1993) model can be made more explicit. I.e. when:

constant $\alpha = (1 - \rho_r)$

$b(t)$ becomes a one step ahead expectation $E_{t+1, t}[f(\pi_{t+1}, \pi_{t+1}^-, y_{t+1}, y_{t+1}^-)]$, i.e.:

$$b(t) = E_{t+1, t} [(\rho_\pi (\pi_{t+1} - \pi_{t+1}^-) + (\rho_{\Delta\pi} \Delta(\pi_{t+1} - \pi_{t+1}^-) + \rho_{\Delta\pi} \Delta(y_{t+1} - y_{t+1}^-) + \rho_\pi (y_{t+1} - y_{t+1}^-)) / (1 - \rho_r)]$$

$(t_{i+1} - t_i)^{1/2} z(i+1) = dW(t+1)$ where $z \sim N(0, 1)$, and hence,

$\sigma_r(t_{i+1} - t_i)^{1/2} z(i+1) \sim N(0, \sigma_r) \sim \varepsilon_{R,t+1}$ when $(t_{i+1} - t_i) = 1$ unit (period) of time.

The major difference appears to be that in Hull and White's (1990) model, the drift term $b(t)$ is calculated differently so that $r(t)$'s drift can stochastically and asymptotically fit the drift of the forward rate and $r(t)$ the arbitrage free expectations (see above).

However, one of the problems with simple arbitrage-free models is that bond pricing based purely on the fitting of the forward rates yield curve may lead to economically ungrounded, self-fulfilling prophecies and rational bubbles in financial markets. Addressing that issue, Hull and White(1990) show that their model also retains its drive towards a long-term equilibrium reversion along the lines of the Vasicek (1977) model.

Consequently, many of the more complex Taylor (1993) rule based models may be viewed as multi-factor extensions but also a stationary close approximation of either, the earlier defined, time-variant (and non-stationary) Hull and White (1990) or the Vasicek's (1977) time-invariant (and stationary), single factor equilibrium model.

What here transpires is that a factor that appears missing in most of the economic models are expected/forward rates, along the lines of GEW07, whilst the financial models seem to be missing more general economic factors and data.

This research extends the SW07 model by fitting it to a yield curve along similar lines to those of GEW07. However, this work intends to bridge both the financial and economic sectors and be closer to the models derived by Taylor (1993), Hull and White (1990) and Vasicek's (1977).

The observed current interest rates for different periods, however, are not observations of the factual, measured values of those interest rate/yield curves (those will be known at the end of the lending period), but are observations of the current (rational) expectations of those future interest rate yield curves, in a similar way to the equity prices which are current expectations of future income curves. They are therefore rational expectations of future economic equilibrium behaviour, and the longer the interest rates' periods, the less they are influenced by the current fluctuations¹⁶⁹.

¹⁶⁹ The currently observed spot prices of goods on the markets are, on the other hand, not measurement of RE of their future demand but of their spot demand.

Appendix 9: Way(s) out of the 1930's and other crises:

NOTE: This chapter is a small digression from the main subject of the thesis but, as it provides a supplementary information to its main cause, it is included as appendix.

In line with findings of many authors, Romer, 1992 argues that the recovery from the Great Depression came about as a result of the then contemporary monetary expansion and the monetary easing through lowered short term interest rates.

A partisan view by Higgs (2009) states that, contrary to the popular view, the policies of Franklin D. Roosevelt's government did not contribute greatly to ending of the Great Depression but, instead, prolonged it by introducing an uncertainty in the security of property rights. Higgs thinks this discouraged the long-term private investment needed to revive the economy. One piece of evidence the author finds is the increased spread between the yield on longer-term and the one-year corporate bonds perceived in mid 1930's remained high until WW2. He claims that this is a reflection of numerous court decisions that were perceived as a threat to property rights and an investment deterrent by many potential high power investors seeking higher risk premium midst uncertainty in the forthcoming years. An alternative explanation for the premium, however, may be that the Fed rate was perceived to be unrealistically low, temporary aimed at boosting the economic recovery.

A.9.1 Effects of WW2 and military spending as a fiscal intervention

In any case, the wake of WW2 brought a remarkable rise in GNP for the US and its final exit from the years of slow recovery. This rapid growth was initiated not by the Fed's actions but with the high gold and capital inflows in late 1930s due to political instability in Europe. It then accelerated with the rise in fiscal expansionary spending at the start of the war needed for financing its needs (see Romer (1992)). Ramey and Shapiro (1998) create model simulations and use estimations on real data to show how military spending associated with the Korean and Vietnam wars and with the military

build-up in late 1970s and early 1980s during the first Afghan and Iran crisis boosted US economy.

