Strategic Dimensions of Macroeconomic Policy in OECD countries

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Abstract

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This research is focused on the study of international aspects of interdependence between monetary and fiscal policies. Its main objective is to reveal specific measurements and features of the impacts of cross-country and cross-policy spillovers among heterogeneous economies interrelated within networks of commercial and financial exchange.

In the achievement of this purpose, our study also contributes to the enhancement of dynamic stochastic general equilibrium (DSGE) models by the inclusion of a wider scope of analysis able to address the consequences of regional and global disturbances in the context of a multi-country setting. Other important additions in our international modelling framework, as the incorporation of financial intermediation, also play an important role in the enhancement of its potential as a wide and versatile platform for policy evaluation.

With a similar international approach, we also adapt complementary methodologies, as those in the spatial econometrics literature, to scrutinise the effects of national and international cross-policy externalities as the nominal effects of fiscal policies, in particular.

By the means of a range of empirical exercises performed with the aid of our resulting body of specialised econometric tools, this study provides valuable insights on policy interactions within and between economies and regions as diverse as those in the Organisation for Economic Cooperation and Development.

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Chapter 1

Introduction

1.1 Research design

This investigation is aimed to contribute to the research on macroeconomic policy interactions from an international point of view. We take as starting points recent research outcomes on the implications for domestic policies derived from open-economy interrelationships but the scope of research applied here, however, is broader than the common practice found in a considerable amount of previous studies on macroeconomic policy in the sense that it consists of a multi-country framework by the means of which fiscal and monetary policies are jointly evaluated as two important factors of macroeconomic fluctuations at national and regional levels.

During the design of fiscal and monetary policies a vast number of considerations can be incorporated in the relevant *information set*, that is, in the amount of data and information available to the policy-maker at the time his decisions (and expectations) are made. Among them, we are interested in analysing the extent to which external decisions and events, from the point of view of each policy-making authority, are determinant in the achievement of the objectives set for their own domestic policies and, therefore, how those externalities imply the need for adjustments in domestic policy programmes.

1.1.1 Main objective and relevance

The main objective we pursue is to reveal the features of an interactive setting of fiscal and monetary policies among heterogeneous economies and quantify the potential impacts of the externalities generated in the context of different regional and global conditions. For this purpose, this research primarily concentrates on the characterisation of the international variations originated by economic and financial shocks constituting the main bases of a strategic framework accounting for commercial and financial interrelations.

We pursue the hypothesis that, under the proposed configuration of analysis, significant international policy externalities distinctively arise for different economic structures and roles of either individual economies or groups of them linked within economic and financial networks.

Obtaining specific measurements and features of those international factors for OECD economies is, therefore, an intrinsic goal of this investigation. Our multi-country framework of research (using DSGE modelling and spatial econometrics methods) is specifically designed to embrace the complex space of cross-country and cross-policy interactions.

These issues are of particular relevance in the current context of globalised networks of commercial and financial exchanges in which macroeconomic policies are developed and applied. Our work contributes to achieve an enhanced awareness and comprehension of the characteristics of the international effects of macroeconomic policies (where they both generate and receive heterogeneous externalities) which constitute important bases for the promotion of greater cooperation, especially in the presence of common international shocks.

On the other hand, there is also an important area of domestic implications from our analysis. Even if no formal agreement mediates between the policies of diverse economies, the exposure and vulnerability to their international effects mean a range of conditions to the accomplishment of domestic objectives. Elements like *imported* inflation or output responses to foreign policies and events impinge on the ability of domestic authorities to succeed in their own programmes. This way, our discussion constitutes an extension of the work on cross-policy conditioning in Eusepi and Preston (2008) to an international space where domestic and foreign authorities are immerse in a complex net of interactions (as shown in our previous work on international coordination, see Mata (2005)).

The research on these topics holds considerable relevance for both academics and policy-makers as it provides new information on the comparative potentialities of macroeconomic international externalities under various regional and global scenarios. It is also an issue of considerable social relevance in the sense that contributions to the knowledge on macroeconomic policy-making, supporting the development of more efficient and effective programmes, can ultimately reflect into the promotion of sustained trends of economic growth, a fundamental variable in every nation's well-being measurement.

1.1.2 Research questions

In accordance with the described objectives, the main research questions addressed in this thesis are:

- What is the extent and features of cross-country and cross-policy externalities from monetary and fiscal policies in OECD economies?
- What are the consequences, in terms of those externalities, of heterogeneities in their profiles of economic structure and international linkages?
- What is the role of financial intermediation in the transmission of international shocks? Is there evidence of multiplicative (better known as *acceleration*) effects?
- How the preferences of policy makers in the regional and global economy affect the space of manoeuvre for domestic policies?

While complementary questions, at a more instrumental level, are:

- How does heterogeneity between economies modify the features of macroeconomic interrelations? How those heterogeneities can be effectively integrated in a multi-country DSGE macroeconometric framework?
- How relevant is a regional approach for the study of macroeconomic policies?
- How relative risk conditions affect the outcomes of fiscal and monetary policies?

1.1.3 Contribution

Although some recent research examples have devoted their efforts to continue the lines of Canzoneri and Lambertini (2001, 2003) on the symbiotic nature of the interactions between monetary and fiscal policies, further advances are needed on the subject in order to bring them back to a modern discussion integrating new elements, such as financial considerations and international transmission mechanisms. We offer an enhanced appraisal of those interactions and of their potential implications in a revised theoretical framework addressing the issues of international components in macroeconomic policies with a similarly re-engineered body of econometric tools for their empirical evaluation.

In the typical discussion on policy coordination (for example Lambertini, L. (2006) or Dixit and Lambertini (2003a and 2003b), monetary and fiscal policies share common fields of operation making the decisions of each side relevant to the other. Treasuries issue bonds which are deeply affected by the trends of monetary decisions, fiscal programmes can impact on the central bank's ability to meet an inflation target, fiscal imbalances put pressure on external accounts and exchange rates, money emission provides a source of seigniorage revenue, etc. Additionally, looking deeply into the main motivators on these two sides of macroeconomic policy-making, we can argue that there are common concerns too about growth (or unemployment) trends. As a result, those common grounds give rise to a strategic field and, importantly, to potential synergies between macroeconomic stimuli denoted in an important branch of research as that of *policy coordination*.

We incorporate such considerations in our revision of currently leading modelling examples which focused mainly on monetary issues (as in Bernanke et al. (1999), Christiano et al. (2005), Adolfson et al. (2005, 2007), Tillmann (2008)) so that, within our framework, fiscal policies also play an important role in the generation of national and international disturbances in the macroeconomic and financial fields. In this sense, our approach to the study of macroeconomic policy leads to a more integrated perspective in which fiscal policies not only have re-gained a consequential place in stabilization and longer-term development trends but also where their role in enhancing (or obstructing) the outcomes of monetary policies is given greater attention.

But these cross-policy interactions do not only occur within the domestic space. The current context of international exchanges constitutes a source of interconnections between economies by the means of which multiple international factors of variation, including those arisen from macroeconomic policies, are also transmitted.

We argue that, nevertheless, a crucial weakness in the current literature is the lack of representation of complex international relationships which have significant macroeconomic repercussions. The current state of the modelling literature still displays restricted attention to these international factors beyond cases of hegemonic economies or, more recently and frequently, monetary unions (see for example Gomes, Jacquinot and Pisani (2010)). As Dees et al. (2014) argue, ignoring more systemic interconnections in the global economy risks reaching misleading conclusions in the study of macroeconomic phenomena.

Previous models, as we explain in the next section, have relied in partial attempts, at best, of representing international conditions and the way they promote or restrict the management of domestic policies. Even open-economy models display, in various degrees, a *local bias* consisting of restricted attention to shocks and developments occurring in wider regions than those within the core interest of the research bodies developing them.

Without a comprehensive international perspective allowing for multiple channels of transmission and diverse national economic features, macroeconomics risks failing to explain the outcomes of phenomena occurring beyond national spheres, in a layer of international systemic interactions out of reach for the influence of domestic uncoordinated economic authorities. This is the case of common shocks to production, prices, interest rates or fiscal accounts, for example, all of which have been recorded in recent economic history across various regions of the world economy.

Policy-makers, under those circumstances, lack information on the potential effects that regional or global shocks can have on their economies and their decisions, therefore, may derive in inefficient policies. To the extent they are significant, disregarding international cross-country and cross-policy effects of monetary and fiscal policies, for example, can only contribute to an inefficient setting for the design of domestic policies which, as we show, find their space of action being subject to the outcomes of external policies and shocks.

By bringing about a discussion on the international externalities of macroeconomic policies through a multi-country DSGE model, our investigation targets such deficiencies and evaluates the economic environment of larger spaces as economic regions within the OECD. We offer an original exploration of the international repercussions of macroeconomic and financial shocks using a systemic approach where diverse economies are grouped into regions across and between which the effects of such disturbances are analysed. This approach is aimed at reducing the mentioned local bias in macroeconomic modelling.

A distinctive network-based approach dominates along the sections of this investigation. Our design of bi-directional international weights embracing trade and financial relationships is, in this context, a key innovative component of our research which enabled us to perform meaningful, specific characterisations of interactions between economies displaying considerable diversity in their own structures as well as in the linkages they have with the rest of the world. Learning from previous examples of such classifications through international weighting schemes (see Chudik and Fratzscher (2011), Sun, Heinz and Ho (2013), Triki and Maktouf (2012) and Dees et al. (2007)), we propose a setting that integrates measurements of both commercial and financial international relationships and, in the case of our spatial studies in Chapter 4, they also include indicators of geographic distances which act as proxies for other relevant aspects of interrelations between economies as institutions, migration and remittances, technology transfers, etc.

These weights mediate in the international macroeconomic and financial links described in our models participating in the calculation of country-specific foreign variables. In that place, they contribute to achieve a precise depiction of the potentialities of international shocks impacting heterogeneous economies through the description of the strength of commercial and financial channels of international transmission. Asymmetries within the regional networks, revealed by historical data, participate in our description of the relative position each economy holds as *generator* or *receiver* of regional shocks, providing factual foundations for the assignment of such leadership roles.

Our results display the comparative outcomes of policy and macroeconomic externalities in three OECD regions: North America, the Euro-zone and Asia-Pacific. The inter and intra-regional comparative repercussions of selected shocks are characterised in terms of size and persistence providing wider information, from the international point of view, to discussions on policy-relevant issues as rules versus discretion and the implications of the preferences of foreign policy makers on a set of macroeconomic variables denoting the aggregate welfare of the heterogeneous economies within those regions. None of these comparison exercises were feasible by the means of the original body of models we took as foundations for our international framework.

Subsequently, an important effort was made to incorporate financial components in our policy-oriented framework. Based on a body of recent research among which key contributions came from Cúrdia and Woodford (2009, 2010) as well as from Gertler and Kiyotaki (2010) our modelling further incorporates, in a coherent way, a depiction of the international monetary spillovers with important implications for the operative conditions of credit markets. This way, we obtained from our modelling a concise, yet revealing, account of international financial interactions which were not explored by those models.

By combining our DSGE platform with their financial modelling we achieve an important synergy by the means of which key financial considerations are integrated to a robust macroeconomic, open-economy scheme, which they lack, while, in turn, their financial depiction decidedly helps to address the weakness of the original DSGE setting in relation to its capability for the analysis of relevant financial components and phenomena.

Our study of international financial interactions is particularly focused on the supply-side of credit markets, the nominal conditions in which banks operate and the relative valuation of their assets. This valuation is important in determining the incentives of bankers to default or continue their activity and accumulate net worth so our international extension means that we can provide new comparative information on the way common shocks influence decisions in banking systems. This also provides a macro-prudential aspect to our investigation, relevant for both national and international regulatory bodies.

On the bases of the same criticisms we have made on the current state of macroeconomic analysis, our efforts to take these financial depictions to an international framework are intended to provide analysts and policy-makers with a comprehensive description of the features of the exposure and vulnerability in credit markets to policies and shocks generated abroad. The lack of this information brings about important restrictions for monetary authorities in terms of their responses to the effects that international externalities have on their nominal space of action and on the conditions of operation for domestic financial markets.

Given the recurrence in recent years after the 2007-2009 financial crisis of policies targeting liquidity in credit markets, we explored the international implications of such interventions and compared their potential spillovers to those from monetary policies operating through interest rates instead. This comparative approach has not been analysed before in the wider OECD context leaving a gap in our understanding of the implications that those choices have in the regional and global economies.

Based on the latest contributions from macro-financial models, our financial setting embraces a distinctive description of the conditions leading to default of banks as well as of the implications of market imperfections in banking systems.

Within our integrated approach, we describe the vulnerabilities of financial and macroeconomic systems to the prevailing conditions of fiscal soundness as expressed by the developments of public debt. We provide, for example an international assessments of the role of fiscal policies in driving variations of risk indicators.

In our international analysis of cross-policy effects, our departure from previous perspectives which concentrated on the inflationary aspects of fiscal policies emanates from an exploration of current fiscal practices and statistics. We notice that there is an international component involving banking networks across the world exposed to the conditions of public debt in economies which may even be outside the relevant region. This way, banking systems constitute significant potential channels for the international transmission of fiscally-generated risks between economies which have not been profusely analysed in previous literature.

Evidently, an international modelling structure as ours is required for the study of such transmission mechanisms and the implications they have for nominal variables and monetary policies. In our investigation we make the case for a reconsideration of the role of fiscal policies in the determination of risks with important repercussions for the management of monetary policies. The wider international perspective we adopted also finds expression in the study we perform on the repercussions of public finance conditions on comparative financial risk indicators of selected economies and their corresponding implications for the operation of banking systems and monetary policies.

In our empirical analysis, we emphasise on the disentanglement of the national and international (that is, network-) effects of fiscal policies on financial risks prevailing in each economy. Without this differentiation monetary policy makers cannot accurately assess the potential impacts of international developments in public debt and adjust their own policies accordingly.

The discussion of fiscally-generated externalities in this thesis is similarly intended to break the home bias (as well as non-negligible degree of monetary bias) recurrent in previous models which affects their capability to provide more integrated accounts of consequential nominal effects of fiscal policies. Recent experiences as the 2009 European debt crisis and studies on the potential risks of fiscal crises led us to focus on an international approach to the mechanisms by the means of which national fiscal decisions impact nominal conditions of economies across the OECD.

Our modelling, in general, provides analysts and policy makers with a new, wide range of information on international interactions valuable not only for the re-assessment of domestic policies in view of such external effects but also from the perspective of agencies with a larger scope of interests on the international economy as the OECD.

1.1.4 Macroeconomic modelling

For the purposes of our analysis, we adhere to the school of dynamic stochastic general equilibrium (DSGE) models. In the current modelling context, DSGE models have become an important toolbox for building a bridge between theoretical and applied considerations in the research of macroeconomics. Among many of their recent applications[1], their use for macroeconomic analysis and policy evaluation has been extended in many countries.

Being central tools in the contemporary analysis of macroeconomic policies, DSGE models are constantly adapted from a fairly common baseline structure to more specialised versions capable of depicting key factors and relationships of the phenomena under scrutiny in a coherent fashion.

Nevertheless, we found that the previous literature using DSGE models for international analyses is largely dominated by three generic partial attempts to study international interactions[2]: 1) models investigating the conditions imposed by monetary unions only, 2) two or three-country settings where the included economies generally share hegemonic roles (as the United States facing the Euro-zone as an

[1] Which include topics as diverse as environmental, social, health and public policy issues, to mention but a few examples.

[2] A notable exception is the GIMF model (see Kumhof et al. (2010)), however its breadth and degree of complexity escapes the reach of a single researcher for further development.

aggregate and, in some cases, Japan) and 3) models of national economies interacting with one large, exogenous economy representing the rest of the world. Their account of more complex interactions as those between heterogeneous economies sharing regional economic links and policy spillovers is, therefore, restricted by the scope of either of those approaches.

Those weaknesses leave a gap in our understanding of the asymmetric and heterogeneous interactions between and within economic regions in the world. They prevent us from identifying specific features of the exposure and vulnerability that distinct economies may display in relation to their economic and financial network-partners.

Given such limitations, new models are required to assess a broader range of conditions for the operation of diverse economies in the context of the international networks they form. Particularly, in order to account for a richer variety of degrees of vulnerability, modern tools for macroeconomic analysis must be adapted to reflect the reach and extent of common shocks across and between regions.

Our model constitutes one of such extensions. Based on an open-economy DSGE structure, our extended framework embraces numerous key features of heterogeneous economies as well as of the linkages they display between each other.

We adapt the current paradigm established by Christiano, Eichenbaum and Evans (2005) (CEE henceforth) to develop a multi-country DSGE model for the analysis of monetary and fiscal policies and their interrelations at the international level.

Specifically, we contribute to reduce the aforementioned deficiencies by extending the DSGE framework provided by Adolfson et al. (2005) which constitutes a cornerstone for our multi-country version. Their open, single-economy model is adapted in Chapter 2 to embrace the interactions of multiple, heterogeneous national units with their optional aggregation into regions.

The nature of the extensions allows national units to incorporate the inputs from multiple foreign counterparts which models are also solved in the resulting framework. This is in contrast with the the original model, given that foreign economies do not just represent an exogenously given aggregated foreign sector (as in Adolfson et al.) but individually contribute to the representation[3] of foreign conditions faced by each participant.

In addition to allowing for the inclusion of heterogeneous economies in the experimental settings, which is one of the main motivations of this research, those

[3]Given the current coverage of world economies in our framework, this is, obviously, still a partial representation. However, our best effort has been made in including the most relevant economies in the geographic regions we study and, with them, the most important sources of interactive effects.

changes are aimed to obtain a more detailed description of the specific potentialities and consequences of shocks generated in foreign economies and regions.

Heterogeneous economies, this way, distinctively interact in a global system which provides a detailed description of the consequences of national, regional and global shocks.

Not only an important number of national economic authorities (mainly central banks) are developing research and implementing policies assisted by this modelling practice but also international institutions such as the International Monetary Fund (IMF), the Organisation for Economic Co-operation and Development (OECD) and the European Central Bank (ECB) have dedicated considerable resources to research within the DSGE context.

These models have also played a central role in large-scale research initiatives such as DSGE-Net[4] and the European Commission's Monetary and Fiscal Policy FP7 Project (*Modeling and implementation of optimal fiscal and monetary policy algorithms in multi-country econometric models*, MONFISPOL), all with the aim of contributing to the development of effective macroeconomic policies in the current economic environment of interaction and exchange.

Nevertheless, DSGE models have repeatedly been criticised for containing poor or no representations of the financial system (Woodford (2010), Quadrini (2011)). From the international perspective, this has a detrimental impact on their ability to account for a relevant set *high-power* interactions (see Bernanke et al. 1999 for an exposition at the national level) with significant effects on the macroeconomic conditions of the regions we consider. In particular, variations in interest rates in key economies have not been profusely explored as sources of nominal and real variations from a regional perspective using DSGE modelling.

For this reason, our international approach also aimed to integrate compatible financial components in the modelling which contribute to describe the diverse features (mainly in terms of size and persistence) of the financial sensitivity exhibited by economies and regions to monetary shocks.

After an empirical contextualisation of recent trends observed in the international credit markets, further developments of the model in Chapter 3 consist of the inclusion of additional components intended to reflect the key international conditions and interactions of such markets in a scheme which includes the effects of financial frictions. For this purpose, our modelling framework is extended with our log-linearisation of a model based on Gertler and Kiyotaki (2010) to which we add

[4]Research network integrated by the Bank of Finland, the Bank of France, The Capital Group Companies, the European Central Bank, the Federal Reserve Bank of Atlanta, Norges Bank, Sveriges Riksbank, the Swiss National Bank and Centre Pour la Recherche Economique et ses Applications (CEPREMAP, France).

elements from Christiano and Ikeda (2011) and Cúrdia and Woodford (2010).

These additions allow the model to jointly evaluate the repercussions of macroeconomic and financial disturbances considering the influence of both national and international (inter-bank) credit markets. In particular we focus our interest on the comparative international effects of two versions of monetary policy.

In terms of the solution methods for the extended model, we follow those originally used by Adolfson et al. (2005) which means heavily relying on the Bayesian methodology. Although there is an increasing body of modelling and estimation tools within the Bayesian scope, we restrict ourselves to the use of well proven resources in the field as Dynare©[5] since it provides all the required facilities for the purposes of this investigation within the reach of an accessible programming language.

In turn, spatial econometrics similarly play an important part in our research framework. Chapter 4 combines more stylised elements from previous sections to extend the models of Lambertini (2006) and Dixit and Lambertini (2000, 2001, 2003a and 2003b) to an international setting with special emphasis on the implications derived from fiscal policies on financial risk scores and the relative premia associated to financial risk. Our interest concentrates on reducing a crucial gap in the study of the interactions between macroeconomic policies and financial systems. In Chapter 4, in particular, we turn our attention to nominal repercussions of fiscal policies with significant implications for the operation of national and international credit markets. We study, this way, a variant of a *financial accelerator* effect with origin in fiscal policies (see Bernanke et al. 1999 for the monetary case).

The approach and extent of our investigation (involving heterogeneous economies outside a monetary union) are not present in previous literature which has focused on other nominal aspects as inflation. In view of such opportunity for research, this modelling is designed to provide concrete information on the role of national and foreign fiscal decisions on the international nominal conditions in which credit markets operate.

The resulting model incorporates main contributions from Cochrane (2005), Muscatelli, Tirelli and Trecroci (2004), Adolfson et al. (2005), Taylor (2001, 2008) and Akitobi and Stratmann (2008). Those modifications provides us with a macroeconomic model with policy interactions, financially-relevant variables and an innovative classification of the strength exhibited by international economic and financial networks.

In terms of policy design, in addition to the inclusion of regional components, our modelling framework embraces recently developed elements such as spread-adjusted

[5]Dynare is property of the Dynare Team.

Taylor rules (Taylor (2008)) and follows Hördahl, Tristani and Vestin (2008) in highlighting the strategic restrictions between fiscal and monetary policies, view that we further expand to an international context.

1.1.5 Sample selection and period of study

Specific descriptions on the data used are given in each chapter but, in general terms, our policy analysis platform focuses on the 34 economies of the Organisation for Economic Cooperation and Development (OECD). In accordance with the current data availability, we developed economic and financial profiles for most of the members and perform empirical exercises as Bayesian estimations relying on actual macroeconomic data for a panel of 12 economies distributed across three regions and spatial econometrics applications on 25 economies.

The OECD group of economies[6] is deemed an adequate set for this analysis since it includes examples from various regions around the world with a data-enriching diversity of economic structures and roles in the international arena. Diversity between central banks and treasuries among this group gives it a wide spectrum of cases which are useful for the analysis of macroeconomic policy interactions from both national and international perspectives (see Mata (2005)). It is also convenient for the evaluation of the implications derived from special policy regimes such as the European Monetary Union.

The units of analysis to be used here are each country's fiscal and monetary authorities (either individual or common, as in the case of the Euro-zone). The data sample consists of information on policy-related variables such as monetary and fiscal indicators, macroeconomic aggregates, variables related to the model's international weightings and the inclusion of financial indicators, particularly related to the banking systems. The data coverage is mainly from 1980 to 2014 unless otherwise indicated.

1.1.6 Structure of the thesis

The remainder of the thesis is structured as follows:

- Section 1.2 provides a succinct discussion of relevant literature on DSGE modelling and on the bases for the extensions and modifications we perform in subsequent chapters.
- In Chapter 2 we develop and apply a new macroeconometric multi-country DSGE platform for the analysis of macroeconomic, risk, and policy shocks

[6] Mainly the original OECD-20 plus Australia, Finland, Japan, Mexico and New Zealand.

in an international context emphasising on the interdependencies between economies. A structure of international weights is embedded in the model measuring the strength of bi-lateral financial and commercial relationships. Allowing for national, regional and global shocks, the resulting framework is useful for studying the effects of disturbances and policy spillovers among heterogeneous economies. Using data and parameterisations on OECD economies, the estimations and stochastic simulations of the model reveal measurements and features of the international transmission of shocks as well as of monetary and fiscal policy interactions.

- Chapter 3 compares the international implications of liquidity and interest rate-based monetary policies in the presence of financial frictions in the banking system. Building on our multi-country DSGE model, we incorporate financial intermediation and international interbank credit markets in order to evaluate the differentiated impacts of policy shocks across selected economies in the OECD. The results provide a description of distinctive levels of vulnerability between economies specifically defined in terms of the responses of key interest rates.

- Chapter 4 explores the financial repercussions of a novel depiction of a cost channel derived from fiscal policies and the resulting spillovers to monetary policies at national and international levels by the means of a financially-augmented empirical model and spatial econometrics tools. Our main findings indicate that through this channel fiscal policies have significant effects on key nominal variables and, therefore, can modify the space of manoeuvre for monetary policies and also generate international policy spillovers across OECD economies.

- Chapter 5 contains the global conclusions of the thesis, paths for further research and the bibliography.

1.2 Open-economy, macroeconomic policy and DSGE modelling: a modern review

1.2.1 Macroeconomic policy coordination and its strategic approach

Investigation of macroeconomic policy interactions from an international point of view is today a field which, as many other issues in the study of international economics, it is one that is far from being satisfactorily concluded. On the contrary, it keeps evolving to embrace the implications of current developments in the *global economy* as increased exchanges in trade and finance and all their surrounding contexts (as communications, information, trends in the use of financial instruments, international agreements, etc.).

These developments maintain the interest on new ways of identifying, measuring and exploiting the seemingly ever controversial *gains from coordination* in the macroeconomic policy context. An event with important implications for the current research on this subject, is the consolidation of the Economic and Monetary Union (EMU) creating the Euro-zone, an undoubtedly important player in the international strategic setting of policies. Although this study will not specially focus on the Euro-area, it will certainly consider many of its effects on the international setting of macroeconomic policies in a broader international framework.

Several studies have addressed the implications for fiscal policies of a single monetary policy (see Dixit and Lambertini, (2000, 2001, 2003)) in a particular distribution of targets as in Beetsma and Jensen (2005) who evaluate fiscal coordination as a specific stabilising tool aiming at relative inflation and terms of trade whereas the common monetary policy is used for union-wide targets. We consider those relationships are not restricted to the conditions of monetary unions and, therefore, broaden the scope of our analysis by exploring the significance of interactions between monetary and fiscal authorities not necessarily linked by a monetary agreement.

Other events, equally important for our purposes, are related to episodes of common shocks such as the 2007-2009 financial crisis, the subsequent global recession and the European sovereign debt crisis, in face of which isolated policies for the amelioration of the macroeconomic impacts as well as for the achievement of recovery appeared as sub-optimal. Any effort for the incorporation of the transmission mechanisms of widespread shocks requires at least two components to be considered in a deeper way: first, a review of the trade flows as a transmission mechanism related to real and nominal variables and, second but also crucial, the role of financial exchanges as an important component of the interrelation between economies.

The study of the interactions between macroeconomic policies finds multiple examples in game-theory-based research. The game-theoretical approach of macroeconomic policy is well exemplified by studies such as Hamada (1976) and the book by Canzoneri and Henderson (1991) although both of them clearly restrict their attention to the interdependence of monetary policies. An important consideration made by Canzoneri and Henderson (1991, p. 23-27) is that in the international monetary game although a Stackelberg leadership equilibrium may dominate a Nash (meaning non-cooperative) equilibrium (in terms of welfare), it is not well defined which player has the incentives to actually behave as the *leader*.

Our network-based approach on macroeconomic analysis offers concrete elements to discern these international roles based on the observed relevance that each economy holds in relation to key exchanges.

Another example of the game-theoretic approach to macroeconomic policy is found in Dixit (2001) where a series of models are built to describe the restrictions imposed on the outcomes of fiscal and monetary policies, again, in the context of a monetary union. The setting used in that paper is, nevertheless, of considerable value since it allows for the analysis of repeated interactions and pay-offs (including international spillovers) even under conditions of disagreement as well as differences in economic size and *political power* for multiple countries subject to distinct shocks. Such a study is able to keep critical heterogeneities between the players and provide a model that, accordingly, reflects the distinctive implications of their interactions.

Similarly, Caporale et al. (2001) derived and analysed rules for stochastic macroeconomic (monetary and fiscal) policy games in a multi-country modelling setting. Their optimisation method provided an innovative tool enabling for the joint derivation of policy rules for several countries differing in their *bargaining power* and, ultimately, for a suitable depiction of the outcomes of cooperative rules.

In turn, Bosco (1992) aimed to explore the consequences of increased interdependence and spillover effects for fiscal and monetary policies both home and abroad in a two-country Mundell-Fleming setting. Multiple policy combinations are analysed comparing their distinctive potentialities and outcomes relying in the exchange rate as a transmission mechanism between economies and, therefore, assigning a preponderant weight to commercial exchanges. Some of his assumptions, however, leave opportunities for a richer analysis of the policy interrelations. Namely, that of symmetry between economies and, importantly, the one about *naivety* of workers/consumers' expectations (Bosco (1992, p. 214)). Particularly in the latter sense, a contrasting approach has been taken by De Grawe (2008) who, in turn, departed from the standard assumption on the agents' full information and complete understanding of the economic theory and theoretically compared the dynamics generated by simple (heuristic) endogenously selected *rules of thumb* used for forecasting and rational expectations versions of the same DSGE model.

Heuristic approaches are relevant devices in the context of modelling where important weight is given to financial fluctuations. They provide sensible explanations of endogenously generated economic fluctuations associated with consequential *waves* of optimism or pessimism following an expectations-led mechanism as explained in Corsetti et al. (2011), for example, based on a *sovereign risk channel*, through which fiscal policies impact private spending conditional to monetary policy stances and relative effectiveness. Under such configuration policy implications arise for distinct economies from their comparative fiscal and monetary circumstances and exposure to that risk channel.

In our empirical DSGE applications, we use a *partial information* approach (see Pearlman, Currie and Levine (1986)) by the means of which, agents only observe a subset of variables in the model. This appears as a feasible representation mainly in the context of econometric applications where the econometrician remains agnostic about variables out of his/her cognitive reach. In our international framework, a vast number of factors may escape the contents of the model and therefore an informational adjustment of this nature is appropriate.

Other recent works on the interactive approach of macroeconomic policies include Lombardo and Sutherland (2004), who show the gains from international fiscal cooperation conditioned on a cooperatively designed monetary policy. A crucial advantage of their study, in addition to the inclusion of fiscal policy as a stabilisation tool, is that it provides a set of conditions for cooperation to be dominant over Nash equilibria.

Monetary-fiscal interactions operate at two main levels: a) national and b) international. The effect of the resulting externalities gives rise to a potential structure of *vertically* (in the first level) and *horizontally* (in the second) coordinated policies. As an example of the first type of analysis, Muscatelli, Tirelli and Trecroci (2004) studied and empirically tested the interaction between fiscal and monetary policies in the USA. Their approach is useful since they find evidence of distinctive types of interactions (i.e. as substitutes or complements) according to the nature of the shocks faced by the economy. Similarly, Eusepi and Preston (2008) stressed on the constraints that fiscal and monetary policies impose on each other for achieving stabilisation in a context where regime communication and expectations formation are key components.

Extensions towards the study of horizontal coordination include Grenouilleau, Ratto and Roeger (2007) who made a relevant contribution in the sense that they distinguished particular features of nominal and real rigidities between countries (Euro-area and the US) as conditioning factors for the operation of monetary and fiscal policies in a mixed framework of rules and discretion.

Subsequently, Blake and Markovic (2009) accounted for the effects of foreign policies on the success of the domestic ones. In particular they investigate the spillovers from external monetary policies and their contribution towards national economic stability. They found that external (that is, foreign) improvements in monetary policy (defined as moving to a policy framework in which the link between real interest rates and inflation is reinforced) are important factors of the achievement of domestic policies in terms of stabilisation. Their approach on the impact from external monetary conditions is illustrative of the way they operate for small open economies.

Nevertheless, it remains to be analysed how international monetary transmission mechanisms operate in a wider mixture of small and large economies, which is an issue we are interested to address in this investigation in addition to a similar exploration of the effects of foreign fiscal policies given that emphasising on the importance of fiscal policies in terms of stabilisation and, implicitly, on their impact on nominal and real variables is a key component of our study.

The recurrent low appraisal given to fiscal policies is reviewed and then reconsidered in the light of current events by Blanchard, Dell'Ariccia and Mauro (2010). In turn, the policy-related value of their interactions with monetary policies in the context of a monetary union is emphasised in studies like Hughes-Hallett (2008) who evaluates the comparative implications of separated (fiscal or monetary) Stackelberg leaderships as those of simultaneous decision-making. In his study, coordination aims at an improved level of common welfare although Hughes-Hallett pays little attention to international differences in fiscal policies, taking them as a homogeneous/unified group which, in our view, weakens his configuration in terms of providing specific policy alternatives for heterogeneous economies or differentiated shocks.

1.2.2 International financial flows, financial markets and macroeconomic policy

The current state of the world's economy is undoubtedly influenced by the impressing flows that can be observed in the financial markets every day. Their magnitude, speed and functionalities have deep implications to the way policy makers implement their programs, especially when considering the fluctuations in internationally relevant variables as interest rates, exchange rates or, as we will analyse, even in the international exchange of financial assets linked to public debt.

In addition, economic research after the 2007-2009 financial crisis has contributed to restate the considerations made on the power of financial markets to influence real activity with a renewed approach not only over their importance but also on the mechanisms behind it. Introducing financial frictions (that is, increased financial costs derived from market imperfections) in our modelling is a way of accounting for what is, in our view, a crucial factor modifying the outcomes of macroeconomic policies as well as the externalities that operate between them.

An emblematic example of this line of research is found in Bernanke, Gertler and Gilchrist (1999) who made the case for the influence of credit market conditions to be included in models of cyclical fluctuations as true factors of macroeconomic performance. In such settings, real implications can be expected from a deterioration in credit markets since they involve less efficient (i.e. more costly) flows from lenders to heterogeneous borrowers. In addition, those authors argued that the presence of asymmetric information and agent-principal problems in credit markets give especial relevance to their real-economy effects. A principal outcome of their study consists of the description of a *financial accelerator* capable of propagating and amplifying shocks from the financial sector to the rest of the economy.

Studies like Christiano, Trabandt and Walentin (2007) found that by including additional components, as financial frictions[7], the forecasting capabilities of models were improved as was the analytical power of the insights obtained from them.

These considerations are also consistent with the work of Bianchi, Boz and Mendoza (2012) in a recent working paper embracing a financial transmission mechanism, financial frictions, imperfect information, waves of optimism or pessimism, the DSGE paradigm and Bayesian foundations. They defined a financial transmission mechanism in terms not only of credit frictions but also of financial innovation, imperfect information and financial risk. Credit fluctuations are associated, under their point of view, to the presence or absence of financial innovations which, in turn, impact the agents borrowing decisions through an expectations formation process (learning-based, in that case) giving rise to short run waves of optimism or pessimism with a "financial amplification feedback mechanism"[8] between over/under-borrowing decisions and asset prices. Our main departures from it, however, reside in a different representation of private agents without *learning* processes.

Accounting for financial disturbances, such as shocks in credit markets, has also notable implications for macroeconomic policy. In this sense, Cúrdia and Woodford (2010) developed a DSGE model in which conditions of the credit markets have a consequential role in relation to the effectiveness of monetary policies. For that purpose they allowed for heterogeneous (though infinitely-lived) agents and credit spreads and proposed alternative adjustments to the policy (*Taylor*) rule for improved responses in face of financial disturbances (such as increases in credit spreads). We, in turn, will adopt an akin approach over a modified Taylor rule for monetary policies which takes into account disturbances in the interest rates affecting credit markets.

From a similar perspective, Christiano, Motto and Rostagno (2010) allocated increased attention to financial markets and, in particular, to the banking sector as

[7] Although they also included labour frictions, an element we will not pursue here.

[8] Bianchi, Boz and Mendoza (2012, p. 2).

a way of accounting for their impacts on business cycles using an extended DSGE model and estimations for the Euro area and the US. In their configuration asymmetric information, agent-principal problems and credit markets are jointly considered with market risk variations, banking balance sheets and financial liquidity provision as core factors of the influence of financial markets on macroeconomic fluctuations.

Gertler and Kiyotaki (2010) also worked on credit market frictions and an important feature of their analysis is the focus on both monetary and fiscal authorities' responses to the financial turmoil, mainly in the form of newly developed *credit policies* aimed to reduce the impact of the financial crisis on real activity. In a context with agency problems, they modelled financial intermediation in the presence of a *financial accelerator* where the conditions of the balance sheets are reflected in the credit users' expenditure via the external finance premium they pay, contributing to exacerbate or depress the final impact on aggregate activity. Financial intermediaries engage in resource exchanges not only with borrowers (the retail credit market) but also with supplying peers (the wholesale credit market). We exploit similar mechanisms in order to explain the transmission of externalities from fiscal policies and public debt to interest rates and the management of monetary policies.

As Adrian, Moench and Shin (2010) make clear, financial markets constitute a key element to be accounted for in any attempt to develop a sensible explanation of macroeconomic dynamics. They identify the intermediaries' balance sheet adjustment as an important source of variation in terms of risk premia which is also linked to the evolution of macroeconomic variables and, particularly, to monetary policy. Under similar premises, we also reflect in our analysis the conditions of an indicator of the bank's relative valuation of assets and liabilities

In coincidence with branch of literature, the approach we take in this investigation is that financial theory and phenomena have significant implications to be accounted for in economic modelling. Considerable stress is put on the role of financial markets for the transmission of common shocks. On this subject, Corsetti and Müller (2011) even found evidence on the prevalence of financial factors over trade flows in the transmission of shocks between economies.

Further in this direction, Sutherland (2004) has analysed the impact of financial integration on the welfare gains from coordination in a context of asymmetric shocks for countries. By the means of a stochastic general equilibrium model, he concluded that those gains are sensitive to an *expenditure switching* effect[9] and also considers financial exchanges (assets trade) as enhancing elements for the argument in favour of significant gains from policy coordination.

[9]Based on the elasticity of substitution between baskets of domestic and foreign goods.

1.2.3 Current perspectives on international economic linkages

The canonical justification for arguing about international policy coordination relies on the identification (and measurement) of spillovers that operate through specific channels such as trade or international financial flows.

Some examples of research have focused on the trade channel as Beetsma, Giuliodori and Klaassen (2006) and Beetsma and Giuliodori (2011) who, among other objectives, confirm the significance of international fiscal spillovers trough commercial exchange and make distinctions, valuable for our purposes, between them conditional on comparative features of economies such as size and openness[10].

On the other hand, recent efforts have been made to explore the strength of alternative transmission channels. Such works include Faini (2006) who explains and demonstrates the relevance of fiscal spillovers working via the interest rate channel in the EMU and Corsetti and Müller (2011) whose findings point towards the pre-eminence and relevance of financial factors in an international transmission mechanism that works on domestic and foreign private spending through expectations, interest rates and international asset markets, in that sequence, extending the study on the role and impact on private spending of the *sovereign risk channel* as analysed in Corsetti et al. (2011) to an international interdependent context.

1.2.4 Between-country heterogeneity

The combination of transmission mechanisms as those mentioned above results in more complex models as in that of Corsetti, Meier and Müller (2010) in which spillovers operate in a distinctive way when trade elasticities, the relative size and openness of economies and even financial imperfections are taken into account. The inherent message is that country-specific heterogeneities amount as significant factors in the operation of international spillovers. In this sense, *home versus foreign* models cannot be a sensible approach to the study of international spillovers. More complex structures are required for policy analysis where characteristic features of economies define their roles and potential as generators of international macroeconomic externalities.

Countries differ in many aspects that have important implications for their economic performance and, clearly, for the role their economic authorities will assume in a policy game. A rigorous modelling of such sources of heterogeneity is, therefore,

[10] They specifically targeted the members of the European Union. An interesting extension with such a sample would have been to equally evaluate monetary spillovers between Euro-zone members and non-members in a similar fashion as they did for the fiscal ones.

required as an input for this investigation. An example reflecting the current context of analysis can be found in Hassan (2012) who provides a model intended to distinguish OECD members economic structures, monetary returns and their interest rate spreads based mostly on their size.

Another valuable piece of research in this sense can be traced back to Lipińska, Spange and Tanaka (2009) who, in a two-country open economy model, explain international externalities of monetary policies (with different stances) when the involved economies differ in size (being one *big* and the other *small*). Such external effect appears in the inflation-output volatility trade-off and its main transmission mechanism is restricted to bi-lateral trade channels putting aside financial channels and any role for the fiscal policy[11]. This expression of externalities from monetary policies has, nevertheless, important results for policy design purposes as it implies that the outcomes of policies in the small economy are conditional to the preferences (and actions) of the large economy.

Comparative sizes are, however, just an element of a set of characteristics that define an economy's profile. For this reason fully-fledged DSGE models, as ours, include a wider parameterisations involving numerous elasticities, mark-ups, persistence measurements, and other components integrating micro and financial foundations to their operative mechanisms. Our modelling exploits complex profiles which are also relevant in the study of financial interactions.

1.2.5 Strategic policies approach

All the above contents allow us to visualise the fast pace with which DSGE modelling has recently evolved and how it is now at a central place for macroeconomic research, particularly, for our purposes, in a policy-related context. However, as we have seen, interaction and strategic issues between heterogeneous economies have not been fully integrated in the modern context of analysis yet beyond the conditions of a monetary union and this opens a promising path for further research in the field.

In a study on strategic policies using dynamic equilibrium, Coenen et al. (2008) focused on strategic monetary policies in a two-region (United States and Euro area) game portrayed with the assistance of a large-scale DSGE model but, as they acknowledge, their application is unbalanced by disregarding the potential of fiscal policies in the map of interactions.

Another relevant example in the DSGE context is found in Gomes, Jacquinot and Pisani (2010) who developed the Euro Area and Global Economy (EAGLE) model as a policy-analysis tool intended to reflect the effects of macroeconomic

[11] Which is not even mentioned in the paper.

interdependence and policy spillovers both within the monetary union and between its members and other countries taking into account country-specific features and common shocks. Their interest in the international dimension of macroeconomic policies is shared by our own modelling as are features as staggered prices, the consideration of geographic regions, the analysis of shocks to a risk premium and the presence of both monetary and fiscal authorities although, contrastingly, the detailed description of their policies still lacks a significant component allowing for common macroeconomic shocks beyond those generated by a common monetary authority.

Also, their use of international weights is comparatively sparse. They use economic size-based weights in the definition of a common monetary target for the Euro-zone and a *double-weighting* scheme in the calculation of the effective real exchange rate which is based on bi-lateral trade weights (see Buldorini, Makrydakis and Thimann (2002)).

But perhaps the main difference with our modelling is that they keep a largely aggregated configuration (where *Home* interacts with the rest of the Euro-zone, the United States and the rest of the world) which, we argue, is insufficient especially in terms of the analysis of policy implications for a larger set of heterogeneous economies interacting in an international system. Another notable difference with our application is that they assume perfect foresight in their simulations while we give preference to a less restrictive assumption (*partial information*, see Pearlman, Currie and Levine (1986)).

The model's multi-bloc application in Gomes et al. (2010) considers a setting for the international analysis of fiscal policies although their approach goes to the anti-Ricardian extreme in which, at a zero interest rate bound, monetary policy is ineffective and all the policy responses fall into the fiscal field, limiting, therefore the scope of interactions to those between national fiscal authorities. Although this setting has some appeal for the study of *zero lower bound* conditions, it certainly lacks usefulness for a more complete analysis of the macroeconomic policy game where both fiscal and monetary authorities have roles to play and might influence their conclusions on the advantages of coordination.

We believe that exploiting an interactive framework for fiscal and monetary policies at national and international levels would lead to a better understanding of the opportunities arising from policy coordination.

1.2.6 DSGE modelling for macroeconomic policy purposes

Although there is a considerable record of previous literature (a meticulous reference for applied uses of DSGE models is found in Canova (2007)), a clear watershed in the recent development of DSGE models can be found in the contribution of Christiano, Eichembaum and Evans (2005). Based on their structure, these models have been extensively used for policy analysis purposes within a wide variety of particular interests. Their use in the context of monetary and fiscal policies research is well known nowadays.

Country-specific models are currently being used by national economic authorities namely, many central banks (see Tovar (2008)) and research bodies. Multi-country specifications, in turn, have appeared with much lower frequency in the current research activities of international organisations such as the International Monetary Fund.

These models locate themselves in a highly competitive field of modelling with well known rivalling (although sometimes complementary) alternatives such as vector auto-regressive (VAR) models. Nevertheless, the two modelling schools have often been used as true complements in such ways that they can even provide better joint forecasting outcomes as in Ghent (2009) when compared with what he calls *atheoretical models*[12]. Source of criticism against DSGE models argue on their weakness to incorporate the effects of financial markets as well as on difficulties for their empirical testing.

As described in Tovar (2008, p. 4), DSGE models are generally characterised by a theoretical reliance on the New Keynesian school and a natural bent towards real business cycles analysis. The basic general equilibrium approach, supported by thorough micro-foundations, consists of:

- Households, who

  o Consume, invest and provide differentiated labour
  o Set wages
  o Dynamically maximise a utility function which is separable in consumption, leisure and (if included) money balances subject to a budget constraint
  o Smooth consumption over time
  o Trade domestic and foreign bonds

- and Firms, which

  o Hire labour, rent capital and provide differentiated goods (intermediate, final, tradable, non-tradable, consumption, investment, public consumption)
  o Set prices (including effects such as exchange rate pass-through)

[12]When referring to VAR models, Ghent (2009, p. 880).

o Dynamically maximise a profit function (or, equivalently, dynamically minimise a cost function) subject to nominal rigidity and labour supply

These agents form equilibrium allocations and set equilibrium prices (i.e. goods prices and wages) restricted by their budget or resource constraints. Prices/wages can be modelled in a staggered (Calvo (1983)) scheme reflecting their difficulties for achieving costless and instantaneous adjustment opening, by these means, a space of action for monetary policy.

Economic authorities (namely, central banks and treasuries) influence this equilibrium setting via some policy-related instrument (such as the interest rate or taxes and expenditure) subject to exogenous (stochastic) shocks.

Nominal and real rigidities are modelled within this context in the form of staggered wages and prices, as examples of the former, and habit formation in consumption, investment costs, adjusting costs in imports and exports or incomplete capital utilisation for the latter.

When financial frictions are included, also additional agents are needed. That is why Christiano, Trabandt and Walentin (2007, p. 2) introduced *entrepreneurs*, economic agents managing capital which is financed by both domestic and external sources.

Government spending and taxation can also be included in this setting although a common practice was to rely on the individuals' Ricardian behaviour (see Barro (1974), Heijdra and van der Ploeg (2002, Ch. 6) and Blanchard and Fischer (1989, p. 56, 114, 129-130)) hence the emphasis was put on monetary policy while the role of fiscal policy was repeatedly minimised. Clear examples are found in Christiano et al. (2011) and Christoffel, Coenen and Warne (2010) who use DSGE models exclusively for monetary policy analysis in a balanced budget context as also depicted by Walsh (2010).

Nonetheless, recent developments such as GIMF (see Kumhof et al. (2007)) and Stähler and Thomas (2011) assume more realistic features in a non-Ricardian style[13] and provide an equally consequential space of action for fiscal policies. A very good and deep discussion of the contrasting modelling elements and results of non-Ricardian models has been developed by Bénassy (2007).

Diverse sectors have attracted the attention of modellers while pursuing specific research objectives. Hence there are models that incorporate the housing sector, trading and non-trading sectors, industry specific features (for example, the oil sector) and considerable, although still disperse, efforts have been done to enhance the

[13]Commonly agents with liquidity constraints, limited lifetime horizons, or the presence of distortionary taxes are features of models departing from the Ricardian paradigm.

DSGE modelling practice by the means of including financial sectors.

The stochastic component in this modelling practice arises in the form of supply, demand and monetary random shocks which are transmitted by propagation mechanisms that transform them into business cycle fluctuations.

By solving a general equilibrium model, a set of parameters is obtained from which a structural description of the economy can be derived. In particular DSGE models are expected to make available a subset of structural (*deep*) parameters as well as a complementary subset of expectations-dependent parameters.

This separation provides a concrete field for the evaluation of policies and the measurement of the impacts of shocks. This is because the model parameters describing agents' preferences, the prevailing technology and the impact mechanisms of the stochastic shocks are expected to remain invariant to policy shocks.

However, the DSGE school has also faced criticism on the grounds of the *Lucas critique* (Lucas (1976)) about the appropriateness of econometric models' recommendations for policy analysis. In Lucas' account forward-looking agents display changes in their decision rules after policy changes which leads to parameter shifts in the models. In a modern discussion on these issues Chari, Kehoe and McGrattan (2009), for example, center their criticism on the structurality and interpretability of the shocks used in New Keynesian models. In particular, they also disapprove the practice of including additional parameters in the models with the aim of improving their fit to data series while, on the other hand, those parameters lack the support of microeconomic data.

In turn, against previous studies which argued on the week relevance of the *critique* for practical purposes (among which are Estrella and Fuhrer (2003), Rudebusch (2005) and Leeper and Zha (2003)), empirical support for this criticism was provided with US data by Lubik and Surico (2010) on the grounds of not only shifts in reduced-form coefficients but also in reduced-form error variances. They argue on the sensitivity of such variances to policy changes and, therefore, on the impact this can have on the subsequent hypothesis testing. They only used, however, a compact canonical three-equation New Keynesian model with backward-looking extensions as a reduced-form representation instead of a fully-specified DSGE model which may raise questioning of their results on the following grounds:

1) In its origin, the Lucas critique was mainly directed at backward-looking models with deeper weaknesses in the description of expectations when compared to modern frameworks. As a way to address the Lucas Critique, modern DSGE modelling relies on micro-foundations and on the treatment of agents as rational utility optimizers. At the same time, empirical tools as Bayesian estimation have contributed enhance their fit to the data when compared to previous calibration

techniques (see Levine, Pearlman and Yang (2008)).

2) As stated by Walsh (2010, p. 267) the recent development of DSGE models has paid attention to the questionings pointed out by the Lucas critique by incorporating equilibrium conditions resulting from solutions to the agents and firms optimisation problems, allowing many of the models' parameters to achieve a representation of structural relationships. Micro-founded models adhering to the rational expectations hypothesis are presented as better suited for policy analysis (see Bårdsen and Nymoen (2009)). Their ability to separate structural parameters from expectational ones has been within the main argument for their robustness against the critique and in favour of their use for policy evaluation (Woodford (2003)).

But the introduction of micro-foundations does not guarantee the invariability of parameters as shown by Hurtado (2014), Cogley and Yagihashi (2010) and Chang et al. (2011) who emphasise on the misspecification in the models as a different source of similar consequences in terms of parameter drifts.

An alternative interpretation of parameter invariability that does not require deep parameters to remain unchanged forever is developed by Fernández-Villaverde and Rubio-Ramírez (2007). In their view, this interpretation still allows for structural DSGE parameters to be modelled as *time-varying*[14]. Perhaps the main criticism to such a stance would elaborate on the lack of a clear reference delimiting the range of variation within which some parameters could still be considered *structural*.

The theory on the distinction of structural parameters (intrinsically related to the identification problem in econometrics) is repeatedly traced back to Hurwicz (1962) who explains what can be branded as *structurality conditions* in a system of interdependent equations in a model "in order to make its causal properties meaningful"[15]. In the words of Sims (1977): "An identified structural equation is one which uniquely remains invariant under a certain class of "interventions"in the system."[16]

According to Ericsson and Irons (1995), the Lucas critique is, nevertheless, a theorem referring to a possible condition in the models but not a definite, general characterisation.

In view of the state of this discussion, the formulation of a DSGE model immune to the Lucas critique is a challenge that still requires a considerable amount of research which escapes the scope of this thesis. However, as stated by Hurtado (2014) these conditions are not sufficient for discarding the utility of the models in a policy-analysis context as long as the researchers acknowledge their limitations.

We have adhered to state-of-the-art DSGE modelling practices with the aim of

[14] They also included a framework of agents understanding and reacting to policy changes.
[15] Hurwicz (1962, p. 238).
[16] Sims (1977, p. 6).

providing an international perspective of macroeconomic and financial interactions. Our scheme, in this sense, inherits from those models elements like their micro-foundations, their description of rational optimising private agents and a preference for Bayesian methodologies in their estimation. All of these components, as the cited research explains, enhance the models' standing in face of possible parameter shifts.

However, as we have seen, even these considerations are not guarantee of parameter invariance. In this regard, our modelling is as exposed to the Lucas critique as the original sources we are learning from (mainly Christiano, Eichenbaum and Evans (2005) and Adolfson et al. (2005, 2007) for these purposes) which obviously constitutes an open door for further research.

An additional complication is that to the best of our knowledge no previous research has been done to this date on testing the structurality of parameters in a systemic, multi-country context featuring national and international interactions between policy-makers. This complex map of interactions is likely to have an impact on the considerations for assessing the implications of the *critique*. In our view, special considerations have to be made in the formulation of a specialised testing of the Lucas critique in this context in terms, for example, of the observability of foreign policies to domestic agents or even domestic authorities and, by these means, of their impact on expectations-formation processes.

Chapter 2

A new multi-country DSGE platform for policy analysis in OECD countries

2.1 Introduction

Dynamic Stochastic General Equilibrium (*DSGE*) modelling constitutes a central element of the current practice in macroeconomics. Among the most noted features of these models is their ability to portray the workings of the macro-economy in a consistent way integrating crucial inputs from micro-foundations and contributions from neoclassical, real-business-cycle, Keynesian and New Keynesian theories. Their framework allows for the presence of short-run disturbances (that is, unanticipated shocks) at the core of their stochastic component while, at the same time, embraces the concept of *steady state* consisting of a stable equilibrium where the depicted system rests in the absence of current and expected shocks[1]

An all-inclusive, therefore *general*, equilibrium is described as the outcome where agents (households, firms, governments, etc.) make optimising, inter-temporal decisions subject to resource constraints, initial endowments, the prevailing technology and information sets. Those agents are related to each other in the markets where prices constitute a conciliatory common ground for the exchange of goods, services (including labour) and assets.