“Consider first the four major military build-ups of the last 60 years: World War II, the Korean War, the Vietnam War, and the Carter-Reagan build-up. In all of these periods, government spending on durable goods increased far more than other categories of spending. During World War II, when total government spending more than quintupled, spending on durable goods rose from 3 percent to 35 percent of total government spending. During the Korean War it rose from 9 percent, to 19 percent; during the Vietnam build-up it rose slightly from 10 percent to 12 percent; and during the 1980s build-up, it rose from 9 percent to 14 percent. Thus, particularly during World War II and the Korean War, the share of spending that went to durable goods increased substantially.” (ibid, pp 149)

Figures A.9.1.1 and A.9.1.2: US Government per-capita spending (left) and unemployment (right).

Figure A.9.1.1

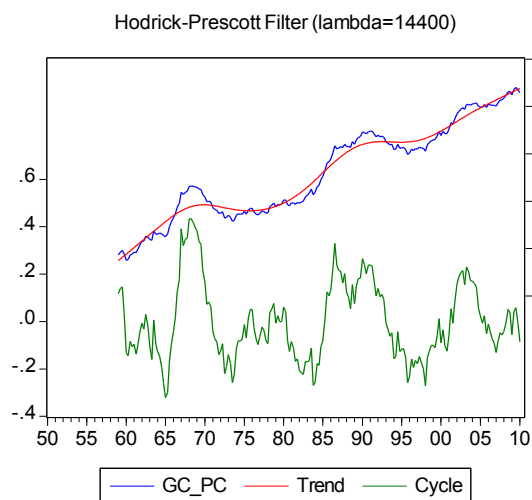
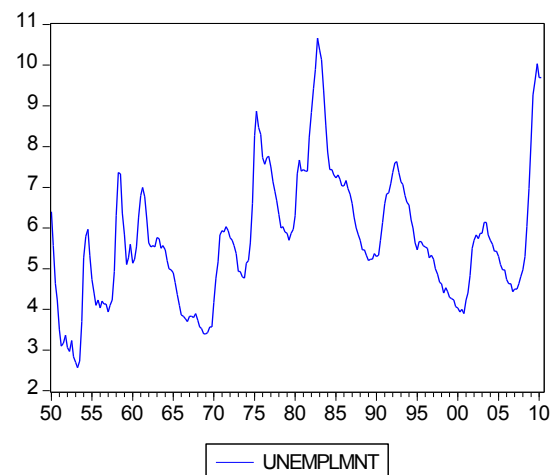


Figure A.9.1.2



One can see large surges during periods of rapidly declining unemployment that are contemporary with build-up of the wars: Vietnam 1964-70, building up arms production and sales during the Iran crisis 1985-90, the 1st Iraq war (The Gulf War) in

1990, the Afghanistan intervention in 2001 and a further spending increase jump (and unemployment drop) during the 2nd Iraq war starting in early 2003

Laidler (2009) however states that one of major contributors to the rise of inflation in the US in early 1970s was its engagement in the Vietnam War. He claims as a result of the politicians' desire to keep its cost hidden from the electorate, the resulting fiscal deficits accommodated by monetary growth triggered world-wide inflation. This rose slowly from the late 1960s and led towards the breakdown of the Bretton-Woods agreement and, eventually, the oil price hike and high inflation in the mid -1970s.

On the other hand, as a further development along the lines of the aforementioned Romer (1992) analysis, despite of all the public cost, deficit and borrowing excesses, Labonte and Levit (2010) state that an increase in military spending for larger military interventions (or preparations for such interventions) typically brings economic booms because the associated borrowing and money creation boosts aggregate demand. Consequently, their statistics show that in 2004, after start of the 2nd Iraq intervention, there was doubling of real GDP growth in comparison to the pre-Iraq war year 2002 and, similarly, midst the Reagan Era military build-up, real GDP growth in 1984 was an astonishing 7.6% comparing with mere 0% in 1980.

Both periods were associated with about a 20% increase in military spending. It is, however, clear from their findings that economically the most beneficial intervention was the Korean conflict in the 1950s with military outlays rising nearly 300%, from 4.8% to 14.1% of GDP and real GDP growth 500% from 2.4% to 11.4%. In their concluding remarks they state that money creation is the least preferred way of financing wars since, as Laidler (2009) also showed, it results in uncontrolled inflation.

Although the growth of 2003-2005 was probably augmented by low interest rates, even in peacetime, military spending may work out as both, fiscal spending that boots GDP and the contingency (insurance) policy against future likely destructive events¹⁷⁰.

¹⁷⁰ For example, the US Armed Forces' budget of 547 billion of USD in 2007 is nearly half of

the world's total military spending at 1,214bn USD. It is around 2/3 of total NATO spending at 804bn USD and nearly 10 times higher than that of the 2nd and 3rd ranking countries, Great Britain and China at 60 and 58 bill. USD respectively (see table 1.1 in Hartley and Keith 2011).

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