[1] We refer, this way, to the *deterministic* definition of steady state as opposed to the *risky* steady state in which case, although there are no current shocks either, agents expect future shocks with a known probability distribution (see Juillard (2011)). For a dynamic system of the form: $x_t = [y'_{t-1}, y'_t, y'_{t+1}, u'_t]$, where y is a vector of endogenous variables and u a vector of exogenous variables (shocks and their auto-regressive structure) both contained in x, a deterministic steady state, $\bar{x}$, is defined as a solution to the system where: $0 = f(\bar{y}, \bar{y}, \bar{y}, 0) = f(\bar{x})$, that is, where past and present shocks are absent as is the uncertainty about the future (see Lan and Meyer-Gohde (2013)). There, f is a continuously differentiable vector-valued function.

The use of *policy shocks*[2] in the DSGE characteristic forward-looking framework is illustrative of causes of deviations from a steady state equilibrium derived from specific actions taken by economic authorities and, in this respect, valuable for experimental design looking on the interactions between those authorities. For the purposes of our empirical study, we concentrate of this class of shocks although the model also allows for experimental exercises based on other types of disturbances as technology, preferences and markup shocks which we leave for future applications.

It is clear that the information provided by these models is bounded by the number of relationships they are able to manage. The DSGE school has recently been subject to a wave of criticism in relation to particular shortcomings related to the analysis of conditions that lead to the 2007-2009 financial crisis. Among those criticisms was the lack of components representing developments in the financial sector and the impact of the associated financial frictions. In response, the DSGE school evolved into a generation of models with greater awareness about financial phenomena with macroeconomic implications. The depiction of financial intermediation has made considerable progress and put the models in better shape to embrace the resulting relationships.

But, in our view, another relevant aspect seems to be repeatedly neglected by the previous DSGE literature in relation to a wider regional or even global perspective of macroeconomic analysis. Our criticism stems from the observation that the current conditions of international exchanges of goods, services, assets and others, like financial risks, in spite of their evident relevance in practice, have not been sufficiently discussed by this branch of modelling literature and, then, contribute to justify our claim on the need for models with a more comprehensive outlook on international networks, distinguishing the outcomes of interactions between heterogeneous economies.

Ever since the initial steps towards the creation of the Euro-zone a considerable number of models emerged looking into the implications of the monetary union for the constituent economies while, at other side of the spectrum, there is a list of national models describing with varied degrees of interest the economic relationships with foreign economies, sometimes even falling for the simplifying two-country scheme where the *domestic* and the *foreign* economy interact with little attention

[2]Defined in the context of our study as actions taken by economic authorities, as treasuries or central banks, in relation to a variable under their influence (which therefore constitutes a *policy instrument* such as government spending and taxation in the case of fiscal policies or official interest rates for monetary policies), which cannot be anticipated by private agents in the model. The uncertainty component invoked in this definition on the part of households and firms, effectively discounts those policy responses which are generated in an automatic manner after specific and observable economic developments as is the case of the actions associated to pre-committed rules by the economic authorities.

to the heterogeneities that distinguish each one of them.

Previous literature on DSGE macroeconomic modelling has been largely dominated by three generic partial attempts to approach international interactions:

1. models investigating the conditions imposed by monetary unions, only, (Smets and Wouters (2003), Coenen and Wieland (2005), Dieppe et al. (2005), Adolfson et al. (2007), Ratto et al. (2009), Christoffel et al. (2009), Gelain (2010), Gerali et al. (2010)),

2. two or three-country settings where the included economies generally share hegemonic roles (as the United States, the Euro-zone as an aggregate, and Japan) (Taylor (1993), Coenen and Wieland (2002), Erceg et al. (2008), Coenen et al. (2008), Rabanal (2009), Cogan et al. (2013)), and

3. national models interacting with the rest of the world assumed as an exogenous, large economy (Rudebusch and Svensson (1999), Levin et al. (2003), Altig et al. (2005), Murchison and Rennison (2006), Lubik and Schorfheide (2007), Medina and Soto (2007), Gouvea et al. (2008), Christiano et al. (2010), Funke et al. (2011), Taylor and Wieland (2011), Funke and Paetz (2013)).

Their account of international interactions and specific outcomes of relevance for macroeconomic policies is, therefore, restricted by the scope of either of those stances. Economic and financial interactions also have a crucial role on the performance of national economies not sharing a common currency but where supply chains, trade agreements and financial flows similarly constitute international factors of relevance for economies which, most frequently, do not display economic convergence nor have undergone deliberate programs to achieve it. The interactions between dissimilar economies has been poorly explored within the DGSE literature and therefore offers ample scope for new contributions.

But the extent of current international networks also implies that a simple repeated calibration and application of national models, as in the third group, is not enough for the depiction of the external conditions faced by each economy, in particular, when considering the presence of common regional or global shocks and international policy spillovers.

Few exceptions escape the above classification by incorporating a wider international perspective in DSGE macroeconomics as Kumhof et al. (2010). To address the limitations of previous literature, we aim to follow their lead by analysing a more complex spectrum of national cases and the networks they form in the corresponding world regions. In this sense, we believe that modern tools for macroeconomic analysis must be adapted in response to an increasing extent in the reach of common shocks across and between regions.

Our approach and modelling constitutes one of such extensions. Based on an open-economy DSGE structure, our extended framework accounts for numerous features of heterogeneous economies (as described by the country-specific parameterisations we calculated for each national model) as well as for key linkages they display between each other all of which results in an enhanced setting for the analysis of their exposure to international economic and financial shocks. We contribute to the integration of a larger regional scope of analysis into a DSGE scheme in such a way that we can assess the macroeconomic interactions between the members of three main economic regions of the world (North America, the Euro-zone, and the Asia-Pacific region) as well as their cross-regional interactions.

In the context of this network-based approach, we also innovate by the means of the weighting scheme used in the calculation of country-specific foreign variables which depict commercial and financial linkages between heterogeneous economies across the regions under scrutiny. International weights are embedded into the resulting international DSGE framework mediating between national models which are simultaneously solved depicting in a more consistent way international conditions in the presence of macroeconomic interactions. To the best of our knowledge, this scheme is an original contribution to this field of modelling.

In contrast to previous research, our comprehensive framework with a larger set of participants is useful in order to obtain a corresponding description of crucial comparable characteristics related to the outcomes of disturbances at different levels of international aggregation (by which we mean national, regional or global[3] and, with them, a specific and comparable description of the degrees of exposure displayed by national economies to a collection of international shocks similar to those we have observed in recent economic history.

Previous discussions of international interactions have also faced complications in defining the roles that economies assume in an international *game*. On this issue, based on our bi-directional commercial and financial weights, we provide objective information for the selection of roles given the revealed nature of their intra and inter-regional degrees of influence in commercial and financial terms. This way, within the networks of international exchanges, national units assume different roles in the regions they interact with. Specifically, in our setting they may act as *generators* or *receivers* of regional disturbances according to their relevance towards other economies.

In our modelling the international effects of policy shocks constitute externalities to which national and regional authorities have to interactively adjust. Nonetheless,

[3]Here, a precision must be made since when we refer to *global* aggregation it is in the sense of including *all the economies in a subset of countries* in the world.

in addition to policy shocks, other sources of disturbances in the macroeconomic context, as foreign variables and comparative measurements of risk are equally important to consider for a robust evaluation of the relative vulnerability of an economy to international events. Our results show main features of the impacts of those shocks on a set of representative macroeconomic variables in terms of their direction, relative size and persistence. These are important contributions which our extended framework allows us to analyse from an empirical international perspective.

That is why the Organisation for Economic Cooperation and Development (OECD) provides a well-suited sample for our analysis given the dispersion of their member economies not only in geographic terms but also in relation to their distinctive features as participants of the existing commercial and financial networks across the world. In this sense, our regional coverage is a unique example within DSGE studies[4].

We look, for example, into the relative vulnerabilities displayed by selected economies in this group to regional shocks as well as to the events and policies occurring in key economies, as the United States, Germany and Japan, or regions as the Euro-zone, NAFTA[5] and the Asia-Pacific region[6]. This means, that our regional approach is not restricted to the presence of a monetary union, although it has the ability to include participants which are sharing a single monetary policy, but also includes the analysis of relationships based on other crucial linkages. A region is defined, then, every time there is a network-related justification for considering the grouping of its members as such (on the grounds of intense commercial or financial exchanges, for example).

Our model represents an advancement on the inclusion of international factors in DSGE macroeconomics while, at the same time, it retains the bases of well-established theoretical foundations within its contemporary modelling practice. In addition to country-specific parameterisations, a number of innovations are integrated in the main body of the model for the description of international relationships, among them are the sets of bi-directional weights reflecting the comparative relevance of counterparts in relation to trade and financial exchanges and the calculations of weighted country-specific foreign variables taking advantage of the ability of the model's computing platform to seamlessly adapt to particular sets of countries of interest as required by each experimental setting.

[4]Still, our modelling remains open to further additions in terms of participating countries once subsequent calculations of their national parameters have been performed and the macroeconomic data is fed into the computing platform.

[5]Standing for North-America Free Trade Agreement, signed by Canada, the United States and Mexico.

[6]Under our definition this region is composed by Australia, Japan, New Zealand and South Korea.

The remainder of the Chapter proceeds as follows: Section 2.2 sets out the modelling foundations on which our model is built on, Section 2.3 describes our multi-country transformation of the model and other extensions, Section 2.4 briefly describes the methodological basis for the model's solution and estimation and also gives an account of the data used in the empirical exercises, in Section 2.5 we perform a number of simulations concerning different scenarios with international policy-relevant shocks in OECD economies and regions based on the information provided by our estimations of the model. Finally, Section 2.6 includes our conclusions.

2.2 Contemporary DSGE modelling for macroeconomic policy evaluation

Among other critical features, an improved and concise depiction of nominal rigidities in prices and wages across the economy helped the work of Christiano, Eichenbaum and Evans (2005) (CEE) to become a necessary reference in current DSGE modelling and, in many senses, a new paradigm for this modelling school. The framework of their model has served as the baseline for numerous modified versions, each one looking to specialise in specific areas of interest for researchers. In the next section we describe the main representative components of their modelling, many of which constitute the bases for subsequent adaptations in the context of our own configuration.

2.2.1 The bases of the CEE paradigm

Households

In this setting, a mass of $i \in (0,1)$ homogeneous households care about *changes* in their consumption, c_t, the amount of labour effort they apply, l_t, and real money balances, q_t. Therefore their discounted expected lifetime utility functions are defined as:

$$E_{t-1}^{i} \sum_{l=0}^{\infty} \beta^{l-t} \left[u\left(c_{t+l} - bc_{t+l-1}\right) - z(l_{i,t+l}) + v(q_{t+l}) \right] \tag{2.2.1}$$

where l_t measures hours of work[7] and $q_t = \frac{Q_t}{P_t}$ with Q_t being nominal cash balances and P_t the price level. The parameter $b > 0$, it represents a degree of habit formation. In turn, the expectations operator E_{t-1}^{i} denotes the idiosyncratic nature of the

[7] The notation has been modified in order to give as much consistency with the following sections as possible.

information available to each household [8] and β is a discount factor.

Asset dynamics

The mechanism of households' asset variation in time is given by:

$$\begin{aligned} M_{t+1} = R_t \left[M_t - Q_t + (\mu_t - 1) M_t^a \right] + B_{i,t} + Q_t \\ + W_{i,t} l_{i,t} + R_t^k u_t \bar{k}_t + D_t - P_t \left[i_t + c_t + a(u_t) \bar{k}_t \right] \end{aligned} \tag{2.2.2}$$

where M_t is the money stock in period t, μ_t is gross rate of growth of the per capita stock of money, $W_{i,t} h_{i,t}$ is labour income, $\bar{k}_t$ is the physical stock of capital, u_t is a rate of capital utilisation, R_t is the gross nominal interest rate, while R_t^k is a rate of return from lending capital to firms. D_t are profits transfers from firms and B_t are the cash inflows from state-contingent security markets. The purchases of investment goods at time t are represented by i_t.The cost of consumption is represented by $P_t c_t$ while $P_t \left[i_t + a(u_t) \bar{k}_t \right]$ reflects the costs of investing and maintaining physical capital.

Capital accumulation and utilisation

Capital dynamics are complemented in this framework by describing a technology function $F(\cdot)$ which transforms investment goods, i_t, into physical capital. Capital accumulation therefore follows:

$$k_{t+1} = (1 - \delta) k_t + F(i_t, i_{t-1}) \tag{2.2.3}$$

where:

$$F(i_t, i_{t-1}) = \left[1 - S\left(\frac{i_t}{i_{t-1}} \right) \right] i_t \tag{2.2.4}$$

and the function $S(\cdot)$ describes a mechanism of investment adjustment costs. In CEE this function is restricted to satisfy $S(1) = S'(1) = 0$.

One of the features of the CEE model is that it allows for different rates of capital utilisation, u_t, selected by households in such a way that:

$$k_t = u_t \bar{k}_t \tag{2.2.5}$$

This gives rise to the possibility of operating capital, k_t, being lower than the actual capital stock available in the economy. This decision has a direct impact on their financial earnings as shown by $R_t^k u_t \bar{k}_t$ in equation (2.2.2) as well as the costs they incur in relation to capital maintenance expenses denoted by $a(u_t) \bar{k}_t$ with $a(\cdot)$ being an increasing convex function.

[8] Although there is no variation in their types as in other models, especially those addressing the implications of financial intermediation.

Wage setting

Each household is a monopolistic supplier of differentiated labour, able to set its wage. It is hired by a representative firm which adds its total labour inputs, L_t, as:

$$L_t = \left(\int_0^1 l_{i,t}^{\frac{1}{\lambda_w}} \, di \right)^{\lambda_w} \tag{2.2.6}$$

with the wage markup $1 \leq \lambda_w < \infty$.

The labour demand for a household depends on the wages as:

$$l_{i,t} = \left(\frac{W_t}{W_{i,t}} \right)^{\frac{\lambda_w}{(\lambda_w - 1)}} L_t \tag{2.2.7}$$

W_t is the aggregate wage rate resulting from:

$$W_t = \left[\int_0^1 (W_{i,t})^{\frac{1}{(1-\lambda_w)}} \, di \right]^{1-\lambda_w} \tag{2.2.8}$$

From the perspective of each household L_t and W_t are given references.

The introduction of Calvo (1983) contracts as a way of explaining nominal rigidities is characteristic of this modelling framework which has been repeatedly replicated in numerous successive model adaptations. Under this configuration, households may or may not be able to re-optimise its nominal wage each period according to a probability of $1 - \xi_w$. This probability is assumed to be independent between households and time periods. In the case of those households who are not able to re-optimise, their wages follow a simple backward-looking indexation rule:

$$W_{i,t} = \pi_{t-1} W_{i,t-1} \tag{2.2.9}$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is the economy-wide inflation rate.

Wage stickiness plays and important part in the description of nominal rigidities in this context. In fact, the empirical analysis performed in CEE shows that the nominal rigidities arising from wage stickiness are even more important than those resulting from price stickiness in terms of their contribution to the performance of the model.

Intermediate goods firms

Intermediate production is realised in monopolistic markets using capital, $k_{j,t}$, and labour, $L_{j,t}$,with the following technology:

$$Y_{j,t} = \left\{ \begin{array}{ccc} k_{j,t}^{\alpha} L_{j,t}^{1-\alpha} - \phi & \text{if} & k_{j,t}^{\alpha} L_{j,t}^{1-\alpha} \geq \phi \\ 0 & & \text{Otherwise} \end{array} \right\} \tag{2.2.10}$$

where $0 < \alpha < 1$ is the output-elasticity of capital and $\phi > 0$ represents a fixed cost of production.

Wages paid in advance mean that each intermediate firm must borrow $W_t L_{j,t}$ from a financial intermediary at the beginning of each period, repaying it at the end with the costs implied by the interest rate, R_t.

Total costs of production, therefore, are calculated as the sum of the rental costs of capital, wages paid in advance (with the associated charges) and fixed costs:

$$TC_t = r_t^k k + w_t R_t l + \phi \tag{2.2.11}$$

where $r_t^k = \frac{R_t^k}{P_t}$ and $w_t = \frac{W_t}{P_t}$ yielding a real marginal cost of:

$$s_t^{CEE} = \left(\frac{1}{1-\alpha} \right)^{1-\alpha} \left(\frac{1}{\alpha} \right)^{\alpha} \left(r_t^k \right)^{\alpha} \left(w_t R_t \right)^{1-\alpha} \tag{2.2.12}$$

Then, total profits are given by:

$$\Pi_t = \left[\left(\frac{P_{j,t}}{P_t} \right) - s_t^{CEE} \right] P_t Y_{j,t} - \phi \tag{2.2.13}$$

Price setting

In a similar fashion as wages, a Calvo scheme implies that prices are set each period with a probability $1 - \xi_p$ of the firm being able to re-optimise it independently from other firms and time periods. Under these conditions re-optimisations, $\tilde{P}_t$, when they occur, do so before the realisation of money growth in that period and aim to maximise:

$$E_{t-1} \sum_{l=0}^{\infty} \left(\beta \xi_p \right)^l \upsilon_{t+l} \left(\tilde{P}_t X_{tl} - s_{t+l}^{CEE} P_{t+l} \right) Y_{j,t+l} \tag{2.2.14}$$

subject to (2.2.18), (2.2.12) and:

$$X_{tl} = \left\{ \begin{array}{ccc} \pi_t \times \pi_{t+1} \times ... \times \pi_{t+l-1} & \text{for} & l \geq 1 \\ 1 & \text{for} & l = 0 \end{array} \right\} \tag{2.2.15}$$

where υ_t is the exogenous and constant marginal value of a monetary unit for a household in terms of utility, E_{t-1} is a shorthand for $E\left[\cdot|\mu_{t-l}\right]$ with $l \geq 1$, that is, the expectations operator conditional on lagged rates of money growth, μ_{t-l}.

Alternatively, firms unable to re-optimise simply index their prices to past inflation:

$$P_{j,t} = \pi_{t-1} P_{t-1} \tag{2.2.16}$$

Final goods firms

The production scheme is based on a representative firm in a perfectly competitive market for the final consumption good Y_t which requires a set of intermediate goods, $Y_{j,t}$. The production technology is:

$$Y_t = \left(\int_0^1 Y_{j,t}^{\frac{1}{\lambda_f}} \, dj \right) \tag{2.2.17}$$

with a markup in the domestic goods markets $1 \leq \lambda_f < \infty$.

This market structure implies that the firm takes the final and intermediate goods prices, P_t and $P_{j,t}$, respectively, as given. This way, the Euler equation for profit maximisation is given by:

$$\left(\frac{P_t}{P_{j,t}} \right)^{\frac{\lambda_f}{\lambda_f - 1}} = \frac{Y_{j,t}}{Y_t} \tag{2.2.18}$$

The general price level is aggregated as:

$$P_t = \left[\int_0^1 P_{j,t}^{\frac{1}{1-\lambda_f}} \, dj \right]^{1-\lambda_f} \tag{2.2.19}$$

Monetary and fiscal policies

This framework is largely focused on monetary policy leaving, therefore, a negligible role for fiscal policies by assuming Ricardian features in the behaviour of households and a permanently balanced governmental budget. Monetary policy, in turn, is defined as a cumulative series of policy shocks, ϵ_{t-l}:

$$\mu_t = \mu + \theta_0 \epsilon_t + \theta_1 \epsilon_{t-1} + \theta_2 \epsilon_{t-2} + ... \tag{2.2.20}$$

where μ_t is the mean growth rate of money which constitutes the monetary instrument of this model. Each shock has an associated weighting, θ_l, although CEE are not explicit on the features associated to these parameters.

Monetary components and financial intermediation

Each household's money stock is affected by the general level of per capita money M_t^a which grows at a rate μ_t, therefore $(\mu_t - 1)\, M_t^a$ represents a lump-sum transfer from the monetary authority.

In turn, households make deposits in financial intermediaries by the amount of $M_t - Q_t + (\mu_t - 1)\, M_t^a$ from which they earn a return equal to the gross nominal interest rate R_t.

The resources that are not kept by households as cash, $M_t - Q_t$, are deposited in financial intermediaries who also receive $(\mu_t - 1)\, M_t$ from the monetary authority. In equilibrium $M_t^a = M_t$.

Market clearing and equilibrium

In CEE, the money market clearing condition implies that advanced payments to intermediate firms' labour are financed by loans equalling the total of intermediaries' money:

$$W_t L_t = \mu_t M_t - Q_t \tag{2.2.21}$$

Finally, the aggregate resource constraint in this economy[9] is given by:

$$c_t + i_t + a(u_t)\bar{k}_t \leq Y_t \tag{2.2.22}$$

The equilibrium of the model was approximated by a method of undetermined coefficients following Christiano (2002).

2.2.2 Further developments in DSGE modelling

Notwithstanding their popularity among central banks, especially during the last two decades, for the analysis of monetary aspects, other components beyond the monetary context have gained increased acceptance as relevant additions to the basic lines of DSGE modelling. This way hybrid models arose in the search for further enhancements in the depiction of elements like demographic dynamics and other policy issues as in the case of non-Ricardian models[10].

A more robust theoretical background along with improved estimation techniques placed these models as direct competitors to Bayesian vector auto-regressive (BVAR) models as explained in Smets and Wouters (2003). In some instances, the

[9]We believe this is the correct expression. In CEE (p. 14) this equation appears as:

$$c_t + i_t + a(u_t) \leq Y_t$$

[10]See Bènassy (2007) and the example of the GIMF model in Kumhof et al. (2010).

two branches would *join* in a collaborative scheme as proposed by Del Negro and Schorfheide (2004).

This discussion has also led to a relevant contribution in the context of our study as is the case made by Dees et al. (2014) for a multi-country macroeconomic modelling scheme assisted by the GVAR framework (Pesaran et al. (2004) and Dees et al. (2007)). In such a scheme the GVAR econometric structure is used for the estimation of individual (national) models which are then combined into a larger global system able to display the international effects of shocks. Their application to a compact New Keynesian model shows the versatility of the GVAR methodology. An recent example of its joint application with more complex DSGE systems is found in Razafindrabe (2016) where a global VAR model is used for the estimation of the steady state observable endogenous variables of a DSGE model depicting international linkages between heterogeneous economies. His analysis, mainly focused on the international implications of economic shocks for the Eurozone, makes use of international trade weights through the setting of the global VAR methodology.

As economic research tools, DSGE models have displayed a considerable orientation towards policy analysis and, in that context, emblematic models have been developed by national and international institutions. The Federal Reserve's SIGMA, the Chilean central bank's MAS, the Bank of England's BEQM, the Sveriges Riksbank RAMSES I and II, the European Comission's QUEST and the IMF's GEM and GIMF models are some examples of the place given to the DSGE school in policy-related contexts as well as of the breadth of their insertion in economic research departments.

The bases of a contemporaneous DSGE model are mostly provided by New Keynesian and real business cycle theoretical structures enhanced by micro-foundations and relevant descriptions on the mechanisms behind real and nominal rigidities. The models are able to describe the economic interrelations operating between households, firms and macroeconomic authorities in an economy and, in some cases, they adopt a wider international perspective as in multi-country models where the relevance of international shocks is carefully analysed.

Within the set of building blocks for these models there is a description of agent preferences, technological constraints and exogenous shocks all of which boil down to decision rules expressed as first order conditions from the solution of optimisation problems. It must also be mentioned that behind the design of any of these models are critical assumptions on the formation of expectations on future trends for variables within the agents' concern. Bringing together all these elements, the ultimate role of the model is to fill the connections between endogenous variables, parameters (reflecting information about micro-foundations, for example) and stochastic shocks in such a way that a stable solution (denoted as the *steady state*) can be achieved.

A varied structure of shocks can be incorporated to this framework including technology, preferences, mark-up and policy shocks (fiscal and monetary). This is valuable for exploring the consequences of disturbances within different aspects of the economy and, particularly, the repercussions of macroeconomic policies. The extension from open-economy models to multi-country settings is also an interesting development in terms of the study of spillovers between economies. In the current context, this also implies a strong requirement for DSGE models to incorporate an improved set of components reflecting the impact of financial sectors and their inherent disturbances.

On this requirement, a response has taken the form of new models integrating the *financial accelerator* approach based on Bernanke, Gertler and Gilchrist (1999) by the means of which the fluctuations in credit markets are transmitted (and amplified) to the rest of the economy. As we will analyse in the next chapter, alternative approaches in relation to the representation of the banking system as in Gertler and Kiyotaki (2010) have gained popularity in the description of the effects of financial frictions.

The expansion of DSGE models to a multi-country space allows for a number of attractive lines of research. International financial and policy spillovers can be analysed by the means of such a setting where the opportunities for formal or informal coordination are revealed. Our multi-country model, in particular, incorporates two special features which make it stand out from the canonical structures of previous models. First, international financial and trade weights intervene in the definition of country-specific foreign variables where each counterpart is given a role (weight) in consistence with the distinctive historical evidence on bi-lateral exchanges. Secondly, we introduce a collection of common shocks between economies which can operate at the regional or even at the global level. In our view, this is an enhanced reflection of current circumstances dominated by network-clusterings that arise as a result of commercial and financial flows.

The contributions of our model are, therefore, centred around the international component of macroeconomic policies which we exploit to measure the impact of the externalities exchanged between economies. Other country-specific conditions modify the potential of those externalities, in particular, elements from each economy's characteristic profile such as technology, the composition of consumption and investment (that is, both including domestic and foreign goods in particular proportions) or inflation persistences are key components that provide a specific depiction of the potential international impacts registered by each country in terms of macroeconomic and financial variables.

From the simulation of the model we learn about the international repercussions of a number of country-specific and regional shocks. The spread and characteristic intensity of their impacts also supply valuable information about of the roles held by each of the studied economies within the OECD group.

2.2.3 A note on linearisation

It is common practice to linearise the model's equations around the steady state before calculating a solution. This also contributes to achieve a clearer interpretation of the results from subsequent simulations and/or estimations.

The most common method is known as log-linearisation. This procedure relies on two main components:

a) A Taylor series expansion. Given a function $F(X_t, Y_t)$, a first-order expansion proceeds as:

$$F(X_t, Y_t) \approx F(X, Y) + \frac{\partial F}{\partial X_t}(X_t - X) + \frac{\partial F}{\partial Y_t}(Y_t - Y)$$

where X and Y represent steady-state values.

b) The definition of log-linearised variables as:

$$\widehat{X}_t = \frac{X_t - X}{X}$$

Integrating these two elements, log-linearisation results in expressions like:

$$f(X_t, Y_t) \approx \frac{X}{F}\frac{\partial F}{\partial X_t}\widehat{X}_t + \frac{Y}{F}\frac{\partial F}{\partial Y_t}\widehat{Y}_t$$

2.3 Multi-country open-economy model

The literature on DSGE modelling has given birth to a myriad of particular transformations and adaptations intended to account for important features that economies display in the current context of international exchanges. One such derivation incorporating a number of valuable features for the study of macroeconomics with an international perspective has been provided by Adolfson, Laseén, Lindé and Villani (2005, 2007) (henceforth *ALLV*) in the RAMSES[11] model, encompassing the CEE modelling paradigm as well as issues concerning the international transmission of shocks and contributions from the *New Open Economy Macroeconomics*.

[11] Riksbank Aggregate Macromodel for Studies of the Economy of Sweden.

The ALLV benchmark contains key features for the description of interactions in an international context where households' consumption and investment are composed by both domestic and imported goods and where there is an exporting sector completing the commercial set of exchanges with their corresponding nominal and real implications for the involved economies.

Its formulation in terms of price-rigidities both at home and abroad in conjunction with the inclusion of foreign trade and foreign bonds accounts for crucial components participating in the transmission of shocks between economies. The effects of such shocks are modified by an incomplete pass-through mechanism built in the spirit of Smets and Wouters (2002).

Building on the ALLV open-economy model's structure, we develop a multi-country setting capable of accounting for a number of heterogeneities between economies as well as for regional factors affecting their macroeconomic performance as is the case of regional and/or global shocks in the sense explained above. As it will become evident in the subsequent sections, our emphasis mainly develops around the international effects of policy shocks although the richness of the model in relation to available shocks allows for a wide variety of experiments beyond that set.

From the ALLV framework Calvo (1983) schemes contribute to establish a background with nominal rigidities which partially temper the international impacts of disturbances in a participant economy. We additionally incorporate a set of bi-lateral weightings to distinguish in more detail the specific implications of the shocks for each country as well as for its economic and financial network.

Under our configuration, the model is extended to include $i = 1, 2, ..., N$ countries and $r = 1, 2, ..., G$ regions[12] with $G \leq N$ (at the extreme case each country is a region). Each individual economy is characterised by a set of idiosyncratic and, if applicable, common (i.e. regional) parameters constituting a *profile*. *Core* or structural heterogeneities arise from distinctive economy sizes, endowments of capital and parameter profiles while *operative* heterogeneities appear as a consequence of differences between countries in other variables such as the consumption/investment ratio or policy-related indicators.

2.3.1 Households

Each economy, i, comprises a mass of h households who derive utility from consumption, C (which includes domestic and foreign goods) and real assets, Q/P, and dis-utility from labour, l. The lifetime discounted utility of households is then given

[12] Not every country has necessarily to be in a region. On the other hand, there is enough flexibility in the model to perform simulations or estimations including, at the same time, countries both in and out of a pre-defined region.

by:

$$E_0^h \sum_{t=0}^{\infty} \beta_i^t \left[\zeta_{i,t}^c \ln \left(C_{h,i,t} - b_i C_{h,i,t-1} \right) + A_q \frac{\frac{Q_{h,i,t}}{z_{i,t} P_{i,t}}^{1-\sigma_i^q}}{1-\sigma_i^q} - \zeta_{i,t}^l A_L \frac{\left(l_{h,i,t} \right)^{1+\sigma_i^L}}{1+\sigma_i^L} \right] \quad (2.3.1)$$

where β_i^t is a discount rate, b_i measures habit formation, $z_{i,t}$ is a scaling parameter for non-interest real assets, A_L and A_q are constants while σ_i^q and σ_i^L are risk aversion parameters of the CRRA[13] elements of this utility function.

Preference shocks on consumption and labour are described by the following time-series:

$$\widehat{\zeta}_{i,t}^c = \rho_{i,\zeta^c} \widehat{\zeta}_{i,t-1}^c + \sigma_{i,\zeta^c} \varepsilon_{\zeta^c,i,t} \quad (2.3.2)$$

$$\widehat{\zeta}_{i,t}^l = \rho_{i,\zeta^l} \widehat{\zeta}_{i,t-1}^l + \sigma_{i,\zeta^l} \varepsilon_{\zeta^l,i,t} \quad (2.3.3)$$

where ρ_{i,ζ^c} and ρ_{i,ζ^l} measure one-period persistence and $\varepsilon_{\zeta^c,i,t}$ and $\varepsilon_{\zeta^l,i,t}$ are *iid* country-specific shocks.

Equation (2.3.2) depicts consumption preference shocks and (2.3.3) labour supply shocks[14] with $E(\zeta_{i,t}^c) = E(\zeta_{i,t}^l) = 1$, $\widehat{\zeta}_{i,t}^c = \left(\zeta_{i,t}^c - 1 \right)$ and $\widehat{\zeta}_{i,t}^l = \left(\zeta_{i,t}^l - 1 \right)$.

Consumption is integrated by domestic, $C_{i,t}^d$, and imported, $C_{i,t}^m$, goods in a basket as:

$$C_{i,t} = \left[\left(1 - \omega_i^{mc} \right)^{\frac{1}{\eta_{mc}}} \left(C_{i,t}^d \right)^{\frac{\eta_{mc}-1}{\eta_{mc}}} + \left(\omega_i^{mc} \right)^{\frac{1}{\eta_{mc}}} \left(C_{i,t}^m \right)^{\frac{\eta_{mc}-1}{\eta_{mc}}} \right]^{\frac{\eta_{mc}}{\eta_{mc}-1}} \quad (2.3.4)$$

where η_{mc} is the elasticity of substitution between domestic and imported consumption goods and ω_i^{mc} is the proportion of spending on imported consumption goods which also weights the participation of their prices in the overall consumption price index:

$$P_{i,t}^c = \left[\left(1 - \omega_i^{mc} \right) \left(P_{i,t} \right)^{1-\eta_{mc}} + \omega_i^{mc} \left(P_{i,t}^{mc} \right)^{1-\eta_{mc}} \right]^{\frac{1}{1-\eta_{mc}}} \quad (2.3.5)$$

Maximisation of (2.3.4) subject to $P_{i,t} C_{i,t}^d + P_{i,t}^{mc} C_{i,t}^m = P_{i,t}^c C_{i,t}$ provides the demand functions for each component of aggregate consumption:

$$C_{i,t}^d = \left(1 - \omega_i^{mc} \right) \left[\frac{P_{i,t}}{P_{i,t}^c} \right]^{-\eta_{mc}} C_{i,t} \quad (2.3.6)$$

$$C_{i,t}^m = \omega_i^{mc} \left[\frac{P_{i,t}^{mc}}{P_{i,t}^c} \right]^{-\eta_{mc}} C_{i,t} \quad (2.3.7)$$

Following a similar structure, investment, $I_{i,t}$ is composed by domestic , $I_{i,t}^d$, and

[13]Constant Relative Risk Aversion.

[14]As ALLV, we denote log-linearised variables with a hat throughout the model.

imported goods, $I^m_{i,t}$:

$$I_{i,t} = \left[\left(1-\omega^{mi}_i\right)^{\frac{1}{\eta_{mi}}}\left(I^d_{i,t}\right)^{\frac{\eta_{mi}-1}{\eta_{mi}}} + \left(\omega^{mi}_i\right)^{\frac{1}{\eta_{mi}}}\left(I^m_{i,t}\right)^{\frac{\eta_{mi}-1}{\eta_{mi}}}\right]^{\frac{\eta_{mi}}{\eta_{mi}-1}} \tag{2.3.8}$$

where η_{mi} is the elasticity of substitution between domestic and imported investment goods and ω^{mi}_i is the proportion of spending on imported investment goods which also weights the participation of its prices in the aggregate investment price index:

$$P^i_{i,t} = \left[\left(1-\omega^{mi}_i\right)\left(P_{i,t}\right)^{1-\eta_{mi}} + \omega^{mi}_i\left(P^{mi}_{i,t}\right)^{1-\eta_{mi}}\right]^{\frac{1}{1-\eta_{mi}}} \tag{2.3.9}$$

Equality between the prices of domestically produced consumption goods and domestically produced investment goods provides the following investment demand functions:

$$I^d_{i,t} = \left(1-\omega^{mi}_i\right)\left[\frac{P_{i,t}}{P^i_{i,t}}\right]^{-\eta_{mi}} I_{i,t} \tag{2.3.10}$$

$$I^m_{i,t} = \omega^{mi}_i\left[\frac{P^{mi}_{i,t}}{P^i_{i,t}}\right]^{-\eta_{mi}} I_{i,t} \tag{2.3.11}$$

Besides additional investments, households control a variable rate of utilisation of capital:

$$u_{h,i,t} = K_{h,i,t}/\overline{K}_{h,i,t} \tag{2.3.12}$$

defining the difference between capital in use, $K_{i,t}$, and total available capital, $\overline{K}_{i,t}$. The log-linearised version of this relationship aggregated at the national level can be written as:

$$\widehat{u}_{i,t} = \widehat{k}_{i,t} - \widehat{\overline{k}}_{i,t} \tag{2.3.13}$$

But changes in the utilisation are subject to a cost function $a(u_{h,i,t})$ with $a(1) = 0$, $a' = (1-\tau^k_i)r^k_i$, where τ^k_i is a capital-income tax and r^k_i is the rental rate of capital, and $a'' \geq 0$.

Capital accumulation (aggregated at the national level) after depreciation, δ_i, is given by:

$$\overline{K}_{i,t+1} = (1-\delta_i)\overline{K}_{i,t} + \Upsilon_{i,t}F(I_{i,t}, I_{i,t-1}) \tag{2.3.14}$$

which linearised becomes[15]:

$$\widehat{\bar{k}}_{i,t+1} = (1-\delta_i)\frac{1}{\mu_z}\widehat{\bar{k}}_{i,t} - (1-\delta_i)\frac{1}{\mu_z}\hat{\mu}_{z,i,t} + \left(1-(1-\delta_i)\frac{1}{\mu_z}\right)\widehat{\Upsilon}_{i,t} + \left(1-(1-\delta_i)\frac{1}{\mu_z}\right)\widehat{i}_{i,t} \tag{2.3.14*}$$

Assuming the transformation technology:

$$F(I_{i,t}, I_{i,t-1}) = \left(1 - \tilde{S}\left(\frac{I_{i,t}}{I_{i,t-1}}\right)\right) I_{i,t} \tag{2.3.15}$$

with $\tilde{S}(\mu_{i,z}) = \tilde{S}'(\mu_{i,z}) = 0$, $\mu_{i,z}$ is an exogenously given technology growth parameter and $\Upsilon_{i,t}$ following a stationary exogenous AR(1) process for investment technology shocks:

$$\widehat{\Upsilon}_{i,t} = \rho_{i,\Upsilon}\widehat{\Upsilon}_{i,t-1} + \sigma_{i,\Upsilon}\varepsilon^{\Upsilon}_{i,t} \tag{2.3.16}$$

where $\widehat{\Upsilon}_{i,t} = (\Upsilon_{i,t} - 1)$.

ALLV describe two sources of uncertainty faced by households. In the first place they are subject to the common (nation-wide) shocks and, secondly, as labour suppliers they also experience idiosyncratic risks in the form of Calvo-style[16] staggered wages leading them to acquire a portfolio of securities as insurance against that set of risks (assuming, then, complete financial markets). A household's budget constraint is given by:

$$\begin{aligned}
&M_{h,i,t+1} + \widetilde{S}_{i,t}B^*_{h,i,t+1} + P^c_{i,t}C_{h,i,t}(1+\tau^c_{i,t}) + P^i_{i,t}I_{h,i,t} + P_{i,t}\left(a(u_{h,i,t})\overline{K}_{h,i,t}\right)\\
&= R_{i,t-1}(M_{h,i,t} - Q_{h,i,t}) + Q_{h,i,t} + (1-\tau^k_{i,t})\Pi_{h,i,t} + (1-\tau^y_{i,t})\frac{W_{h,i,t}}{1+\tau^w_{i,t}}l_{h,i,t}\\
&\quad + (1-\tau^k_{i,t})R^k_{i,t}u_{h,i,t}\overline{K}_{h,i,t} + R^*_{i,t-1}\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right)\widetilde{S}_{i,t}B^*_{h,i,t}\\
&\quad - \tau^k_{i,t}\Bigg[(R_{i,t-1}-1)(M_{h,i,t} - Q_{h,i,t})\\
&\qquad + \left(R^*_{i,t-1}\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right) - 1\right)\widetilde{S}_{i,t}B^*_{h,i,t} + \left(\widetilde{S}_{i,t} - \widetilde{S}_{i,t-1}\right)B^*_{h,i,t}\Bigg]\\
&\quad + TR_{h,i,t}
\end{aligned} \tag{2.3.17}$$

where the subscript h indicates choice variables for the household while i is used for economy-wide parameters or variables. This expression equalises all the available resources (right hand side) to the use given to them by households (left hand side).

[15]Equations marked with * constitute the basis of the model's programming for its computation in the Matlab/Dynare platform.

[16]See Calvo (1983).

In this notation, interest rates are represented by gross rates (i.e. $R_{i,t} = 1 + r_{i,t}$, where $r_{i,t}$ is the net interest rate).

As capital owners, households receive a current of profits, $\Pi_{h,i,t}$ which in steady state are all zero. Financial wealth is distributed between nominal cash balances, $Q_{h,i,t}$, domestic deposits, $M_{h,i,t} - Q_{h,i,t}$, and foreign bonds, $B^*_{h,i,t} = \sum_{j=1}^{N-1} B_{h,j,i,t}$ subject to a weighted nominal valuation factor of the form:

$$\widetilde{S}_{i,t} = \sum_{j=1}^{N-1} I'_{i,j} S_{i,j,t} \tag{2.3.18}$$

with $i \neq j$[17] and where $I'_{i,j}$ is a $N-1$ normalised weighting vector[18] reflecting the intensity of bi-lateral financial exchanges between i and j and $S_{i,j,t}$ is the corresponding pairwise nominal exchange rate.

Domestic deposits earn an interest rate $R_{i,t-1}$ while savings in foreign bonds provide a before-tax gross rate of $R^*_{i,t-1}\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right)$ where $\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right)$ is a state-dependent premium that adjusts these returns conditional on the net foreign asset position of the domestic economy represented by:

$$A_{i,t} = \frac{\widetilde{S}_{i,t} B^*_{i,t+1}}{P_{i,t}} \tag{2.3.19}$$

so that borrowing countries (with $B^*_{i,t+1} < 0$) face higher interest rates while lending countries (with $B^*_{i,t+1} > 0$) have access to lower interest rates[19] in the international markets. $\tilde{\phi}_{i,t}$ is an exogenous time-varying shock on the risk premium. As in ALLV, it is assumed that $\frac{\partial \Phi}{\partial A_{i,t}} < 0$ and $\Phi(0,0) = 1$. The foreign interest rate $R^*_{i,t}$ is calculated as a weighted average of rates in the rest of the world:

$$R^*_{i,t} = \sum_{j=1}^{N-1} I'_{i,j} R_{j,t} \tag{2.3.20}$$

Households receive positive or negative lump-sum transfers from the government, $TR_{h,i,t}$.

The households' Lagrangian problem is:

$$\max_{C_{h,i,t}, M_{h,i,t+1}, \bar{K}_{h,i,t+1}, I_{h,i,t}, u_{h,i,t}, Q_{h,i,t}, B^*_{h,i,t+1}, l_{h,i,t}} E_0^h \sum_{t=0}^{\infty} \beta_i^t \left[\widetilde{L}_{i,t}\right]$$

[17] From here onwards, whenever we equate an i-th value to a weighted average of j-th values, $i \neq j$ prevails.

[18] This is a sub-matrix of a global $N \times N$ weighting matrix $I_{i,j}$ measuring the depth of financial bi-lateral positions between countries.

[19] The charges they encounter in the credit markets are lower thanks to this negative premium, but also are their income flows from financial investments abroad.

with:

$$\widetilde{L}_{i,t} = \zeta^c_{i,t}\ln(C_{h,i,t} - bC_{h,i,t-1}) - \zeta^l_{i,t}A_L\frac{(l_{h,i,t})^{1+\sigma^L_i}}{1+\sigma^L_i} + A_q\frac{(\frac{Q_{h,i,t}}{z_{i,t}P_{i,t}})^{1-\sigma^q_i}}{1-\sigma^q_i}$$
$$+ \upsilon_{i,t}\Big\{R_{i,t-1}(M_{h,i,t} - Q_{h,i,t}) + Q_{h,i,t} + (1-\tau^k_{i,t})\Pi_{i,t} + (1-\tau^y_t)\frac{W_{h,i,t}}{1+\tau^w_{i,t}}l_{h,i,t}$$
$$+ (1-\tau^k_{i,t})R^k_{i,t}u_{h,i,t}\bar{K}_{h,i,t} + R^*_{i,t-1}\Phi(a_{i,t-1},\tilde{\phi}_{i,t-1})\tilde{S}_{i,t}B^*_{h,i,t}$$
$$- \tau^k_{i,t}\Big[(R_{i,t-1}-1)(M_{h,i,t}-Q_{h,i,t}) + \Big(R^*_{i,t-1}\Phi(a_{i,t-1},\tilde{\phi}_{i,t-1}) - 1\Big)\tilde{S}_{i,t}B^*_{h,i,t}$$
$$+ B^*_{h,i,t}(\tilde{S}_{i,t} - \tilde{S}_{i,t-1})\Big] + TR_{h,i,t}$$
$$- \Big[M_{h,i,t+1} + \tilde{S}_{i,t}B^*_{h,i,t+1} + P^c_{i,t}C_{h,i,t}(1+\tau^c_{i,t}) + P^i_{i,t}I_{h,i,t} + P_{i,t}(a(u_{h,i,t})\bar{K}_{h,i,t})\Big]\Big\}$$
$$+ \omega_{i,t}\left\{(1-\delta_i)\bar{K}_{h,i,t} + \Upsilon_{i,t}F(i_{i,t}, i_{i,t-1}) - \bar{K}_{h,i,t+1}\right\}$$

for which the first order condition with respect to consumption ($c_{i,t}$) is:

$$\frac{\zeta^c_{i,t}}{c_{i,t} - bc_{i,t-1}\frac{1}{\mu^z_{i,t}}} - \beta_i bE_{i,t}\frac{\zeta^c_{i,t+1}}{c_{i,t+1}\mu^z_{i,t+1} - bc_{i,t}} - \psi^z_{i,t}\frac{P^c_{i,t}}{P_{i,t}}(1+\tau^c_{i,t}) = 0 \qquad (2.3.21)$$

where $\psi_{i,t} = \upsilon_{i,t}P_{i,t}$, and $\mu^z_{i,t}$ is a scaling term explained below applied as $\psi^z_{i,t} = z_{i,t}\psi_{i,t}$.

Log-linearisation produces:

$$E_{i,t}\left[-b_i\beta_i\mu^z_i\hat{c}_{i,t+1} + \left[(\mu^z_i)^2 + b^2_i\beta_i\right]\hat{c}_{i,t} - b_i\mu^z_i\hat{c}_{i,t-1} + b_i\mu^z_i(\hat{\mu}^z_{i,t} - \beta_i\hat{\mu}^z_{i,t+1})\right.$$
$$+(\mu^z_i - b_i\beta_i)(\mu^z_i - b_i)\hat{\psi}^z_{i,t} + \frac{\tau^c_i}{1+\tau^c_i}(\mu^z_i - b_i\beta_i)(\mu^z_i - b_i)\hat{\tau^c_i} + (\mu^z_i - b_i\beta_i)(\mu^z_i - b_i)\hat{\gamma}^{c,d}_{i,t}$$
$$\left.-(\mu^z_i - b_i)(\mu^z_i\hat{\zeta}^c_{i,t} - b_i\beta_i\hat{\zeta}^c_{i,t+1})\right] = 0$$
$$(2.3.21^*)$$

In turn, the first order condition with respect to investment ($i_{i,t}$) is:

$$-\psi^z_{i,t}\frac{P^i_{i,t}}{P_t} + \psi^z_{i,t}\Upsilon_{i,t}F_t(i_{i,t}, i_{i,t-1}, \mu^z_{i,t})$$
$$+ \beta E_{i,t}\left[\frac{\psi^z_{i,t+1}}{\mu^z_{i,t+1}}\Upsilon_{i,t+1}F_{t+1}(i_{i,t+1}, i_{i,t}, \mu^z_{i,t+1})\right] = 0 \qquad (2.3.22)$$

Using Equation (2.3.15), log-linearisation yields:

$$E_{i,t}\left\{\hat{\Upsilon}_{i,t} - \hat{\gamma}^{i,d}_{i,t} - (\mu^z_i)^2\tilde{S}''\left[(\hat{i}_{i,t} - \hat{i}_{i,t-1}) - \beta_i(\hat{i}_{i,t+1} - \hat{i}_{i,t}) + \hat{\mu}^z_{i,t} - \beta_i\hat{\mu}^z_{i,t+1}\right]\right\} = 0$$
$$(2.3.22^*)$$

Similarly, the first order condition with respect to domestic bonds ($m_{i,t+1}$) is:

$$-\psi^z_{i,t} + \beta_i E_{i,t}\left[\frac{\psi^z_{i,t+1}}{\mu^z_{i,t+1}}\frac{R_{i,t}}{\pi_{i,t+1}} - \frac{1}{\mu^z_{i,t+1}}\frac{\psi^z_{i,t+1}}{\pi_{i,t+1}}\tau^k_{i,t+1}(R_{i,t}-1)\right] = 0 \qquad (2.3.23)$$

which linearised becomes:

$$E_{i,t}\Bigg[-\mu_i\hat{\psi}^z_{i,t}+\mu_i\hat{\psi}^z_{i,t+1}-\mu_i\hat{\mu}^z_{i,t+1}+(\mu_i-\beta_i\tau^k_i)\hat{R}_{i,t} \\ -\mu_i\hat{\pi}_{i,t+1}+\frac{\tau^k_i}{1-\tau^k_i}(\beta_i-\mu_i)\hat{\tau}^k_{i,t+1}\Bigg]=0 \tag{2.3.23*}$$

From the first order condition with respect to available capital ($\bar{k}_{i,t+1}$):

$$-\psi^z_{i,t}+\beta_iE_{i,t}\left\{\frac{\psi^z_{i,t+1}}{\mu^z_{i,t+1}}\left[(1-\delta_i)+(1-\tau^k_{i,t+1})r^k_{i,t+1}u_{i,t+1}-a(u_{i,t+1})\right]\right\}=0 \tag{2.3.24}$$

the log-linearised version is:

$$E_{i,t}\Bigg[\hat{\psi}^z_{i,t}+\hat{\mu}^z_{i,t+1}-\hat{\psi}^z_{i,t+1}-\frac{\beta_i(1-\delta_i)}{\mu_z}-\frac{\mu_z-\beta_i(1-\delta_i)}{\mu_z}\hat{r}^k_{i,t+1} \\ +\frac{\tau^k}{(1-\tau^k)}\frac{\mu_z-\beta_i(1-\delta_i)}{\mu_z}\hat{\tau}^k_{i,t+1}\Bigg]=0 \tag{2.3.24*}$$

The first order condition with respect to capital utilisation ($u_{i,t}$) is:

$$\psi_{z,i,t}\left[\left(1-\tau^k_{i,t}\right)r^k_{i,t}-a'(u_{i,t})\right]=0 \tag{2.3.25}$$

and using Equation (2.3.13):

$$\widehat{u}_{i,t}=\frac{1}{\sigma_{a,i}}\widehat{r}^k_{i,t}-\frac{1}{\sigma_{a,i}}\frac{\tau^k}{(1-\tau^k)}\widehat{\tau}^k_{i,t} \tag{2.3.25*}$$

In turn, the first order condition with respect to nominal balances ($q_{i,t}$) is:

$$\zeta^q_{i,t}A_qq_{i,t}^{-\sigma^q_i}-\left(1-\tau^k_{i,t}\right)\psi_{z,i,t}(R_{i,t-1}-1)=0 \tag{2.3.26}$$

which log-linearised is:

$$\hat{q}_{i,t}=\frac{1}{\sigma^q_i}\left[\widehat{\zeta}^q_{i,t}+\frac{\tau^k_i}{1-\tau^k_i}\widehat{\tau}^k_{i,t}-\widehat{\psi}_{z,i,t}-\frac{R_i}{R_i-1}\widehat{R}_{i,t-1}\right] \tag{2.3.26*}$$

Finally, the first order condition with respect to foreign bonds ($b^*_{i,t+1}$) is:

$$-\psi^z_{i,t}\widetilde{S}_{i,t}+\beta_iE_{i,t}\Bigg\{\frac{\psi^z_{i,t+1}}{\mu^z_{i,t+1}\pi_{i,t+1}}\Big[\widetilde{S}_{i,t+1}R^*_{i,t}\Phi(a_{i,t},\tilde{\phi}_{i,t}) \\ -\tau^k_{i,t+1}\widetilde{S}_{i,t+1}(R^*_{i,t}\Phi(a_{i,t},\tilde{\phi}_{i,t})-1)-\tau^k_{i,t+1}(\widetilde{S}_{i,t+1}-\widetilde{S}_{i,t})\Big]\Bigg\}=0 \tag{2.3.27}$$

which combined with Equation (2.3.23) and after linearisation becomes an uncovered interest parity condition:

$$\widehat{R}_{i,t} - \widehat{R}^{*}_{i,t} = E_{i,t}\Delta\widetilde{\widehat{S}}_{i,t+1} - \tilde{\phi}^{a}_{i}\widehat{a}_{i,t} + \widehat{\tilde{\phi}}_{i,t} \qquad (2.3.27^{*})$$

where the premium on foreign bonds follows $\Phi(a_{i,t}, \tilde{\phi}_{i,t}) = exp(-\tilde{\phi}^{a}_{i}(a_{i,t} - \overline{a_{i}}) + \tilde{\phi}_{i,t})$.

2.3.2 Wage setting

As in the CEE framework, wage adjustments follow a Calvo setting with random access to re-optimisations depending on a probability ξ_w of not re-optimising but indexing instead as explained below. As monopolistic producers, households transform labour into a homogeneous input, L, which is aggregated as:

$$L_{i,t} = \left[\int_{0}^{1} (l_{h,i,t})^{\frac{1}{\lambda_w}}\, dh\right]^{\lambda_w} \qquad (2.3.28)$$

for each economy with $1 \leq \lambda_w < \infty$ as the wage markup. The demand for labour for an individual household depends on the wage it is able to set, $W_{h,i,t}$, relative to the economy-wide rate:

$$l_{h,i,t} = \left(\frac{W_{h,i,t}}{W_{i,t}}\right)^{\frac{\lambda_w}{1-\lambda_w}} L_{i,t} \qquad (2.3.29)$$

$W_{i,t}$ is the (nation-wide) aggregate wage rate resulting from:

$$W_{i,t} = \left[\int_{0}^{1} (W_{h,i,t})^{\frac{1}{1-\lambda_w}}\, dh\right]^{1-\lambda_w} \qquad (2.3.30)$$

For each household $L_{i,t}$ and $W_{i,t}$ are given parameters.

The wage adjusting mechanism for households unable to re-optimise, as in ALLV, includes lagged consumption-price inflation, the current inflation target and a technology-driven factor:

$$W_{h,i,t} = \left(\pi^{c}_{i,t-1}\right)^{\kappa_{i,\omega}} \left(\bar{\pi}^{c}_{i,t}\right)^{1-\kappa_{i,\omega}} \mu^{z}_{i,t} W_{h,i,t-1} \qquad (2.3.31)$$

with $\mu^{z}_{i,t} = \frac{z_{i,t}}{z_{i,t-1}}$ for the technology level $z_{i,t}$ and

$$\mu^{z}_{i,t} = (1 - \rho_{\mu_z,i})\mu_z + \rho_{\mu_z,i}\mu^{z}_{i,t-1} + \sigma_{\mu,i}\varepsilon^{z}_{i,t} \qquad (2.3.32)$$

where μ_z denotes an exogenous trend of technological development.

Therefore, for an optimising household an interruption in the ability to re-optimise its wage for s periods ahead implies:

$$W_{h,i,t+s} = \left(\pi^{c}_{i,t}...\pi^{c}_{i,t+s-1}\right)^{\kappa_{\omega,i}} \left(\bar{\pi}^{c}_{i,t+1}...\bar{\pi}^{c}_{i,t+s}\right)^{(1-\kappa_{\omega,i})} \left(\mu_{z,i,t+1}...\mu_{z,i,t+s}\right) W_{h,i,t} \qquad (2.3.33)$$

In turn, for a household able to re-optimise its wage, the optimisation problem is written as:

$$\max_{\widetilde{W}_{h,i,t}} E_{i,t} \sum_{s=0}^{\infty} (\beta_i \xi_w)^s \Bigg\{ -\zeta^h_{i,t+s} A_L \frac{(h_{h,i,t+s})^{1+\sigma_L}}{1+\sigma_L} + \upsilon_{i,t+s} \frac{\left(1-\tau^y_{i,t+s}\right)}{\left(1-\tau^w_{i,t+s}\right)} \times \\ \left[\left(\pi^c_{i,t} ... \pi^c_{i,t+s-1}\right)^{\kappa_{\omega,i}} \left(\bar{\pi}^c_{i,t+1} ... \bar{\pi}^c_{i,t+s}\right)^{(1-\kappa_{\omega,i})} \left(\mu_{z,i,t+1} ... \mu_{z,i,t+s}\right) \widetilde{W}_{h,i,t} \right] l_{h,i,t+s} \Bigg\} \tag{2.3.34}$$

The linearised first order condition for this problem is:

$$E_{i,t} \Big[\eta_{0,i} \widehat{\bar{w}}_{i,t-1} + \eta_{1,i} \widehat{\bar{w}}_{i,t} + \eta_{2,i} \widehat{\bar{w}}_{i,t+1} + \eta_{3,i} (\hat{\pi}^d_{i,t} - \widehat{\bar{\pi}}^c_{i,t}) + \eta_{4,i} (\hat{\pi}^d_{i,t+1} - \rho^{\widehat{\bar{\pi}}^c_i} \widehat{\bar{\pi}}^c_{i,t}) \\ + \eta_{5,i} (\hat{\pi}^c_{i,t-1} - \widehat{\bar{\pi}}^c_{i,t}) + \eta_{6,i} (\hat{\pi}^c_{i,t} - \rho_i^{\widehat{\bar{\pi}}^c} \widehat{\bar{\pi}}^c_{i,t}) + \eta_{7,i} \hat{\psi}^{\tau}_{z,i,t} + \eta_{8,i} \hat{L}_{i,t} \\ + \eta_{9,i} \hat{\tau}^y_{i,t} + \eta_{10,i} \hat{\tau}^w_{i,t} + \eta_{11,i} \hat{\zeta}^h_{i,t} \Big] = 0 \tag{2.3.35*}$$

where:

$$b_{w,i} = \frac{\lambda^w_i \sigma_L - (1-\lambda^w_i)}{(1-\beta\xi_{w,i})(1-\xi_{w,i})}$$

and:

$$\begin{aligned}
\eta_{0,i} &= b_{w,i} \xi_{w,i} \\
\eta_{1,i} &= (\sigma_L \lambda^w_i - b_{w,i}(1+\beta_i \xi^2_{w,i})) \\
\eta_{2,i} &= b_{w,i} \beta_i \xi_{w,i} \\
\eta_{3,i} &= -b_{w,i} \xi_{w,i} \\
\eta_{4,i} &= b_{w,i} \beta_i \xi_{w,i} \\
\eta_{5,i} &= b_{w,i} \xi_{w,i} \kappa^w_i \\
\eta_{6,i} &= -b_{w,i} \beta_i \xi_{w,i} \kappa^w_i \\
\eta_{7,i} &= (1-\lambda^w_i) \\
\eta_{8,i} &= -(1-\lambda^w_i) \sigma_L \\
\eta_{9,i} &= -(1-\lambda^w_i) \frac{\tau^y_i}{(1-\tau^y_i)} \\
\eta_{10,i} &= -(1-\lambda^w_i) \frac{\tau^w_i}{(1-\tau^w_i)} \\
\eta_{11,i} &= -(1-\lambda^w_i)
\end{aligned}$$

2.3.3 Employment

The ALLV framework also includes a succinct depiction of employment dynamics which connects to the rest of the model by the means of the discount factor, β_i, and the labour inputs applied each period, L_i. An element of rigidity appears in the demand for labour assuming that only a fraction $(1-\xi_i^E)$ of firms are able to adjust to their preferred employment level, $\widetilde{E}_{j,i,t}^{new}$[20]. If they have access to adjustments, they choose $\widetilde{E}_{j,i,t}^{new}$, otherwise they have to maintain the prevailing level in the previous period: $\widetilde{E}_{j,i,t} = \widetilde{E}_{j,i,t-1}^{new}$.

This way, they solve the following problem:

$$\min_{\widetilde{E}_{j,i,t}^{new}} \sum_{s=0}^{\infty} (\beta_i \xi_i^E) \left(n_j \widetilde{E}_{j,i,t}^{new} - L_{j,i,t+s} \right)^2$$

with n_j is the number of work hours per worker.

The linearised first order condition for this problem reflects aggregate employment as:

$$\Delta \widehat{E}_{i,t} = \beta_i E_{i,t} \left(\Delta \widehat{E}_{i,t+1} \right) + \frac{(1-\xi_i^E)(1-\beta_i \xi_i^E)}{\xi_i^E} \left(\widehat{L}_{i,t} - \widehat{E}_{i,t} \right) \tag{2.3.36}$$

with $\widehat{E}_{i,t} = d\widetilde{E}_{i,t}/\widetilde{E}_i$. Equivalently:

$$\widehat{E}_{i,t} = \frac{\beta_i}{1+\beta_i} E_{i,t} \left(\widehat{E}_{i,t+1} \right) + \frac{1}{1+\beta_i} \widehat{E}_{i,t-1} + \frac{(1-\xi_i^E)(1-\beta_i \xi_i^E)}{(1+\beta_i)\xi_i^E} \left(\widehat{L}_{i,t} - \widehat{E}_{i,t} \right) \tag{2.3.36*}$$

2.3.4 Firms

In each country there are three types of firms: intermediate goods producers, final non-traded goods producers and final traded goods producers. Final goods international traders are able to differentiate their production and become monopolistic suppliers (for example, by the use of *branding* strategies).

Production is organised in the following way:

- Intermediate firms
  - Hire capital and labour from households
  - Produce differentiated intermediate goods
  - Sell to final goods producers
- Final non-traded goods firms
  - Buy intermediate goods
  - Sell final goods to domestic households and exporting firms

[20] In this subsection j denotes each firm in country i.

    - Are monopolist sellers

- Final traded goods firms
    - Exporting firms
        * Buy domestic final goods
        * Sell differentiated final goods to the world market
        * Are monopolist sellers (branding)
    - Importing firms
        * Buy final homogeneous goods in the world market
        * Sell final differentiated consumption or investment goods to domestic households
        * Are monopolist sellers (branding)

2.3.5 Intermediate goods firms

In each country k intermediate goods firms generate output using capital, K, and labour, L, as inputs:

$$Y_{k,i,t} = z_{i,t}^{1-\alpha_i} \epsilon_{i,t} K_{k,i,t}^{\alpha_i} L_{k,i,t}^{1-\alpha_i} - z_{i,t}\phi_i \tag{2.3.37}$$

where ϕ_i is a fixed production cost and $z_{i,t}$ constitutes a permanent technology shock evolving in time at a rate $\mu_{i,t}^z$:

$$\frac{z_{i,t}}{z_{i,t-1}} = \mu_{i,t}^z \tag{2.3.38}$$

and $\epsilon_{i,t}$ is a covariance stationary technology shock following:

$$\hat{\epsilon}_{i,t} = \rho_{\epsilon,i}\hat{\epsilon}_{i,t-1} + \sigma_{\epsilon,i}\varepsilon_{i,t}^{\epsilon} \tag{2.3.39}$$

with $E(\epsilon_{i,t}) = 1$ and $\hat{\epsilon}_{i,t} = (\epsilon_{i,t} - 1)$ while $\varepsilon_{i,t}^{\epsilon}$ represent country-specific shocks.

As in ALLV, a fraction ν_i^w of the payroll is financed with domestic banking loans resulting, for labour cost purposes, in an effective interest rate of:

$$R_{i,t}^f = \nu_{i,t}^w R_{i,t-1}^l + 1 - \nu_{i,t}^w \tag{2.3.40}$$

where $R_{i,t}^l$ is the rate charged by banks in the domestic credit retail market (retail bank lending rate). In log-linearised terms this equation becomes:

$$\hat{R}_{i,t}^f = \frac{\nu_i^w R_i^l \widehat{R}_{i,t}^l + \nu_i^w (R_i^l - 1)\widehat{\nu}_{i,t}^w}{\nu_i^w R_i^l + 1 - \nu_i^w} \tag{2.3.40*}$$

Given the two production inputs (labour and capital), cost minimisation implies:

$$\min_{K_{k,t},L_{k,t}} W_{i,t}R^f_{i,t}L_{k,t} + R^k_{i,t}K_{k,t} + \lambda_{k,t}P_{k,t}\left[Y_{k,i,t} - z^{1-\alpha_i}_{i,t}\epsilon_{i,t}K^{\alpha_i}_{k,t}L^{1-\alpha_i}_{k,t} + z_{i,t}\phi_i\right] \quad (2.3.41)$$

where $R^k_{i,t}$ is the gross rental rate of capital, $W_{i,t}$ the nominal wage, and $L_{k,t}$ are units of labour.

First order conditions for Equation (2.3.41) then yield:

$$W_{i,t}R^f_{i,t} = (1-\alpha_i)\lambda_{k,t}P_{k,t}z^{1-\alpha_i}_{i,t}\epsilon_{i,t}K^{\alpha_i}_{k,t}L^{-\alpha_i}_{k,t} \quad (2.3.42)$$

$$R^k_{i,t} = \alpha_i\lambda_{k,t}P_{k,t}z^{1-\alpha_i}_{i,t}\epsilon_{i,t}K^{\alpha_i-1}_{k,t}L^{1-\alpha_i}_{k,t} \quad (2.3.43)$$

Following the same stationarisation procedure as ALLV:

$$r^k_{i,t} = \frac{R^k_{i,t}}{P_{i,t}}, \quad \bar{w}_{i,t} = \frac{W_{i,t}}{P_{i,t}z_{i,t}}, \quad k_{i,t+1} = \frac{K_{i,t+1}}{z_{i,t}}, \quad \bar{k}_{i,t+1} = \frac{\overline{K}_{i,t+1}}{z_{i,t}} \quad (2.3.44)$$

with $\overline{K}_{i,t+1}$ as the physical capital stock. Using stationarised variables according to Equation (2.3.44) and combining Equations (2.3.42) and (2.3.43) a solution is found for the rental rate of capital:

$$r^k_{i,t} = \frac{\alpha_i}{1-\alpha_i}\bar{w}_{i,t}\mu^z_{i,t}R^f_{i,t}k^{-1}_{i,t}L_{i,t} \quad (2.3.45)$$

which in log-linearised terms becomes:

$$\hat{r}^k_{i,t} = \hat{\mu}^z_{i,t} + \widehat{\bar{w}}_{i,t} + \hat{R}^f_{i,t} + \hat{L}_{i,t} - \hat{k}_{i,t} \quad (2.3.45^*)$$

A firm's real marginal cost (here $mc_{k,t} = \lambda_{k,t}$) then becomes:

$$mc_{k,t} = \left(\frac{1}{1-\alpha_i}\right)^{1-\alpha_i}\left(\frac{1}{\alpha_i}\right)^{\alpha_i}\left(r^k_{i,t}\right)^{\alpha_i}\left(w_{i,t}R^f_{i,t}\right)^{1-\alpha_i}\frac{1}{\epsilon_{i,t}} \quad (2.3.46)$$

and log-linearising:

$$\begin{aligned}\widehat{mc}_{k,t} &= \alpha_i\hat{r}^k_{i,t} + (1-\alpha_i)\left[\widehat{\bar{w}} + \hat{R}^f_{i,t}\right] - \hat{\epsilon_{i,t}} \\ &= \alpha_i(\hat{\mu}^z_{i,t} + \hat{L}_{i,t} - \hat{k}_{i,t} + \widehat{\bar{w}}_{i,t} + \hat{R}^f_{i,t} - \hat{\epsilon}_{i,t} \quad (2.3.46^*)\end{aligned}$$

Price setting follows a similar procedure as in CEE and Smets and Wooters (2003). Firms are allowed to re-optimise their prices subject to a probability $(1-\xi_{d,i})$ for gaining access to re-optimisations. However, if a firm is not allowed to re-optimise (with probability $\xi_{d,i}$), it has to index its selling price using the previous price as a reference:

$$P_{i,t+1} = (\pi_{i,t})^{\kappa_{d,i}} (\bar{\pi}^c_{t+1})^{1-\kappa_{d,i}} P_{i,t} \tag{2.3.47}$$

this way, an interruption of the access to re-optimisation for s periods implies:

$$P_{i,t+s} = (\pi_{i,t}\pi_{i,t+1} \dots \pi_{i,t+s-1})^{\kappa_{d,i}} (\bar{\pi}^c_{t+1}\bar{\pi}^c_{t+2} \dots \bar{\pi}^c_{t+s})^{1-\kappa_{d,i}} P_{i,t} \tag{2.3.48}$$

On the other hand, when firms are allowed to re-optimise, it is assumed that they all set the same price $\tilde{P}_{i,t}$ (therefore, the subscript k is suppressed).

Their optimisation problem becomes:

$$\begin{aligned} \max_{\tilde{P}_{i,t}} E_{i,t} \sum_{s=0}^{\infty} (\beta_i \xi_{d,i})^s \, \upsilon_{i,t+s} \Big\{ \Big[(\pi_{i,t} \times \pi_{i,t+1} \times ... \times \pi_{i,t+s-1})^{\kappa_d} \\ \left(\bar{\pi}^c_{i,t+1} \times \bar{\pi}^c_{i,t+2} \times ... \times \bar{\pi}^c_{i,t+s}\right)^{1-\kappa_d} \tilde{P}_{i,t} \Big] Y_{k,i,t+s} \\ - MC_{k,i,t+s} \left(Y_{k,i,t+s} + z_{i,t+s}\phi_i \right) \Big\} \end{aligned} \tag{2.3.49}$$

where β_i is a discount factor, υ_t represents marginal utility of nominal income and $MC_{k,i,t}$ is each firm's nominal marginal cost.

The aggregate price index then reflects both indexing and optimising prices as:

$$P_{i,t} = \left[\left(\int_0^{\xi_{d,i}} \left(P_{i,t-1} \left(\pi_{i,t-1}\right)^{\kappa_{d,i}} \left(\bar{\pi}^c_{i,t}\right)^{1-\kappa_{d,i}} \right)^{\frac{1}{1-\lambda^d_{i,t}}} + \int_{\xi_{d,i}}^1 \left(\tilde{P}_{i,t}\right)^{\frac{1}{1-\lambda^d_{i,t}}} \right) dk \right]^{1-\lambda^d_{i,t}} \tag{2.3.50}$$

and therefore, in terms of the optimising access probability, ξ:

$$P_{i,t} = \left[\xi_{d,i} \left(P_{i,t-1} \left(\pi_{i,t-1}\right)^{\kappa_{d,i}} \left(\bar{\pi}^c_{i,t}\right)^{1-\kappa_{d,i}} \right)^{\frac{1}{1-\lambda^d_{i,t}}} + (1-\xi_{d,i}) \left(\tilde{P}_{i,t}\right)^{\frac{1}{1-\lambda^d_{i,t}}} \right]^{1-\lambda^d_{i,t}} \tag{2.3.51}$$

2.3.6 Final goods firms

The production function for the final goods is:

$$Y_{i,t} = \left[\int_0^1 Y_{k,i,t}^{\frac{1}{\lambda^d_{i,t}}} dk \right]^{\lambda^d_{i,t}} \tag{2.3.52}$$

where k indicates intermediate goods and $1 \leq \lambda^d_{i,t} < \infty$ is a stochastic process that governs mark-up changes in time:

$$\lambda^d_{i,t} = (1-\rho_{\lambda_d,i})\lambda_{d,i} + \rho_{\lambda_d,i}\lambda_{d,i,t-1} + \sigma_{\lambda_d,i}\varepsilon^{\lambda_d}_{i,t} \tag{2.3.53}$$

where shocks $\varepsilon_{i,t}^{\lambda_d}$ are assumed to be white noise.

These elements lead to obtain the Euler equation from profit maximisation :

$$\left(\frac{P_{i,t}}{P_{k,i,t}}\right)^{\frac{\lambda_{i,t}^d}{\lambda_{i,t}^d-1}} = \frac{Y_{k,i,t}}{Y_{i,t}} \tag{2.3.54}$$

and, subsequently, the i-th economy's aggregate price index is:

$$P_{i,t} = \left[\int_0^1 P_{k,i,t}^{\frac{1}{1-\lambda_{i,t}^d}} dk\right]^{\left(1-\lambda_{i,t}^d\right)} \tag{2.3.55}$$

Using Equation 2.3.54, the first order condition for the problem in Equation 2.3.49 is:

$$E_t \sum_{s=0}^{\infty} (\beta_i \xi_{i,d})^s \upsilon_{t+s} \left(\frac{\left(\frac{P_{i,t+s-1}}{P_{i,t-1}}\right)^{\kappa_{d,i}} \left(\bar{\pi}_{i,t+1}^c \bar{\pi}_{i,t+2}^c \dots \bar{\pi}_{i,t+s}^c\right)^{1-\kappa_{d,i}}}{\left(\frac{P_{i,t+s}}{P_{i,t}}\right)} \right)^{-\frac{\lambda_{i,d,t+s}}{\lambda_{i,d,t+s}-1}} Y_{i,t+s} P_{i,t+s}$$
$$\times \left[\frac{\left(\frac{P_{i,t+s-1}}{P_{i,t-1}}\right)^{\kappa_{d,i}} \left(\bar{\pi}_{i,t+1}^c \bar{\pi}_{i,t+2}^c \dots \bar{\pi}_{i,t+s}^c\right)^{1-\kappa_{d,i}}}{\frac{P_{i,t+s}}{P_{i,t}}} \frac{\tilde{P}_{i,t}}{P_{i,t}} - \frac{\lambda_{i,d,t} MC_{k,i,t+s}}{P_{i,t+s}} \right] = 0 \tag{2.3.56}$$

After log-linearising Equations 2.3.56 and 2.3.51 their combination results in a New Keynesian Phillips Curve:

$$\begin{aligned}\left(\hat{\pi}_{i,t} - \hat{\bar{\pi}}_{i,t}^c\right) = {} & \frac{\beta_i}{1+\kappa_{d,i}\beta_i}\left(E_t \hat{\pi}_{i,t+1} - \rho_{\pi,i}\hat{\bar{\pi}}_{i,t}^c\right) + \frac{\kappa_{d,i}}{1+\kappa_{d,i}\beta_i}\left(\hat{\pi}_{i,t-1} - \hat{\bar{\pi}}_{i,t}^c\right) \\ & - \frac{\kappa_{d,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{d,i}\beta_i}\hat{\bar{\pi}}_{i,t}^c + \frac{\left(1-\xi_{d,i}\right)\left(1-\beta_i\xi_{d,i}\right)}{\xi_{d,i}\left(1+\kappa_{d,i}\beta_i\right)}\left(\widehat{mc}_{i,t} + \widehat{\lambda}_{d,i,t}\right)\end{aligned} \tag{2.3.56*}$$

reflecting the relationship between inflation and marginal costs. The definition of $\rho_{\pi,i}$ is given in Section 2.3.11.

2.3.7 Importing firms and incomplete exchange rate pass-through

Importing firms pay a price $P_{i,t}^*$ in the world market for the final goods they buy. ALLV then make use of local-currency price stickiness to model incomplete exchange rate pass-through to consumption and investment. This means that a fraction of importing firms do not have access to price adjustments in given periods and, therefore, foreign inflation is not fully transmitted to an importing economy. The contention barrier operates through a differentiated probability for the ability of importing firms to re-optimise their selling prices, $P_{i,t}^{m,c}$ and $P_{i,t}^{m,inv}$, for imported consumption and investment goods, respectively. The probabilities for re-optimisation are correspondingly given by $(1-\xi_{m,c,i})$ and $(1-\xi_{m,inv,i})$.

If a firm is not allowed to re-optimise, it sets its price as an indexation of the one set in the previous period:

$$P_{i,t+1}^{m,dest} = (\pi_{i,t}^{m,dest})^{\kappa_{m,dest,i}} (\bar{\pi}_{i,t+1}^{c})^{1-\kappa_{m,dest,i}} P_{i,t}^{m,dest} \tag{2.3.57}$$

with $dest \in \{c, inv\}$.

Then, if the ability to re-optimise is interrupted for s periods, the price is set as:

$$\begin{aligned} P_{i,t+s}^{m,dest} = &(\pi_{i,t}^{m,dest} \times \pi_{i,t+1}^{m,dest} \times ... \times \pi_{i,t+s-1}^{m,dest})^{\kappa_{m,dest,i}} \\ &\times (\bar{\pi}_{i,t+1}^{c} \times \bar{\pi}_{i,t+2}^{c} \times ... \times \bar{\pi}_{i,t+s}^{c})^{1-\kappa_{m,dest,i}} P_{i,t}^{m,dest} \end{aligned} \tag{2.3.58}$$

In turn, the optimisation problems for those firms allowed to use it can be formulated as:

$$\begin{aligned} &\max_{\tilde{P}_{i,t}^{m,c}} E_{i,t} \sum_{s=0}^{\infty} (\beta_i \xi_{m,c,i})^s \upsilon_{i,t+s} \Bigg[\left(\pi_{i,t}^{m,c} \times \pi_{i,t+1}^{m,c} \times ... \times \pi_{i,t+s-1}^{m,c}\right)^{\kappa_{m,c,i}} \\ &(\bar{\pi}_{i,t+1}^{c} \times \bar{\pi}_{i,t+2}^{c} \times ... \times \bar{\pi}_{i,t+s}^{c})^{1-\kappa_{m,c,i}} \tilde{P}_{i,t}^{m,c} C_{m,i,t+s}^{m} \\ &\qquad - \left(\sum_{j=1}^{N-1} \bar{S}_{i,t+s} P_{j,t+s} \right) \left(C_{m,i,t+s}^{m} + z_{i,t+s} \phi_i^{m,c} \right) \Bigg] \end{aligned} \tag{2.3.59}$$

for importers selling consumption goods and

$$\begin{aligned} &\max_{\tilde{P}_{i,t}^{m,inv}} E_{i,t} \sum_{s=0}^{\infty} (\beta_i \xi_{m,inv,i})^s \upsilon_{i,t+s} \Bigg[\left(\pi_{i,t}^{m,inv} \times \pi_{i,t+1}^{m,inv} \times ... \times \pi_{i,t+s-1}^{m,inv}\right)^{\kappa_{m,inv,i}} \\ &(\bar{\pi}_{i,t+1}^{c} \times \bar{\pi}_{i,t+2}^{c} \times ... \times \bar{\pi}_{i,t+s}^{c})^{1-\kappa_{m,inv,i}} \tilde{P}_{i,t}^{m,inv} I_{m,i,t+s}^{m} \\ &\qquad - \left(\sum_{j=1}^{N-1} \bar{S}_{i,t+s} P_{j,t+s} \right) \left(I_{m,i,t+s}^{m} + z_{i,t+s} \phi_i^{m,inv} \right) \Bigg] \end{aligned} \tag{2.3.60}$$

for those selling imported investment goods. In both problems $\bar{S}_{i,t} = \sum_{j=1}^{N-1} T'_{i,j} S_{i,j,t}$ is a weighted average of exchange rates according to the relevance of each counterpart in trade as reflected by $T'_{i,j}$ which is a $N-1$ unit-normalised vector of trade weights reflecting the strength of commercial exchanges between country i and every other in the rest of the world.

In these expressions $\phi_i^{m,c}$ and $\phi_i^{m,inv}$ are fixed costs. As above, it is assumed that all importing firms set the same re-optimised price $\tilde{P}_{i,t}^{m,dest}$. The marginal cost for importing firms is given by:

$$MC_{i,t}^{m,dest} = \sum_{j=1}^{N-1} T'_{i,j} \left(\frac{P_{j,t} S_{i,j,t}}{P_{i,t}^{m,dest}} \right) \tag{2.3.61}$$

or equivalently:

$$\widehat{mc}_{i,t}^{m,dest} = \sum_{j=1}^{N-1} T'_{i,j} \left(\hat{p}_{j,t} + \hat{s}_{i,j,t} - \hat{p}_{i,t}^{m,dest} \right) \tag{2.3.62}$$

The imported fraction of consumption, $C_{i,t}^{m}$, is composed by m differentiated imported goods:

$$C_{i,t}^{m} = \left[\int_0^1 \left(C_{m,i,t}^{m} \right)^{\frac{1}{\lambda_{i,t}^{m,c}}} dm \right]^{\lambda_{i,t}^{m,c}} \tag{2.3.63}$$

with $1 \leq \lambda_{i,t}^{m,c} < \infty$ following the process:

$$\lambda_{i,t}^{m,c} = (1 - \rho_{\lambda^{m,c},i}) \lambda_{i}^{m,c} + \rho_{\lambda^{m,c},i} \lambda_{i,t-1}^{m,c} + \sigma_{\lambda^{m,c},i} \varepsilon_{i,t}^{\lambda^{m,c}} \tag{2.3.64}$$

Consequently, the demand for each importing firm, m, selling consumption goods is:

$$C_{m,i,t}^{m} = \left(\frac{P_{m,i,t}^{m,c}}{P_{i,t}^{m,c}} \right)^{-\frac{\lambda_{i,t}^{m,c}}{\lambda_{i,t}^{m,c} - 1}} C_{i,t}^{m} \tag{2.3.65}$$

Similarly, imported investment goods add as:

$$I_{i,t}^{m} = \left[\int_0^1 \left(I_{m,i,t}^{m} \right)^{\frac{1}{\lambda_{i,t}^{m,inv}}} dm \right]^{\lambda_{i,t}^{m,inv}} \tag{2.3.66}$$

to constitute total imported investment with $1 \leq \lambda_{i,t}^{m,inv} < \infty$ following:

$$\lambda_{i,t}^{m,inv} = (1 - \rho_{\lambda^{m,inv},i}) \lambda_{i}^{m,inv} + \rho_{\lambda^{m,inv},i} \lambda_{i,t-1}^{m,inv} + \sigma_{\lambda^{m,inv},i} \varepsilon_{i,t}^{\lambda^{m,inv}} \tag{2.3.67}$$

and the demand for each imported investment good (therefore the sub-index m) is given by:

$$I_{m,i,t}^{m} = \left(\frac{P_{m,i,t}^{m,inv}}{P_{i,t}^{m,inv}} \right)^{-\frac{\lambda_{i,t}^{m,inv}}{\lambda_{i,t}^{m,inv} - 1}} I_{i,t}^{m} \tag{2.3.68}$$

The aggregate price index for imported goods is expressed as:

$$P_{i,t}^{m,dest} = \left[\int_0^1 \left(P_{m,i,t}^{m,dest} \right)^{\frac{1}{1 - \lambda_{i,t}^{m,dest}}} dm \right]^{1 - \lambda_{i,t}^{m,dest}} \tag{2.3.69}$$

therefore:

$$P^{m,dest}_{i,t} = \left[\xi_{m,dest,i}\left(P^{m,dest}_{i,t-1}\left(\pi^{m,c}_{i,t-1}\right)^{\kappa_{m,dest,i}}\left(\bar{\pi}^{c}_{i,t}\right)^{1-\kappa_{m,dest,i}}\right)^{\frac{1}{1-\lambda^{m,dest}_{i,t}}} + \left(1-\xi_{m,dest,i}\right)\left(\widetilde{P}^{m,dest}_{i,t}\right)^{\frac{1}{1-\lambda^{m,dest}_{i,t}}}\right]^{1-\lambda^{m,dest}_{i,t}} \tag{2.3.70}$$

with $dest \in \{c, inv\}$.

As in the previous section, a log-linearised expression of the price-output relationship takes the form of a New Keynesian Phillips curve. In the first place, for imported consumption goods:

$$\left(\hat{\pi}^{m,c}_{i,t} - \hat{\bar{\pi}}^{c}_{i,t}\right) = \frac{\beta_i}{1+\kappa_{mc,i}\beta_i}\left(E_t\hat{\pi}^{m,c}_{i,t+1} - \rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right) + \frac{\kappa_{mc,i}}{1+\kappa_{mc,i}\beta_i}\left(\hat{\pi}^{m,c}_{i,t-1} - \hat{\bar{\pi}}^{c}_{i,t}\right) - \frac{\kappa_{mc,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{mc,i}\beta_i}\hat{\bar{\pi}}^{c}_{i,t} + \frac{\left(1-\xi_{mc,i}\right)\left(1-\beta_i\xi_{mc,i}\right)}{\xi_{mc,i}\left(1+\kappa_{mc,i}\beta_i\right)}\left(\widehat{mc}^{m,c}_{i,t} + \widehat{\lambda}^{m,c}_{i,t}\right) \tag{2.3.70*}$$

and for imported investment goods:

$$\left(\hat{\pi}^{m,i}_{i,t} - \hat{\bar{\pi}}^{c}_{i,t}\right) = \frac{\beta_i}{1+\kappa_{mi,i}\beta_i}\left(E_t\hat{\pi}^{m,i}_{i,t+1} - \rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right) + \frac{\kappa_{mi,i}}{1+\kappa_{mi,i}\beta_i}\left(\hat{\pi}^{m,i}_{i,t-1} - \hat{\bar{\pi}}^{c}_{i,t}\right) - \frac{\kappa_{mi,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{mi,i}\beta_i}\hat{\bar{\pi}}^{c}_{i,t} + \frac{\left(1-\xi_{mi,i}\right)\left(1-\beta_i\xi_{mi,i}\right)}{\xi_{mi,i}\left(1+\kappa_{mi,i}\beta_i\right)}\left(\widehat{mc}^{m,i}_{i,t} + \widehat{\lambda}^{m,i}_{i,t}\right) \tag{2.3.70*}$$

with:

$$\widehat{mc}^{m,c}_{i,t} = -\widehat{mc}^{x}_{i,t} - \hat{\gamma}^{x,*}_{i,t} - \hat{\gamma}^{mc,d}_{i,t}$$
$$\widehat{mc}^{m,i}_{i,t} = -\widehat{mc}^{x}_{i,t} - \hat{\gamma}^{x,*}_{i,t} - \hat{\gamma}^{mi,d}_{i,t}$$

2.3.8 Exporting firms

Since exporting firms buy final goods in the domestic market to sell them abroad, their marginal cost is given by the final goods price, P_t. Demands for individual exporting firms (identified by an x sub-index) are:

$$\widetilde{X}_{x,i,t} = \left(\frac{P^{x}_{x,i,t}}{P^{x}_{i,t}}\right)^{-\frac{\lambda^{x}_{i,t}}{\lambda^{x}_{i,t}-1}}\widetilde{X}_{i,t} \tag{2.3.71}$$

with $\widetilde{X}_{i,t}$ as total exports from country i, individual export prices, $P^x_{x,i,t}$, expressed in the exporter's currency, and the stochastic mark-up $\lambda^x_{i,t}$ following:

$$\lambda^x_{i,t} = (1-\rho_{\lambda_x,i})\lambda_{x,i} + \rho_{\lambda_x,i}\lambda_{x,i,t-1} + \sigma_{\lambda_x,i}\varepsilon^{\lambda_x}_{i,t} \tag{2.3.72}$$

Incomplete pass-through in this case implies price-stickiness of exports in terms of the foreign currency. Exporters face the probability $(1-\xi_{x,i})$ of being able to re-optimise their prices. However, if they are not allowed to do so their price follows an indexation rule as:

$$P^x_{i,t+1} = (\pi^x_{i,t})^{\kappa_{x,i}}(\bar{\pi}^c_{i,t+1})^{1-\kappa_{x,i}}P^x_{i,t} \tag{2.3.73}$$

with $\pi^x_{i,t}$ being the i-th country's exports-related inflation.

Profit-maximisation (expressed in local currency) is given by:

$$\begin{aligned}\max_{\widetilde{P}^x_{i,t}} E_{i,t}\sum_{s=0}^{\infty}(\beta_i\xi_{x,i})^s\,\upsilon_{i,t+s}\Bigg\{&\Big[\left(\pi^x_{i,t}\times\pi^x_{i,t+1}\times\ldots\times\pi^x_{i,t+s-1}\right)^{\kappa_{x,i}}\\ (\bar{\pi}^c_{i,t+1}\times\bar{\pi}^c_{i,t+2}\times\ldots\times\bar{\pi}^c_{i,t+s})^{1-\kappa_{x,i}}\widetilde{P}^x_{i,t}\Big]\,\widetilde{X}_{i,t+s}&\\ &-\frac{P_{i,t+s}}{\bar{S}_{i,t+s}}\left(\widetilde{X}_{i,t+s}+z_{i,t+s}\phi^x_i\right)\Bigg\}\end{aligned} \tag{2.3.74}$$

From it, the log-linearised first order condition yields:

$$\begin{aligned}\left(\hat{\pi}^x_{i,t}-\hat{\bar{\pi}}^c_{i,t}\right) = &\frac{\kappa_{x,i}}{1+\beta_i\kappa_{x,i}}\left(\hat{\pi}^x_{i,t-1}-\hat{\bar{\pi}}^c_{i,t}\right)+\frac{\beta_i}{1+\beta_i\kappa_{x,i}}\left(E_t\hat{\pi}^x_{i,t+1}-\rho_{\pi,i}\hat{\bar{\pi}}^c_{i,t}\right)\\ &+\frac{(1-\beta_i\xi_{x,i})(1-\xi_{x,i})}{\xi_{x,i}(1+\beta_i\kappa_{x,i})}\left(\widehat{mc}^x_{i,t}+\hat{\lambda}^x_{i,t}\right)-\frac{\beta_i\kappa_{x,i}(1-\rho_{\pi,i})}{1+\beta_i\kappa_{x,i}}\hat{\bar{\pi}}^c_{i,t}\end{aligned} \tag{2.3.75*}$$

where the marginal cost for exporting firms is modified by the exchange rate against the currencies in the rest of the world, therefore:

$$MC^x_{i,t} = \frac{P_{i,t}}{\bar{S}_{i,t}P^x_{i,t}} \tag{2.3.76}$$

or, in log-linearised terms:

$$\widehat{mc}^x_{i,t} = \hat{p}_{i,t} - \hat{\bar{s}}_{i,t} - \hat{p}^x_{i,t} \tag{2.3.77}$$

Total foreign demand for the domestically-produced consumption good is:

$$X^c_{i,t} = \sum_{j=1}^{N-1}T'_{i,j}\left(\frac{P^x_{i,t}}{P_{j,t}}\right)^{-\eta^{mc}_j}C_{j,t} \tag{2.3.78}$$

where $C_{j,t}$ and $P_{j,t}$ are foreign consumption and price level, respectively.

In a similar way, the foreign demand for the domestically-produced investment good is:

$$X_{i,t}^{inv} = \sum_{j=1}^{N-1} T'_{i,j} \left(\frac{P_{i,t}^{x}}{P_{j,t}} \right)^{-\eta_j^{mi}} I_{j,t} \tag{2.3.79}$$

where $I_{j,t}$ stands for investments in the rest of the world.

Given that trade exchanges are multi-lateral, additional clearing conditions are required to be added to the ALLV framework:

$$X_{i,t}^{c} = \sum_{j=1}^{N-1} C_{i,j,t}^{m} \tag{2.3.80}$$

$$X_{i,t}^{inv} = \sum_{j=1}^{N-1} I_{i,j,t}^{m} \tag{2.3.81}$$

These conditions match the international trade inflows and outflows of consumption and investment goods, respectively, with the rest of the countries[21].

These features are useful for departing from ALLV's *small-open-economy* assumption giving some economies a larger role in world trade allowing, thus, for a range of heterogeneity given that, in general, $X_{i,t}^{c} \neq X_{j,t}^{c}$ and $X_{i,t}^{inv} \neq X_{j,t}^{inv}$. International participation in trade is exogenously determined[22] and its share of total production is only restricted by output-income equalities (see Section 2.3.13) allowing for diverse commercial strengths.

2.3.9 Relative prices

Important price-relationships between internationally tradeable goods and domestic goods, followed by their log-linearised versions are defined as:

$$\gamma_{i,t}^{mc,d} = \frac{P_{i,t}^{m,c}}{P_{i,t}} \tag{2.3.82}$$

$$\widehat{\gamma}_{i,t}^{mc,d} = \widehat{\gamma}_{i,t-1}^{mc,d} + \widehat{\pi}_{i,t}^{m,c} - \widehat{\pi}_{i,t}^{d} \tag{2.3.82*}$$

[21] Avoiding what has been colloquially known in the modelling context as *exports to the moon*. See OECD (2012).

[22] For the most part, an empirical approach is used to determine the size of these individual flows.

$$\gamma_{i,t}^{minv,d} = \frac{P_{i,t}^{m,i}}{P_{i,t}} \tag{2.3.83}$$

$$\widehat{\gamma}_{i,t}^{minv,d} = \widehat{\gamma}_{i,t-1}^{minv,d} + \widehat{\pi}_{i,t}^{m,i} - \widehat{\pi}_{i,t}^{d} \tag{2.3.83*}$$

for imports prices and

$$\gamma_{i,t}^{x} = \frac{P_{i,t}^{x}}{\sum_{j=1}^{N-1} T'_{i,j} P_{j,t}} \tag{2.3.84}$$

$$\widehat{\gamma}_{i,t}^{x,*} = \widehat{\gamma}_{i,t-1}^{x,*} + \widehat{\pi}_{i,t}^{x} - \widehat{\pi}_{i,t}^{*} \tag{2.3.84*}$$

in the case of exports.

Using these definitions, the relationships between log-linearised marginal costs are:

$$\widehat{mc}_{i,t}^{m,c} = -\widehat{mc}_{i,t}^{x} - \widehat{\gamma}_{i,t}^{x} - \widehat{\gamma}_{i,t}^{mc,d} \tag{2.3.85}$$

$$\widehat{mc}_{i,t}^{m,inv} = -\widehat{mc}_{i,t}^{x} - \widehat{\gamma}_{i,t}^{x} - \widehat{\gamma}_{i,t}^{minv,d} \tag{2.3.86}$$

with:

$$mc_{i,t}^{x} = \frac{P_{i,t}}{\tilde{S}_{i,t} P_{i,t}^{x}} \tag{2.3.87}$$

and therefore:

$$\widehat{mc}_{i,t}^{x} = \widehat{mc}_{i,t-1}^{x} + \widehat{\pi}_{i,t} - \widehat{\pi}_{i,t}^{x} - \Delta\widehat{\tilde{S}}_{i,t} \tag{2.3.87*}$$

In turn, the relationships between domestic goods' prices by destination and the general level of prices are given by:

$$\gamma_{i,t}^{c,d} = \frac{P_{i,t}^{c}}{P_{i,t}} \tag{2.3.88}$$

$$\gamma_{i,t}^{inv,d} = \frac{P_{i,t}^{inv}}{P_{i,t}} \tag{2.3.89}$$

2.3.10 Government

Our depiction of governmental accounts constitutes one of the main variations with respect to the ALLV model. Instead of recurring to a fiscal VAR specification our scheme is composed by an auto-regressive structure subject to individual and regional shocks.

This formulation is preferred since it reflects rigidities in the fiscal policy variables and, with them, the relative difficulty to perform abrupt changes in any component. This, in addition to the explicit expression of common disturbances operating within a region.

Government executes spending, $G_{i,t}$, on domestically-produced goods (assumed to be a fixed combination of consumption and investment goods) financed with taxation on capital gains and profits, $\tau^k_{i,t}$, labour-income, $\tau^y_{i,t}$, payroll, $\tau^w_{i,t}$, and consumption, $\tau^c_{i,t}$.

Until we modify this setting later on, governments have no access to debt and, therefore, are subject to a budget constraint of the form:

$$\begin{aligned} P_{i,t}G_{i,t} + TR_{i,t} = R_{i,t-1}\left(M_{i,t+1} - M_{i,t}\right) + \tau^c_{i,t}P^c_{i,t}C_{i,t} + \left(\tau^y_{i,t} + \tau^w_{i,t}\right)W_{i,t}L_{i,t} + \\ \tau^k_{i,t}\Big[\left(R_{i,t-1} - 1\right)\left(M_{i,t} - Q_{i,t}\right) + R^k_{i,t}u_{i,t}\bar{K}_{i,t} \\ + \left(R^*_{i,t-1}\Phi\left(a_{i,t-1}, \tilde{\phi}_{i,t-1}\right) - 1\right)\widetilde{S}_{i,t}B^*_{i,t} + \Pi_{i,t}\Big] \end{aligned} \tag{2.3.90}$$

where:

$$a_{i,t} = \frac{\widetilde{S}_{i,t}B^*_{i,t+1}}{P_{i,t}z_{i,t}} \tag{2.3.91}$$

and $TR_{i,t}$ captures any deficit, ($TR_{i,t} < 0$), or surplus, ($TR_{i,t} > 0$), that may occur at a given point in time which is automatically (and equitably) transmitted to the respective domestic households.

Expanding the fiscal setting of Fernandez-Villaverde (2010) with regional shocks (but without debt), the tax rates and expenditure assume the following processes:

$$\hat{\tau}^k_{i,t} = \rho_{\tau^k}\hat{\tau}^k_{i,t-1} + \sigma_{\tau^k}\epsilon^{fpk}_{i,t} + \sigma_{\tau^k,r}\sum_{r=1}^{G} D^r_i\epsilon^{\tau,k}_{r,t} \tag{2.3.92*}$$

$$\hat{\tau}^y_{i,t} = \rho_{\tau^y}\hat{\tau}^y_{i,t-1} + \sigma_{\tau^y}\epsilon^{fpy}_{i,t} + \sigma_{\tau^y,r}\sum_{r=1}^{G} D^r_i\epsilon^{\tau,y}_{r,t} \tag{2.3.93*}$$

$$\hat{\tau}^w_{i,t} = \rho_{\tau^w}\hat{\tau}^w_{i,t-1} + \sigma_{\tau^w}\epsilon^{fpw}_{i,t} + \sigma_{\tau^w,r}\sum_{r=1}^{G} D^r_i\epsilon^{\tau,w}_{r,t} \tag{2.3.94*}$$

$$\hat{\tau}^c_{i,t} = \rho_{\tau^c}\hat{\tau}^c_{i,t-1} + \sigma_{\tau^c}\epsilon^{fpc}_{i,t} + \sigma_{\tau^c,r}\sum_{r=1}^{G} D^r_i\epsilon^{\tau,c}_{r,t} \tag{2.3.95*}$$

$$\hat{g}_{i,t} = \rho_g\hat{g}_{i,t-1} + \sigma_g\epsilon^{fpg}_{i,t} + \sigma_{g,r}\sum_{r=1}^{G} D^r_i\epsilon^{g}_{r,t} \tag{2.3.96*}$$

where D^r_i are dichotomous variables indicating whether the country belongs to the r-th region ($D^r_i = 1$ for the affirmative case: $i \in r$, zero otherwise.) and, therefore, if the corresponding region-wide shock, $\epsilon^{\tau,\odot}_{r,t}$, is applicable to the i-th economy. Discretionary policy shocks are represented by $\epsilon^{fp\odot}_{i,t}$.

2.3.11 Central bank and interest rates

We adhere to the approach on policy modelling based on simple rules instead of deriving it as a result of an optimisation exercise. We do so on the grounds given by Schmitt-Grohe and Uribe (2006), for example, arguing that despite their apparent simplicity these rules are able to achieve a similar performance as optimal rules when modelling monetary and fiscal policies.

In addition, we expand the reach of ALLV's monetary rule by allowing it to respond to indicators of financial stress. Based on the considerations put forward by Taylor (2008) and on the empirical approach of Akitobi and Stratmann (2008) our modified Taylor rule incorporates an adjustment factor which embraces the effects of international interest-rate spreads, $spr_{i,t}$.

The aim of integrating this factor is to reflect the capabilities of monetary policies to counteract episodes of financial stress when interest rates in each country or region divert from a stable reference. This modification widens the monetary perspective beyond fundamental variables as output and inflation and recognises the potential impact of disturbances related to financial risks when transmitted to the rest of the economy during episodes like the 2007-2009 financial crisis.

A policy rule is then set from each central bank's response to deviations from the inflation target, developments in the output gap, $\hat{y}_{i,t}$, changes in the log-linearised real exchange rate, $\hat{e}_{i,t}$ and to the spreads, $spr_{i,t}$, between domestic lending rates and an indicator of a risk-free international interest rate:

$$\begin{aligned}\widehat{R}_{i,t} = \rho_i^R \widehat{R}_{i,t-1} + (1-\rho_i^R)\left(\widehat{\bar{\pi}}_{i,t}^c + r_i^\pi\left(\hat{\pi}_{i,t-1}^c - \widehat{\bar{\pi}}_{i,t}^c\right) + r_i^y \hat{y}_{i,t-1} + r_i^e \hat{e}_{i,t-1}\right) \\ + r_i^{\Delta\pi}\Delta\hat{\pi}_{i,t}^c + r_i^{\Delta y}\Delta\hat{y}_{i,t} + r_i^{spr} spr_{i,t} + \varepsilon_{i,t}^R + \sum_{r=1}^{G} D_i^r \varepsilon_{r,t}^R\end{aligned} \tag{2.3.97*}$$

where the real exchange rate is given by:

$$\hat{e}_{i,t} = \sum_{j=1}^{N-1} T'_{i,j}\left(\widehat{S}_{i,j,t} + \widehat{P}_{j,t} - \widehat{P}_{i,t}^c\right) \tag{2.3.98*}$$

while $\varepsilon_{i,t}^R$ and $\varepsilon_{r,t}^R$ are national and regional monetary policy shocks, respectively.

Additionally:

$$\widehat{\pi}_{i,t}^c = \left[(1-\omega_i^c)\left(\gamma_i^{d,c}\right)^{1-\eta_i^c}\right]\widehat{\pi}_{i,t}^d + \left[(\omega_i^c)\left(\gamma_i^{mc,c}\right)^{1-\eta_i^c}\right]\widehat{\pi}_{i,t}^{m,c} \tag{2.3.99*}$$

$$\widehat{y}_{i,t} = \lambda_i^d\left[\widehat{\epsilon}_{i,t} + \alpha_i\left(\widehat{k}_{i,t} - \widehat{\mu}_{z,i,t}\right) + (1+\alpha_i)\widehat{L}_{i,t}\right] \tag{2.3.100*}$$

$$\widehat{e}_{i,t} = -\omega_i^c \left(\gamma_i^{c,mc}\right)^{-(1-\eta_i^c)} \widehat{\gamma}_{i,t}^{mc,d} - \widehat{\gamma}_{i,t}^{x,*} - \widehat{mc}_{i,t}^{x} \tag{2.3.101*}$$

Money growth follows:

$$\mu_{i,t} = \frac{M_{i,t+1}}{M_{i,t}} = \frac{\bar{m}_{i,t+1} z_{i,t} P_{i,t}}{\bar{m}_{i,t} z_{i,t-1} P_{i,t-1}} = \frac{\bar{m}_{i,t+1} \mu_{z,i,t} \pi_{i,t}}{\bar{m}_{i,t}} \tag{2.3.102}$$

in linearised terms:

$$\widehat{\mu}_{i,t} - \widehat{\bar{m}}_{i,t+1} - \widehat{\mu}_{z,i,t} - \widehat{\pi}_{i,t} + \widehat{\bar{m}}_{i,t} = 0 \tag{2.3.102*}$$

The time-varying inflation target involves a persistence component as well as individual and regional target shocks:

$$\widehat{\bar{\pi}}_{i,t}^c = \rho_i^{\pi} \widehat{\bar{\pi}}_{i,t-1}^c + \varepsilon_{i,t}^{\widehat{\bar{\pi}}^c} + \sum_{r=1}^{G} D_i^r \varepsilon_{r,t}^{\widehat{\bar{\pi}}^c} \tag{2.3.103}$$

For these purposes, consumption inflation is measured as a weighted average of domestic and imported goods' prices:

$$\widehat{\pi}_{i,t}^c = \left[(1-\omega_i^{mc}) \left(\gamma_{i,t}^{c,d}\right)^{1-\eta_i^c}\right] \widehat{\pi}_{i,t}^d + \left[(\omega_i^{mc}) \left(\gamma_{i,t}^{mc,d}\right)^{1-\eta_i^c}\right] \widehat{\pi}_{i,t}^{m,c}, \tag{2.3.104}$$

output is given by:

$$\widehat{y}_{i,t} = \lambda_i^d \left[\widehat{\epsilon}_{i,t} + \alpha_i \left(\widehat{k}_{i,t} - \widehat{\mu}_{i,t}^z\right) + (1-\alpha_i) \widehat{L}_{i,t}\right] \tag{2.3.105}$$

and the real exchange rate is:

$$\widehat{e}_{i,t} = -\omega_i^c (\gamma_i^{c,mc})^{-(1-\eta_i^c)} \widehat{\gamma}_{i,t}^{mc,d} - \widehat{\gamma}_{i,t}^{x} - \widehat{mc}_{i,t}^{x} \tag{2.3.106}$$

Given our multi-country setting and in consistency with Equation (2.3.20), when calculating a country-specific foreign reference interest rate for monetary policy, $\widehat{R}_t^*$, we use a weighted average where the financial relevance between each pair of countries, as reflected by $I'_{i,j}$, is taken into account:

$$\widehat{R}_{i,t}^* = \sum_{j=1}^{N} I'_{i,j} \left(\hat{R}_{j,t} + \epsilon_{j,t}^{R^*} + D_j^r D_i^r \epsilon_{r,t}^{R^*}\right) \tag{2.3.107}$$

with $\epsilon_{j,t}^{R^*}$ representing individual foreign shocks and $\epsilon_{r,t}^{R^*}$ common foreign shocks[23].

In an internationally competitive financial market, intermediaries provide in full for domestic and foreign credit demands (no credit shortages) but the rates prevailing

[23] Those shocks experienced by all the j-th countries.

in each economy are differentiated by a risk premium using as common reference a time-varying riskless rate, r_t^{rf}:

$$r_{i,t}^{l} = r_t^{rf} + \Phi\left(a_{i,t-1}, \tilde{\phi}_{i,t-1}\right) \tag{2.3.108}$$

where $r_{i,t}^{l}$ are domestic net lending rates.

Therefore, interest rate spreads, $spr_{i,t}$, reflect the differences in risk premia between countries:

$$spr_{i,t} = r_{i,t}^{l} - r_t^{rf} = \Phi\left(a_{i,t-1}, \tilde{\phi}_{i,t-1}\right) \tag{2.3.109}$$

and, in order to avoid arbitrage between individual markets as a result of these spreads.

Under this approach the risk-free rate can be a selected series such as the n-th country's rate series. This gives the n-th country an hegemonic position in the world although its exchange rate is still subject to adjustments in terms of its net financial position, $\widehat{a}_{i,t}$, and exogenous risk shocks to $\widehat{\tilde{\phi}}_{i,t}$ as in:

$$\widehat{\tilde{\phi}}_{i,t} = \rho_i^{\tilde{\phi}} \widehat{\tilde{\phi}}_{i,t-1} + (\varepsilon_{i,t}^{\tilde{\phi}} + D_i^r \varepsilon_{r,t}^{\tilde{\phi}}) \tag{2.3.110*}$$

where $\varepsilon_{i,t}^{\tilde{\phi}}$ and $\varepsilon_{r,t}^{\tilde{\phi}}$ are country-specific and regional shocks respectively.

Monetary unions

The rule in Equation (2.3.97*) is applied whenever monetary policies operate independently from each other. In the case of a monetary union in region m, however, a common rule applies as:

$$\begin{aligned}\widehat{R}_{m,t} = \rho_{Rm} \widehat{R}_{m,t-1} + (1-\rho_{Rm}) \left(\widehat{\overline{\pi}}_{m,t}^{c} + r_{\pi m}\left(\hat{\pi}_{m,t-1}^{c} - \widehat{\overline{\pi}}_{m,t}^{c}\right) + r_{ym} \hat{y}_{m,t-1}\right) \\ + r_{\Delta \pi m} \Delta \hat{\pi}_{m,t}^{c} + r_{\Delta ym} \Delta \hat{y}_{m,t} + r_{sprm} spr_{m,t} + \varepsilon_{m,t}^{R}\end{aligned} \tag{2.3.111*}$$

with a common inflation target:

$$\widehat{\overline{\pi}}_{m,t}^{c} = \rho_{\pi m} \widehat{\overline{\pi}}_{m,t-1}^{c} + \varepsilon_{m,t}^{\widehat{\overline{\pi}}^{c}} \tag{2.3.112*}$$

where $\varepsilon_{m,t}^{\widehat{\overline{\pi}}^{c}}$ is a (common) policy shock to all countries in $i \in m$.

Regional variables for this rule are calculated as:

$$\hat{\pi}_{m,t}^{c} = \sum_{i=1}^{M} w_i^y \hat{\pi}_{i,t}^{c}, \quad \hat{y}_{m,t} = \sum_{i=1}^{M} w_i^y \hat{y}_{i,t}, \quad spr_{m,t} = \sum_{i=1}^{M} w_i^y spr_{i,t}$$

for the M economies in the region m which constitutes the monetary union. Relative normalised weights, w_i^y, for each economy in the region are calculated on the basis of their participation in the aggregate output of the included countries:

$$w_i^y = \frac{Y_{i,\bar{t}}}{\sum_{i=1}^{M} Y_{i,\bar{t}}} \tag{2.3.113*}$$

where $\bar{t}$ is a fixed time period and $\sum_{i=1}^{M} w_i^y = 1$ by construction.

2.3.12 Country-specific foreign variables

Country-specific foreign variables are generated carefully attending to the relevance of counterparts in each case. Foreign consumption, for example, is a weighted average of consumption in the rest of the world:

$$\hat{c}_{i,t}^* = \sum_{j=1}^{N-1} w_{i,j}^t \left(\hat{c}_{j,t} + \epsilon_{j,t}^{\hat{c}} + D_j^r D_i^r \epsilon_{r,t}^{\hat{c}}\right) \tag{2.3.114*}$$

and, in a similar fashion:

$$\hat{i}_{i,t}^* = \sum_{j=1}^{N-1} w_{i,j}^t \left(\hat{i}_{j,t} + \epsilon_{j,t}^{\hat{i}} + D_j^r D_i^r \epsilon_{r,t}^{\hat{i}}\right) \tag{2.3.115*}$$

$$\hat{y}_{i,t}^* = \sum_{j=1}^{N-1} w_{i,j}^t \left(\hat{y}_{j,t} + \epsilon_{j,t}^{\hat{y}} + D_j^r D_i^r \epsilon_{r,t}^{\hat{y}}\right) \tag{2.3.116*}$$

$$\hat{\pi}_{i,t}^* = \sum_{j=1}^{N-1} w_{i,j}^t \left(\hat{\pi}_{j,t} + \epsilon_{j,t}^{\hat{\pi}} + D_j^r D_i^r \epsilon_{r,t}^{\hat{\pi}}\right) \tag{2.3.117*}$$

$$\hat{R}_{i,t}^* = \sum_{j=1}^{N-1} w_{i,j}^{fdi} \left(\hat{R}_{j,t} + \epsilon_{j,t}^{\hat{R}} + D_j^r D_i^r \epsilon_{r,t}^{\hat{R}}\right) \tag{2.3.118*}$$

Here, zero covariances between cross-sectional shocks are assumed:

$$cov\left(\epsilon_{i,t}^{\odot}, \epsilon_{j,t}^{\odot}\right) = 0,\ i \neq j,\ \odot = \{\hat{c}, \hat{i}, \hat{y}, \hat{\pi}, \hat{R}\}$$

similarly, within each country i:

$$cov\left(\epsilon_{i,t}^{\hat{c}}, \epsilon_{i,t}^{\hat{i}}, \epsilon_{i,t}^{\hat{y}}, \epsilon_{i,t}^{\hat{\pi}}, \epsilon_{i,t}^{\hat{R}}\right) = 0$$

In turn, regional shocks, $\epsilon_{r,t}^{\odot}$, constitute, by definition, disturbances with weighted effects across the variables (not the shocks) of the relevant cross-sections, therefore:

$$cov\left(\epsilon_{i,t}^{\odot}, \epsilon_{r,t}^{\odot}\right) = 0,\ \ \odot = \{\hat{c}, \hat{i}, \hat{y}, \hat{\pi}, \hat{R}\}$$

and, in the same way, the regional shocks involving different variables are assumed to display zero covariance:

$$cov\left(\epsilon_{r,t}^{\hat{c}}, \epsilon_{r,t}^{\hat{i}}, \epsilon_{r,t}^{\hat{y}}, \epsilon_{r,t}^{\hat{\pi}}, \epsilon_{r,t}^{\hat{R}}\right) = 0$$

These definitions and assumptions allow the structure of the model to account for international interrelationships (in the variables), as defined above, while maintaining tractable body of exogenous stochastic components at the national and regional levels. This structure of exogeneity between shocks gives clarity to the experimental application of selected shocks since it implies that international spillovers and externalities operate exclusively through the economic and financial channels described by the deterministic components of the model.

2.3.13 Market-clearing conditions

Unlike ALLV, the addition of government consumption in all countries means that foreign output is no longer limited to the sum of foreign consumption and investment. Given that governments and exporters only have access to domestically-produced goods, for each economy the following aggregate resource constraint must hold:

$$C_{i,t}^{d} + I_{i,t}^{d} + G_{i,t} + X_{i,t}^{C} + X_{i,t}^{I} \leq \epsilon_{i,t} z_{i,t}^{1-\alpha_i} K_{i,t}^{\alpha_i} L_{i,t}^{1-\alpha_i} - z_{i,t}\phi_i - a(u_{i,t})\bar{K}_{i,t} \tag{2.3.119}$$

while global equilibrium[24] additionally requires Equations 2.3.80 and 2.3.81 to hold as equalities, therefore, from the production perspective, the following log-linearised resource constraint must hold for each economy:

$$\begin{aligned} &(1-\omega_i^{mc})\left(\gamma^{c,d}\right)^{\eta_i^c}\frac{c_i}{\bar{y}_i}\left(\widehat{c}_{i,t}+\eta_i^c\widehat{\gamma}_{i,t}^{c,d}\right)+\left(1-\omega_i^{mi}\right)\left(\gamma^{i,d}\right)^{\eta_i^i}\frac{i_i}{\bar{y}_i}\left(\widehat{i}_{i,t}+\eta_i^i\widehat{\gamma}_{i,t}^{id}\right)\\ &\quad+\frac{g_i}{\bar{y}_i}\widehat{g}_{i,t}+\sum_{j=1}^{N-1}\left[\left(\omega_{mc,j}\right)\left(\gamma_{j,t}^{x}\right)^{\eta_j^c}\frac{c_j}{\bar{y}_i}\left(\widehat{c}_{j,t}-\eta_j^c\widehat{\gamma}_{j,t}^{x}+\widehat{\tilde{z}}_{j,t}^{*}\right)\right]\\ &\quad+\sum_{j=1}^{N-1}\left[\left(\omega_{mi,j}\right)\left(\gamma_{j,t}^{x}\right)^{\eta_j^i}\frac{i_j}{\bar{y}_i}\left(\widehat{i}_{j,t}-\eta_j^i\widehat{\gamma}_{j,t}^{x}+\widehat{\tilde{z}}_{j,t}^{*}\right)\right]\\ &\quad=\lambda_d\left(\widehat{\epsilon}_{i,t}+\alpha_i\left(\widehat{k}_{i,t}-\widehat{\mu}_{z,i,t}\right)+\left(1-\alpha_i\right)\widehat{L}_{i,t}\right)\\ &\quad\quad-\left(1-\tau_i^k\right)r_i^k\frac{\bar{k}_i}{\bar{y}_i}\frac{1}{\mu_z}\left(\widehat{k}_{i,t}-\widehat{\bar{k}}_{i,t-1}\right) \end{aligned} \tag{2.3.119*}$$

where $i \neq j$ and un-timed variables ($x_{i/j}$) represent steady state values. In turn $\tilde{z}_{j,t}^{*} = \frac{z_{j,t}}{z_{i,t}}$ are stationary shocks expressing the $(N^2 - N)/2$ technological asymmetries

[24]Here *global* means involving all the N countries in the model.

between economies (in log-linearised terms), each of these series follows:

$$\widehat{\tilde{z}}^{*}_{j,t} = \rho_{\tilde{z}^{*}} \widehat{\tilde{z}}^{*}_{j,t-1} + \varepsilon^{\tilde{z}^{*}}_{j,t} \tag{2.3.120}$$

In turn, net foreign assets satisfy:

$$\begin{aligned} S_{i,t} B^{*}_{i,t+1} = & S_{i,t} P^{x}_{i,t} \left(X^{C}_{i,t} + X^{I}_{i,t} \right) - S_{i,t} P^{*}_{i,t} \left(C^{m}_{i,t} + I^{m}_{i,t} \right) \\ & + R^{*}_{i,t-1} \Phi \left(a_{i,t-1}, \tilde{\phi}_{i,t-1} \right) S_{i,t} B^{*}_{i,t} \end{aligned} \tag{2.3.121}$$

which in log-linearised form leads to:

$$\begin{aligned} \hat{a}_{i,t} = & x^{c}_{i} \sum_{j=1}^{N-1} \left[-\eta^{c}_{j} \left(\omega^{c}_{j} \right) \left(\gamma^{c,m}_{j} \right)^{-\left(1-\eta^{c}_{j}\right)} \hat{\gamma}^{mc,m}_{i,t} + \hat{c}_{j,t} \right] \\ & x^{inv}_{i} \sum_{j=1}^{N-1} \left[-\eta^{inv}_{j} \left(\omega^{inv}_{j} \right) \left(\gamma^{inv,i}_{j} \right)^{-\left(1-\eta^{inv}_{j}\right)} \hat{\gamma}^{mi,m}_{j,t} + \hat{i}_{j,t} \right] \\ & + \sum_{j=1}^{N-1} \left[\left(c^{m}_{j} + i^{m}_{j} \right) \hat{\gamma}^{f}_{j,t} \right] \\ & - c^{m}_{i} \left[-\eta^{c}_{i} \left(1 - \omega^{c}_{i} \right) \left(\gamma^{c,d}_{i} \right)^{-\left(1-\eta^{c}_{i}\right)} \hat{\gamma}^{mc,d}_{i,t} + \hat{c}_{i,t} \right] \\ & - i^{m}_{i} \left[-\eta^{inv}_{i} \left(1 - \omega^{inv}_{i} \right) \left(\gamma^{inv,d}_{i} \right)^{-\left(1-\eta^{inv}_{i}\right)} \hat{\gamma}^{mi,d}_{i,t} + \hat{i}_{i,t} \right] \\ & + \frac{R_{i}}{\pi_{i} \mu^{z}_{i}} \hat{a}_{i,t-1} \end{aligned} \tag{2.3.122}$$

The accumulation of net foreign assets from the i-th country's perspective follows the trends of foreign trade as well as the interest rate gains from their amount in the previous period:

$$\begin{aligned} \overline{S}_{i,t} B^{*}_{i,t} = & \overline{S}_{i,t} P^{x}_{i,t} \left(X^{c}_{i,t} + X^{inv}_{i,t} \right) - \overline{S}_{i,t} P^{*}_{i,t} \left(C^{m}_{i,t} + I^{m}_{i,t} \right) \\ & + \left(\sum_{j=1}^{N-1} T'_{i,j} R_{j,t} \right) \Phi \left(a_{i,t-1}, \widetilde{\phi}_{i,t-1} \right) \overline{S}_{i,t} B^{*}_{i,t} \end{aligned} \tag{2.3.123}$$

Using Equations (2.3.78), (2.3.79), (2.3.80) and (2.3.81) we obtain a relationship between the i-th country's exports and the rest of the world aggregate production:

$$\frac{X^{c}_{i,t}}{z_{i,t}} + \frac{X^{inv}_{i,t}}{z_{i,t}} = \sum_{j=1}^{N-1} \left[\left(\frac{P^{x}_{i,t}}{\sum_{j=1}^{N-1} T'_{i,j} P_{j,t}} \right)^{-\eta_{j}} \frac{Y_{j,t}}{z_{j,t}} \frac{z_{j,t}}{z_{i,t}} \right] \tag{2.3.124}$$

Re-scaling Equation (2.3.123) with $1/(P_{i,t}z_{i,t})$ leads to:

$$\begin{aligned} a_{i,t} &= (mc^x_{i,t})^{-1}(\gamma^x_{i,t})^{-\eta_j} y_{j,t}\bar{z}_{j,t} - (\gamma^f_{i,t})^{-1}(c^m_{i,t} + i^m_{i,t}) \\ &+ \left(\sum_{j=1}^{N-1} T'_{i,j} R_{j,t}\right)(a_{i,t}, \widetilde{\phi}_{i,t-1}) \frac{a_{i,t-1}}{\pi_{i,t}\mu^z_{i,t}} \frac{\bar{S}_{i,t}}{\bar{S}_{i,t-1}} \end{aligned} \tag{2.3.125}$$

where $\bar{z}_{j,t} = \frac{z_{j,t}}{z_{i,t}}$. We keep ALLV's assumptions on the steady-state values of $a_i = 0$, $\Phi(0,0) = 1$, $R_j = R_i$, $\Delta\bar{S}_{i,t} = 0$, $\gamma^f_i = \dfrac{P_i}{\sum_{j=1}^{N-1} T'_{i,j} S_{i,j} P_j} = 1$, $mc^x_i = 1$ and $\gamma^x_i = 1$ which, after total differentiation of Equation (2.3.125) yields:

$$\begin{aligned} \hat{a}_{i,t} &= y^*_i \left(-\widehat{mc}^x_{i,t} - \eta^f_i \widehat{\gamma}^{x,*}_{i,t} + \widehat{y}^*_{i,t} + \widehat{\bar{z}}_{i,t}\right) \\ +(c^m_i + i^m_i)\gamma^f_{i,t} - c^m_i &\left[-\eta^c_i (1-\omega^c_i)\left(\gamma^{c,d}_i\right)^{-\left(1-\eta^c_i\right)} \widehat{\gamma}^{mc,d}_{i,t} + \widehat{c}_{i,t}\right] \\ -i^m_i &\left[-\eta^{inv}_i \left(1-\omega^{inv}_i\right)\left(\gamma^{i,d}_i\right)^{-\left(1-\eta^{inv}_i\right)} \widehat{\gamma}^{mi,d}_{i,t} + \widehat{i}_{i,t}\right] \\ &+ \frac{R_i}{\pi_i \mu_z} \hat{a}_{i,t-1} \end{aligned} \tag{2.3.125*}$$

with $\hat{a} = da_{i,t}$.

The money market clearing condition for each country is:

$$\nu^w_i W_{i,t} L_{i,t} = \mu_{i,t} M_{i,t} - Q_{i,t} \tag{2.3.126}$$

or, in stationarised terms:

$$\nu^w_i \bar{w}_{i,t} L_{i,t} = \frac{\mu_{i,t}\bar{m}_{i,t}}{\pi_{i,t}\mu^z_{i,t}} - q_{i,t} \tag{2.3.127}$$

and log-linearising:

$$\nu^w_i \bar{w}_i L_i(\widehat{\nu^w}_{i,t} + \widehat{w}_{i,t} + \widehat{L}_{i,t}) = \frac{\mu_i \bar{m}_i}{\pi_i \mu_z}(\widehat{\mu}_{i,t} + \widehat{\bar{m}}_{i,t} - \widehat{\pi}_{i,t} - \widehat{\mu}_{z,i,t}) - q\widehat{q}_{i,t} \tag{2.3.127*}$$

2.3.14 Steady state relationships

The following steady state relationships equally apply for all the participating countries[25]:

$$
\begin{aligned}
b_{w,i} &= \frac{\lambda_i^w \sigma_L - (1-\lambda_i^w)}{(1-\beta_i \xi_{w,i})(1-\xi_{w,i})} \\
\eta_{0,i} &= b_{w,i}\xi_{w,i} \\
\eta_{1,i} &= \sigma_L \lambda_i^w - b_{w,i}(1+\beta_i \xi_{w,i}^2) \\
\eta_{2,i} &= b_{w,i}\beta_i \xi_{w,i} \\
\eta_{3,i} &= -b_{w,i}\xi_{w,i} \\
\eta_{4,i} &= b_{w,i}\beta_i \xi_{w,i} \\
\eta_{5,i} &= b_{w,i}\xi_{w,i}\kappa_i^w \\
\eta_{6,i} &= -b_{w,i}\beta_i \xi_{w,i}\kappa_i^w \\
\eta_{7,i} &= (1-\lambda_i^w) \\
\eta_{8,i} &= -(1-\lambda_i^w)\sigma_L \\
\eta_{9,i} &= -(1-\lambda_i^w)\frac{\tau_i^y}{(1-\tau_i^y)} \\
\eta_{10,i} &= -(1-\lambda_i^w)\frac{\tau_i^w}{(1+\tau_i^w)} \\
\eta_{11,i} &= -(1-\lambda_i^w) \\
R_i &= \frac{\pi \mu_z - \tau_i^k \beta_i}{(1-\tau_i^k)\beta_i} \\
R_i^f &= \nu_i^w R_i + 1 - \nu_i^w \\
\eta_i^{m,c} &= \frac{\lambda_i^{mc}}{(\lambda_i^{mc}-1)} \\
\eta_i^{m,inv} &= \frac{\lambda_i^{mi}}{(\lambda_i^{mi}-1)}
\end{aligned}
$$

[25]This set of equalities is treated as *model-local* in Dynare's programming of the model in order to guarantee their constant updating during estimations. See Pfeifer (2014, Remark 4, p.12).

$$\gamma_i^{inv,d} = \left[(1-\omega_i^{inv}) + \omega_i^{inv}\left[\frac{\eta_i^{m,inv}}{(\eta_i^{m,inv}-1)}\right]^{(1-\eta_i^{inv})}\right]^{\frac{1}{1-\eta_i^{inv}}}$$

$$\gamma_i^{c,d} = \left[(1-\omega_i^{c}) + \omega_i^{c}\left[\frac{\eta_i^{m,c}}{(\eta_i^{m,c}-1)}\right]^{(1-\eta_i^{c})}\right]^{\frac{1}{1-\eta_i^{c}}}$$

$$\gamma_i^{d,c} = \frac{1}{\gamma_i^{c,d}}$$

$$\gamma_i^{c,mc} = \left[(1-\omega_i^{c})\left[\frac{(\eta_i^{m,c}-1)}{\eta_i^{m,c}}\right]^{(1-\eta_i^{c})} + \omega_i^{c}\right]^{\frac{1}{1-\eta_i^{c}}}$$

$$\gamma_i^{mc,c} = \frac{1}{\gamma_i^{c,mc}}$$

$$\gamma_i^{i,mi} = \left[(1-\omega_i^{inv})\left[\frac{(\eta_i^{m,inv}-1)}{\eta_i^{m,inv}}\right]^{(1-\eta_i^{inv})} + \omega_i^{inv}\right]^{\frac{1}{1-\eta_i^{inv}}}$$

$$\gamma_i^{mi,i} = \frac{1}{\gamma_i^{i,mi}}$$

$$r_i^k = \frac{\mu_z\gamma_i^{inv,d} - \beta_i(1-\delta)\gamma_i^{inv,d}}{(1-\tau_i^k)\beta_i}$$

$$\bar{w}_i = (1-\alpha_i)\left(\lambda_i^d\right)^{\frac{-1}{(1-\alpha_i)}}(\alpha_i)^{\frac{\alpha_i}{(1-\alpha_i)}}\left(r_i^k\right)^{\frac{-\alpha_i}{(1-\alpha_i)}}\left(R_i^f\right)^{-1}$$

$$\frac{k_i}{L_i} = \frac{\alpha_i}{(1-\alpha_i)}\mu_z\bar{w}_i R_i^f\left(r_i^k\right)^{-1}$$

$$D1_i = (1-\omega_i^c)\left[\gamma_i^{c,d}\right]^{\eta_i^c} + \omega_i^c\left[\gamma_i^{c,mc}\right]^{\eta_i^c}$$

$$D2_i = \frac{(1-gr_i)}{\lambda_i^d}(\mu_z)^{-\alpha_i}\left(\frac{k_i}{L_i}\right)^{\alpha_i} - \left\{(1-\omega_i^{inv})\left[\gamma_i^{inv,d}\right]^{\eta_i^{inv}} + \omega_i^{inv}\left[\gamma_i^{i,mi}\right]^{\eta_i^{inv}}\right\}\left[1-\frac{1-\delta}{\mu_z}\right]\frac{k_i}{L_i}$$

$$D3_i = \left[\frac{(1-\tau_i^y)\frac{1}{\lambda_i^w}\frac{\bar{w}_i}{(1+\tau_i^w)}}{A_L}\right]^{\frac{1}{\sigma_L}}$$

$$D4_i = \left[\frac{(\mu_z-\beta_i b)}{(1+\tau_i^c)(\mu_z-b)}\right]\left[\gamma_i^{c,d}\right]^{(-1)}$$

$$L_i = \left[(D3_i D4_i)^{\frac{1}{\sigma_L}}\left(\frac{D2_i}{D1_i}\right)^{\frac{-1}{\sigma_L}}\right]^{\frac{\sigma_L}{(1+\sigma_L)}}$$

$$
\begin{aligned}
c_i &= \frac{D2_i}{D1_i} L_i \\
\psi_i^z &= \frac{1}{c_i} D4_i \\
\bar{y}_i &= \frac{1}{\lambda_i^d} (\mu_z)^{-\alpha_i} \left(\frac{k_i}{L_i} \right)^{\alpha_i} L_i \\
g_i &= gr_i \bar{y}_i \\
q_i &= \left[\frac{A_q}{(1-\tau_i^k)\psi_i^z (R_i - 1)} \right]^{\frac{1}{\sigma q}} \\
\bar{m}_i &= \nu_i^w \bar{w}_i L_i + q_i \\
k_i &= \frac{k_i}{L_i} L_i \\
\bar{k}_i &= k_i \\
i_i &= \left[1 - \frac{(1-\delta)}{\mu_z} \right] k_i \\
c_i^m &= \omega_i^c \left(\gamma_i^{c,mc}\right)^{\eta_i^c} c_i \\
i_i^m &= \omega_i^{inv} \left(\gamma_i^{i,mi}\right)^{\eta_i^{inv}} i_i \\
y_i^* &= \omega_i^c \left(\gamma_i^{c,mc}\right)^{\eta_i^c} c_i + \omega_i^{inv} \left(\gamma_i^{i,mi}\right)^{\eta_i^{inv}} i_i
\end{aligned}
$$

2.4 Solution, estimation methods and data

2.4.1 DSGE Solution

Given the stochastic nature of the model, perturbation methods are applied for its solution. As noted in the description of the model, in a rational expectations environment, the DSGE setting comprises backward, $\boldsymbol{y}_{t-1}$, forward-looking, $\boldsymbol{y}_{t+1}$, static, $\boldsymbol{y}_t$, and mixed endogenous variables, $\boldsymbol{y}_{t-1,t,t+1}$, as well as a collection of stochastic shocks, $\boldsymbol{u}_t$:

$$
\begin{aligned}
E_t \left\{ f(\boldsymbol{y}_{t-1}, \boldsymbol{y}_t, \boldsymbol{y}_{t+1}, \boldsymbol{u}_t) \right\} &= 0 \\
E(\boldsymbol{u}_t) &= 0 \\
E(\boldsymbol{u}_t \boldsymbol{u}_t') &= \Sigma_u
\end{aligned}
$$

expressing first order and equilibrium conditions.

The solution approach we have applied relies on a process with perturbation methods as performed by Dynare[26]. As succinctly described in its User Guide

[26]Dynare is software which, through a compilation of functions, performs simulations and estimations of DSGE and overlapping generations models. For more details on this platform visit `http://www.dynare.org`.

(Mancini Griffoli (2013)), it starts with a *policy function* relating current and lagged values and current shocks:

$$\boldsymbol{y}_t = g\left(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t\right)$$

which implies:

$$\begin{aligned}\boldsymbol{y}_{t+1} &= g\left(\boldsymbol{y}_t, \boldsymbol{u}_{t+1}\right) \\ &= g\left(\left(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t\right), \boldsymbol{u}_{t+1}\right)\end{aligned}$$

Then define a function F including the past state as well as current and future shocks:

$$F\left(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t, \boldsymbol{u}_{t+1}\right) = f(g(g(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t), \boldsymbol{u}_{t+1}), g(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t), \boldsymbol{y}_{t-1}, \boldsymbol{u}_t)$$

which enters the system as:

$$E_t\left[F(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t, \boldsymbol{u}_{t+1})\right] = 0$$

By definition, in a steady state past, current and future values of variables are the same and no shocks are active, therefore a linearisation around it can be written as:

$$f(\bar{\boldsymbol{y}}, \bar{\boldsymbol{y}}, \bar{\boldsymbol{y}}, 0) = 0$$

with $\bar{\boldsymbol{y}} = g(\bar{\boldsymbol{y}}, 0)$.

A first-order Taylor approximation around the steady state implies:

$$\begin{aligned}E_t\left\{F^{(1)}(\boldsymbol{y}_{t-1}, \boldsymbol{u}_t, \boldsymbol{u}_{t+1})\right\} =& E_t[f(\bar{\boldsymbol{y}}, \bar{\boldsymbol{y}}, \bar{\boldsymbol{y}}) \\ &+ f_{y+}(g_y(g_y\hat{\boldsymbol{y}} + g_u\boldsymbol{u}) + g_u\boldsymbol{u}') \\ &+ f_{y0}(g_y\hat{\boldsymbol{y}} + g_u\boldsymbol{u}) + f_{y-}\hat{\boldsymbol{y}} + f_u\boldsymbol{u}] \\ =& 0\end{aligned}$$

where $\hat{\boldsymbol{y}} = \boldsymbol{y}_{t-1} - \bar{\boldsymbol{y}}, \boldsymbol{u} = \boldsymbol{u}_t, \boldsymbol{u}' = \boldsymbol{u}_{t+1}, f_{y+} = \frac{\partial f}{\partial \boldsymbol{y}_{t+1}}, f_{y0} = \frac{\partial f}{\partial \boldsymbol{y}_t}, f_{y-} = \frac{\partial f}{\partial \boldsymbol{y}_{t-1}}, f_u = \frac{\partial f}{\partial \boldsymbol{u}_t}, g_y = \frac{\partial g}{\partial \boldsymbol{y}_{t-1}}, g_u = \frac{\partial f}{\partial \boldsymbol{u}_t}$. Given that future shocks, $\boldsymbol{u}'$, have zero expected mean, after taking expectations this equals to:

$$
\begin{aligned}
E_t\left\{F^{(1)}(\boldsymbol{y}_{t-1},\boldsymbol{u}_t,\boldsymbol{u}_{t+1})\right\} =& f(\bar{\boldsymbol{y}},\bar{\boldsymbol{y}},\bar{\boldsymbol{y}}) \\
&+ f_{y+}(g_y(g_y\hat{\boldsymbol{y}}+g_u\boldsymbol{u})) \\
&+ f_{y0}(g_y\hat{\boldsymbol{y}}+g_u\boldsymbol{u}) + f_{y-}\hat{\boldsymbol{y}} + f_u\boldsymbol{u} \\
=& \left(f_{y+}g_yg_y + f_{y0}g_y + f_{y-}\right)\hat{\boldsymbol{y}} + \left(f_{y+}g_yg_u + f_{y0}g_u + f_u\right)\boldsymbol{u} \\
=& 0
\end{aligned}
$$

where g_y and g_u are the endogenous and shock components of the policy function g as calculated by Dynare, which, in linear terms, decomposes the endogenous and exogenous variations around the steady state:

$$\boldsymbol{y}_t = \bar{\boldsymbol{y}} + g_y\hat{\boldsymbol{y}} + g_u\boldsymbol{u}$$

providing a solution for the model.

Blanchard and Kahn conditions

In the empirical analysis of DSGE models with rational expectations, discussing the requirements for existence and uniqueness of a solution has become a crucial point to address given that neither of those features are guaranteed a priori. The criteria for evaluating those two properties are embodied in the *Blanchard and Kahn conditions* (Blanchard and Kahn (1980)). These local conditions are based on the analysis of the eigenvalues of the models calculated at the steady state.

The conditions for a unique and stable path for the model are expressed as the requirement for as many unstable eigenvectors in the system (that is, roots larger than one) as the number of forward-looking variables are in the model. Failure to meet these conditions results in explosive systems (excessive number of unstable roots) or indeterminacy (too few unstable roots leading to multiple stable solutions).

The technical assessment of the conditions proceeds as follows. In a DSGE configuration under rational expectations, a model linearised around the steady state such as:

$$E_t\boldsymbol{X}_{t+1} = \boldsymbol{A}\boldsymbol{X}_t + \boldsymbol{\gamma}\boldsymbol{u}_{t+1}$$

can be partitioned into two parts according to their time-focus using $\boldsymbol{X}_t = \begin{bmatrix}\boldsymbol{x}_t\\ \boldsymbol{y}_t\end{bmatrix}$:

$$\begin{bmatrix}\boldsymbol{x}_{t+1}\\ E_t\boldsymbol{y}_{t+1}\end{bmatrix} = \boldsymbol{A}\begin{bmatrix}\boldsymbol{x}_t\\ \boldsymbol{y}_t\end{bmatrix} + \boldsymbol{\gamma}\boldsymbol{u}_{t+1}, \quad \boldsymbol{x}_{t=0} = \boldsymbol{x}_0$$

where $\boldsymbol{x}$ are backward-looking variables while $\boldsymbol{y}$ are forward-looking (i.e. non-predetermined at t) variables. $E_t\boldsymbol{y}_{t+1}$ are agents' expectations held at t such that:

$$E_t\boldsymbol{y}_{t+1} = E\left(\boldsymbol{y}_{t+1}|\Omega_t\right)$$

with $E(\cdot)$ as the mathematical expectations operator and Ω_t as the information set at t including past and current values of $\boldsymbol{x}$, $\boldsymbol{y}$ and $\boldsymbol{u}$.

A *Jordan decomposition* of the matrix $\boldsymbol{A}$ renders a canonical form as $\boldsymbol{A} = \boldsymbol{C}^{-1}\boldsymbol{J}\boldsymbol{C}$ where $\boldsymbol{C}$ is a matrix of eigenvectors and $\boldsymbol{J}$ is a diagonal matrix of eigenvalues of $\boldsymbol{A}$.

Therefore, the Blanchard and Kahn conditions require that the number of eigenvalues in $\boldsymbol{J}$ outside the unit circle is equal to the number of variables in $\boldsymbol{y}$. These conditions characterise a system with unique solution (Blanchard and Kahn (1980, Proposition 1, p. 1308.)) and saddle-path stability[27].

Partial information approach

For the empirical applications of our international macroeconometric platform, we make use of a *partial information* approach in the solution of the models and the subsequent simulations of impulse-response functions. This method is based on Pearlman, Currie and Levine (1986) which was developed with the aim to respond to the practical criticism on the assumption of perfect information on the part of agents in the economy (or, at the very least, of the econometrician) in stochastic models with rational expectations.

Our preference for this method mainly stems from the international structure in our modelling in the sense that it makes implausible for the agents of any individual economy to perfectly observe shocks, macroeconomic developments and policies occurring across the entire relevant networks. This is especially important in our empirical applications given that the models for all the national economies in a particular region are simultaneously solved in each one of our exercises, taking into account not only national but also regionally-common and even global shocks within a single system.

As a result of our representation of international networks, every national model involves variables and shocks from other economies in the same region so, even at the national level, a perfect information assumption would imply access and understanding (for example, in terms of distinguishing between temporary and permanent

[27]Being a necessary requirement set up within the Dynare computing platform before proceeding with the solution and estimation of the model, all our empirical applications satisfy the Blanchard and Kahn conditions.

changes) of a great deal of foreign data on the part of domestic agents[28].

These conditions make reasonable to restrict the scope of the information that domestic agents are effectively able to observe at the time of forming their expectations. Some examples of previous application of this methodology in the context of macroeconomic policy are found in Dellas (2006), Collard, Dellas and Smets (2009), Collard and Dellas (2010), Canzoneri, Collard, Dellas and Diba (2012).

Replacing the full information with a partial information assumption (the technical details on its implementation are in Pearlman (2009)) in our case imply that private agents (households and firms) have access to a restricted set of observable variables, $\mathbf{\Omega}^P$, in their own national models:

$$\mathbf{\Omega}^P_{i,t} = \left\{ \widehat{\pi}_{i,t},\ \widehat{w}_{i,t},\ \widehat{c}_{i,t},\ \widehat{i}_{i,t},\ \widehat{E}_{i,t},\ \widehat{y}_{i,t},\ \widehat{\pi}^c_{i,t},\ \widehat{\tilde{\phi}}_{i,t} \right\}$$

This set of variables has advantages in at least two fronts. While embodying an overall profile of real and nominal macroeconomic conditions for each national economy, these variables are, in practice, within reasonable reach for private agents to observe as domestic data which, at the same time, embrace the final expressions of both domestic and international shocks given, for example, that final consumption, c, and investment, i, include both domestic and imported goods and, with them, the domestic and imported factors of consumer, $\hat{\pi}^c$, and overall inflation, $\hat{\pi}$. The only variable which requires actual observation of foreign data is the national premium risk, $\widehat{\tilde{\phi}}$, but in our modelling this just requires one risk-free interest rate to be compared as reference against the local rate so we assume it is still sensible to keep it in the observable set.

The components of this restricted information set, thus, comply with crucial requirements for our investigation as:

1. reasonable practical feasibility of being observed by private domestic agents in a setting involving complex international economic and financial interactions, and

2. their property of reflecting the weighted impacts of domestic and international shocks trough our modelling.

For the sake of comparison, we included in Appendix G a selection of impulse-responses contrasting the full and the partial information approaches in the simulation of the estimated model. In particular, the graphs show the discrepancy between

[28] Another potential approach, which we do not entertain, stands in the middle ground by considering that agents may have access to and understanding of foreign data with delay. The bases of such a proposition were also hinted in Pearlman, Currie and Levine (1986) but currently we do not count on appropriate tools for evaluating it in our empirical analysis.

the outcomes of the two methods which are accentuated in the case of Mexico facing monetary and policy target shocks in the United States, for example, while the same exercise shows higher consistency between the two approaches in the case of Canada receiving the effects of a target shock in the United States.

In general, however, the differences are significant enough in quantitative and qualitative terms (in some cases even exhibit opposite trends) to conclude that the partial information approach generates distinctive results and given the discussion above, we consider it to be the most appropriate way of addressing the interrelations of interest in a system-based framework with the extent proposed in this Chapter.

2.4.2 DSGE Estimation

Estimation of DSGE models implies a joint estimation of a considerable number of the economy's parameters which means that they are exposed to suffer important losses in terms of consistency due to misspecification, particularly when maximum likelihood (ML) estimates are calculated.

However, there are alternative ways of estimating these models such as the generalised method of moments, GMM (see Canova (2007, p. 191-196), or Bayesian methods (see Smets and Wouters (2003), An and Schorfheide (2007) and Canova (2007, p. 440-461)). On this, Ruge-Murcia (2007) conducted a comparative estimation of a small DSGE model using ML and GMM methods as well as *simulated method of moments* and *indirect inference* confirming the sensitivity of ML to misspecification and showing some computational advantages of moment-based methods favouring GMM in particular.

In turn, Sims (2008, p. 2471) argues that Bayesian DSGE models display a number of important advantages:

- for providing policy-exploitable characterisations of uncertainty,
- for allowing systematic learning,
- for permitting comparisons over their fit,
- by generating probability distributions that can be fed into decision-making processes,
- when compared to Bayesian SVAR's (Structural Vector Auto-Regressive models), DSGE models are more comprehensive accounts of policy mechanisms and outcomes.

Similarly, Adolfson, Lindé and Villani (2005) developed a comparative analysis of a DSGE model for the Euro area against VAR and vector error correction models

(VECM) using ML and Bayesian methods for forecasting purposes. Their findings support the DSGE model capabilities to generate reasonable projections mainly in the medium and short term horizons by using these techniques.

Sub-sample estimations constitute a tool for incorporating a degree of variation of the structural parameters as a result of concise economic development trends or even more dramatic variations which can be caused by regime changes.

This, however, does not constitute a case for the *Lucas critique* but, in harmony with Fernández-Villaverde and Rubio-Ramírez (2007) instead, a recognition that no economy remains unchanged over the years. It is true that the expectations-related parameters display a larger sensitivity to short term factors such as financial turmoil but, on the other hand, there is no reason for the deep parameters to behave as true constants.

Subsequently, time-drifting *structural* parameters require the use of appropriate methods and can also be better understood by using alternative techniques as proposed by Fernández-Villaverde and Rubio-Ramírez (2007) who argue in favour of the usefulness of combining perturbation methods and the particle filter (a methodology that has attracted some recent attention see Andreasen (2011)).

This kind of considerations must be incorporated in any analysis of the results when models are *taken to the data*. A relevant example of time-varying parameters analysis can be found in DiCecio and Nelson (2007) where, for the estimation of a DSGE model, a policy-related structural break is identified for the United Kingdom's economy in 1979.

Achieving an exploitable connection between the models' results and the information needed by policy makers in order to conduct appropriate actions is not an easy step. It is one that largely depends on those results to depict actual phenomena as close as possible. Nevertheless, several complications appear between theoretically well-founded estimations and real figures as long as data does not necessarily match theoretical relationships in a neat (let alone stable) way. Thus, if our models are to survive, they must adapt in such a way that theory should still be providing answers at least in structural terms.

In words of Sims (2008), models should not be evaluated in terms of their ability to fit the data but considered as probability models instead, providing reliable probabilistic distributions (not point-predictions) of the data that are, in turn, useful for decision-making under uncertainty. Sims' advice for modellers is to depart from the *frequentist*[29] approach to inference due to its focus on the variability of estimators instead of a more relevant attention to the distribution of the models' unknown parameters.

[29] With which he implies a preference for Bayesian methods.

As explained by Alvarez-Lois et al. (2008), an alternative procedure to allow DSGE models to provide useful recommendations for policy environments has been taken by the Bank of England's Quarterly Model (BEQM) where a micro-founded *core* DSGE model has been extended by a number of *non-core* equations. The secondary set of equations relates the model's solution vector to real data by linking cointegration relationships in the core and non-core sides in a Vector Error-Correction (VECM) fashion. The advantage of this approach is that the *bridge* variables depicting mechanisms that are not imbued in the core model do not alter the steady state conclusions.

Bayesian methods have also been applied for forecasting purposes within the DSGE context[30] as shown by Christoffel, Coenen and Warne (2010) who used the European Central Bank's New Area Wide Model (NAWM) for out-of-sample forecast evaluation concluding that those predictions are good in comparison to alternative methods although their study lacks spillovers and interactions between the Euro-area and the rest of the world.

The above mentioned paper from Christiano et al. (2011) describe and apply a specialised Bayesian two-step estimation technique (namely, an impulse-response matching technique) based on Rotemberg and Woodford (1997). Starting from a VAR estimation of responses to shocks in the first stage, impulse-response functions are calibrated to match the estimated parameters in the second stage.

Another useful exercise has been made by Stähler and Thomas (2011) by exploiting the policy-simulation capabilities of DSGE models. They provide a series of results of fiscal policy simulations within a monetary union using a two-country FiMod (a DSGE model for fiscal policy simulations) model calibrated for a specific representation of Spain versus the rest of the Euro area.

Their important contributions related to our interests are a) the specific incorporation of fiscal spillovers, b) the description of international linkages not only on the basis of trade of goods and services but also on the exchange of international bonds and c) the specific differentiation of each country's size (although their population-based indicator does not match the purposes of our investigation).

Estimation mechanism

In line with a Bayesian stance, the estimation procedure takes the first order and equilibrium conditions as:

$$E_t = \{f\left(\boldsymbol{y}_{t+1}, \boldsymbol{y}_t, \boldsymbol{y}_{t-1}, \boldsymbol{u}_t\right)\} = 0$$

[30]In log-linearised form.

and the solution of the model written as:

$$\begin{aligned}
\hat{\boldsymbol{y}}_t &= g_y(\boldsymbol{\theta})\hat{\boldsymbol{y}}_{t-1} + g_u(\boldsymbol{\theta})\boldsymbol{u}_t \\
\boldsymbol{y}_t^* &= \boldsymbol{M}\bar{\boldsymbol{y}}(\boldsymbol{\theta}) + \boldsymbol{M}\hat{\boldsymbol{y}}_t + \boldsymbol{N}(\boldsymbol{\theta})\boldsymbol{x}_t + \boldsymbol{\eta}_t \\
E(\boldsymbol{\eta}_t\boldsymbol{\eta}_t') &= V(\boldsymbol{\theta}) \\
E(\boldsymbol{u}_t\boldsymbol{u}_t') &= Q(\boldsymbol{\theta}) \\
E(\boldsymbol{\eta}_t\boldsymbol{u}_t') &= 0 \\
E(\boldsymbol{\eta}_t\hat{\boldsymbol{y}}_1') &= 0 \\
E(\boldsymbol{u}_t\hat{\boldsymbol{y}}_1') &= 0
\end{aligned}$$

where $\hat{\boldsymbol{y}}_t$ are deviations from steady state values, $\bar{\boldsymbol{y}}$. $\boldsymbol{\theta}$ is a vector of deep parameters and $\boldsymbol{y}_t^*$ are observable variables differing from the true variables by an error contained in $\boldsymbol{\eta}_t$. $N(\boldsymbol{\theta})\boldsymbol{x}_t$ reflects a time-trend associated to the structural parameters.

This configuration corresponds to a Kalman filter state-space representation. The values of the state vector $\hat{y}_1$ can be written as a function of disturbances and initial values:

$$\hat{\boldsymbol{y}}_t = \boldsymbol{u}_t + g_y(\boldsymbol{\theta})\boldsymbol{u}_{t-1} + g_y^2(\boldsymbol{\theta})\boldsymbol{u}_{t-2} + ... + g_y^{t-2}(\boldsymbol{\theta})\boldsymbol{u}_2 + g_y^{t-1}(\boldsymbol{\theta})\hat{\boldsymbol{y}}_1$$

for t=2, 3, ..., T.

The filter is applied using:

$$\begin{aligned}
\boldsymbol{\nu}_t &= \boldsymbol{y}_t^* - \bar{\boldsymbol{y}}^* - \boldsymbol{M}\bar{\boldsymbol{y}}_t - \boldsymbol{N}\boldsymbol{x}_t \\
\boldsymbol{F}_t &= \boldsymbol{M}\boldsymbol{P}_t\boldsymbol{M}' + \boldsymbol{V} \\
\boldsymbol{K}_t &= g_y\boldsymbol{P}_t g_y'\boldsymbol{F}_t^{-1} \\
\hat{\boldsymbol{y}}_{t+1} &= g_y\hat{\boldsymbol{y}} + \boldsymbol{K}_t\boldsymbol{\nu}_t \\
\boldsymbol{P}_{t+1} &= g_y\boldsymbol{P}_t(g_y - \boldsymbol{K}_t\boldsymbol{M})' + g_u\boldsymbol{Q}g_u'
\end{aligned}$$

from which a log-likelihood function is calculated as:

$$ln\mathcal{L}(\bar{\boldsymbol{\theta}}|\boldsymbol{Y}_T^*) = \frac{-Tk}{2}ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T}|\boldsymbol{F}_t| - \frac{1}{2}\boldsymbol{\nu}_t'\boldsymbol{F}_t^{-1}\boldsymbol{\nu}_t$$

with $\bar{\boldsymbol{\theta}}$ including all the parameters to be estimated: $\boldsymbol{\theta}, V(\boldsymbol{\theta}), Q(\boldsymbol{\theta})$ and $\boldsymbol{Y}_T^*$ containing the observable variables.

With the inclusion of priors, $p(\bar{\boldsymbol{\theta}})$ a log-posterior kernel is given by

$$ln\mathcal{K}(\bar{\boldsymbol{\theta}}|\boldsymbol{Y}_T^*) = ln\mathcal{L}(\bar{\boldsymbol{\theta}}|\boldsymbol{Y}_T^*) + ln\left[p(\bar{\boldsymbol{\theta}})\right]$$

The posterior distribution is computed by the means of the Metropolis-Hastings algorithm consisting of:

1. Selecting a set of starting values, $\bar{\boldsymbol{\theta}}^0$, to be used in subsequent recursions.

2. Extract a proposed value $\bar{\boldsymbol{\theta}}^*$ from a jumping distribution such as:

$$J(\bar{\boldsymbol{\theta}}^*|\bar{\boldsymbol{\theta}}^{t-1}) = \mathcal{N}(\bar{\boldsymbol{\theta}}^{t-1}, c\boldsymbol{\Sigma}_m)$$

   where $\boldsymbol{\Sigma}_m$ is the inverse of the Hessian matrix when computed at the mode.

3. An *acceptance* ratio consists of:

$$ar = \frac{p(\bar{\boldsymbol{\theta}}^*|\boldsymbol{Y}_T)}{p(\bar{\boldsymbol{\theta}}^{t-1}|\boldsymbol{Y}_T)} = \frac{\mathcal{K}(\bar{\boldsymbol{\theta}}^*|\boldsymbol{Y}_T)}{\mathcal{K}(\bar{\boldsymbol{\theta}}^*|\boldsymbol{Y}_T)}$$

4. A proposed value $\bar{\boldsymbol{\theta}}^*$ is accepted or rejected according to:

$$\bar{\boldsymbol{\theta}}^t = \begin{cases} \bar{\boldsymbol{\theta}}^* & \text{with probability } min(ar, 1) \\ \bar{\boldsymbol{\theta}}^{t-1} & \text{otherwise} \end{cases}$$

   which will update the distribution in case of acceptance. Go back to step 1.

2.4.3 Data and transformations

For estimation purposes we make use of a panel of quarterly data between 1980Q1 and 2014Q3[31]. Keeping the main data structure in ALLV and the correspondence with their definitions in the model, the stationary variables we included are:

- GDP deflator (`gdp_defl`)

$$\widehat{\pi}_{i,t} = \Delta \ln \left(\texttt{gdp\_defl}_{i,t}/\texttt{gdp\_defl}_{i,t-1}\right)$$

  Data from Oxford Economics.

- Real wage (`unit_cost`)

$$\widehat{w}_{i,t} = \Delta \ln \left(\frac{\texttt{unit\_cost}_{i,t}}{\texttt{gdp\_defl}_{i,t}}\right)$$

  Data from Oxford Economics.

[31]Making a total of 137 observations for each variable after taking ratios and differences.

- Real consumption ($\texttt{rcons}$)

$$\widehat{c}_{i,t} = \Delta \ln \left(\texttt{rcons}_{i,t}\right)$$

Data from OECD Quarterly National Accounts.

- Real investment ($\texttt{inv\_real}$)

$$\widehat{i}_{i,t} = \Delta \ln \left(\texttt{inv\_real}_{i,t}\right)$$

Data from OECD Quarterly National Accounts.

- Employment ($\texttt{employment}$)

$$\widehat{E}_{i,t} = \frac{\texttt{employment}_{i,t} - \texttt{employment}_{i,t-1}}{\texttt{employment}_{i,t-1}}$$

Data from Oxford Economics.

- Real GDP ($\texttt{real\_gdp}$)

$$\widehat{y}_{i,t} = \Delta \ln(\texttt{real\_gdp}_{i,t})$$

Data from OECD Quarterly National Accounts.

- Consumer prices ($\texttt{cons\_defl}$)

$$\widehat{\pi}^{c}_{i,t} = \Delta \ln \left(\texttt{cons\_defl}_{i,t}/\texttt{cons\_defl}_{i,t-1}\right)$$

Data from Oxford Economics.

- Risk premium ($\texttt{spread}$)

$$\tilde{\phi}_{i,t} = \Delta \ln \left(\frac{\texttt{st\_irate\_oxec}_{i,t}}{\texttt{tb3ms}_t}\right)$$

Data from Oxford Economics and US Federal Reserve.

Some of the series were already seasonally adjusted, otherwise we applied the US Census Bureau's X-12-ARIMA algorithm (see Ladiray and Quenneville (2001)).

International and bi-lateral weights

One of the main features of the model is its ability to generate country-specific foreign variables according to the regional and global definitions used in each exercise of estimations and/or simulations. In order to address the heterogeneities in the linkages between economies, this is done using weighting schemes aimed to distinguish the relevance each counterpart has from the perspective of an economy. Structural heterogeneities between the economies in this study as well as those in terms of the economic and financial relationships linking them are the main reasons behind the development of such detailed differentiation mechanisms.

The bi-directional nature of these indicators allows to distinguish commercial and financial relationships at the national level for all the economies in our panel (i.e. how relevant is economy i to j and vice versa) which is a valuable feature given the diversity displayed by the economies under scrutiny.

The first set of weights measures the intensity of financial exchanges between any pair of economies as represented by the flows of foreign direct investment (taking into account both inward and outward flows between 2009 and 2012):

$$I_{i,j} = \begin{bmatrix} w^{fdi}_{1,1} & w^{fdi}_{1,2} & \dots & w^{fdi}_{1,N} \\ w^{fdi}_{2,1} & w^{fdi}_{2,2} & \dots & w^{fdi}_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ w^{fdi}_{N,1} & w^{fdi}_{N,2} & \dots & w^{fdi}_{N,N} \end{bmatrix}$$

with

$$w^{fdi}_{i,j} = \frac{\texttt{mean\_out\_fdi}_{i,j} + \texttt{mean\_in\_fdi}_{i,j}}{\sum_{j=1}^{N-1} \texttt{mean\_out\_fdi}_{i,j} + \sum_{j=1}^{N-1} \texttt{mean\_in\_fdi}_{i,j}}$$

and $w^{fdi}_{i,i} = 0$. We use data on FDI inflows and outflows from IMF, Coordinated Direct Investment Survey.

Similarly, trade weights are aimed to reflect the intensity (not the balance) of commercial exchanges (exports plus imports between 1990 and 2012) for each two-country permutation as:

$$T_{i,j} = \begin{bmatrix} w^{t}_{1,1} & w^{t}_{1,2} & \dots & w^{t}_{1,N} \\ w^{t}_{2,1} & w^{t}_{2,2} & \dots & w^{t}_{2,N} \\ \vdots & \vdots & \ddots & \vdots \\ w^{t}_{N,1} & w^{t}_{N,2} & \dots & w^{t}_{N,N} \end{bmatrix}$$

with

$$w^{t}_{i,j} = \frac{\texttt{mean\_exports}_{i,j} + \texttt{mean\_imports}_{i,j}}{\sum_{j=1}^{N-1} \texttt{mean\_exports}_{i,j} + \sum_{j=1}^{N-1} \texttt{mean\_imports}_{i,j}}$$

and $w^{t}_{i,i} = 0$. The data on bi-lateral trade is from IMF, Direction of Trade Statistics database.

Finally, weightings within a region as in Equation (2.3.113*) are calculated using the relative participation in output aggregated to the specific regional level being used:

$$w^y_{i,M} = \frac{\texttt{real\_gdp\_ppp}_{i,2013}}{\sum_{i=1}^{M} \texttt{real\_gdp\_ppp}_{i,2013}}$$

for each of the M members of the defined region. The data for 2013 used in this calculations is from OECD, Annual National Accounts.

All these relative measurements allow for a more precise and updated assessment of the modelled linkages and relative positions in our international framework and, importantly, within this overall modelling structure they contribute to achieve a more accurate depiction of the potentialities of international shocks impacting heterogeneous economies.

Parameter profiles and estimation

Each country in the model has a specific parameter profile including national features as well as the parameters for the applicable foreign variables[32] This parameterisation is updated with the results of estimations of the model over sub-samples of countries. The listings are included in Appendix C. The estimations are performed using the Dynare computing platform (Adjemian et al. (2011)) under the partial information assumption[33] with the previously described set of data as observed variables.

2.5 International shocks in the OECD: an empirical assessment

In this section we perform the empirical application of our model with particular focus on the international implications of specific shocks for the management of fiscal and monetary policies in the involved economies. Recent experiences related to international disturbances and contagion in macroeconomics have renewed the interest on the impact of international shocks on the performance of economies around the world.

The subject of international shocks is relevant for every policy maker operating in an open macroeconomic environment since this expands even further the discussion on monetary and fiscal interactions as it embraces now more players in the macroeconomic policy game. Specifically, in terms of macroeconomic policy issues, some studies are focusing on analysing the interactions and policy spillovers in somewhat compact multi-country settings.

[32]Variables are at the same time domestic for the i-th country and foreign for the rest of the j-th countries.

[33]See Pearlman, Currie and Levine (1986).

However, a common tendency to neglect the heterogeneities between countries as well as the specificities in their actual channels of interaction restrict the ability of previous models to provide a robust account of the international effects of macroeconomic shocks.

In addition, it is noticeable that the regular approach of this branch of research is to focus on a single country receiving exogenous effects from foreign economies (simplified as *star* variables) and then rotating the roles for the next exercise (see Fragetta and Kirsanova (2010)). Our stance, in contrast, consists of considering regions as larger entities where all the member economies are simultaneously studied while making distinction of specific features and interconnections that distinguish them from each other.

This alternative approach, while computationally more demanding is, on the other hand, richer in terms of the information it provides about the comparative implications for fiscal and monetary policies from an international macroeconomic factor.

After we have developed and programmed a suitable model to handle regional and global settings with heterogeneous economies, we proceed in two stages for its empirical application: first we perform estimations using actual macroeconomic series from which we get an enhanced set of selected country-specific parameters.

The execution of these estimations provides considerable improvements in terms of the specificity of priors at national levels although a fraction of the parameters are still maintained as common either because of the prioritisation we have made on policy-related aspects or due to data restrictions. We deem, however, that those common parameters do not critically bias our results. Although they provide an opportunity for further fine-tuning of the model, its main operational features would not vary by the incorporation of new information and, therefore, the tests we perform on its functionalities remain relevant.

For the second stage, we incorporate the obtained information on national parameters and run a number of shock simulations to assess their impacts in the context of international scenarios where regional components play a central role. In order to use a common ground for the comparison of the real and nominal effects of this diversity of shocks, the simulations are executed on a pre-defined set of representative variables:

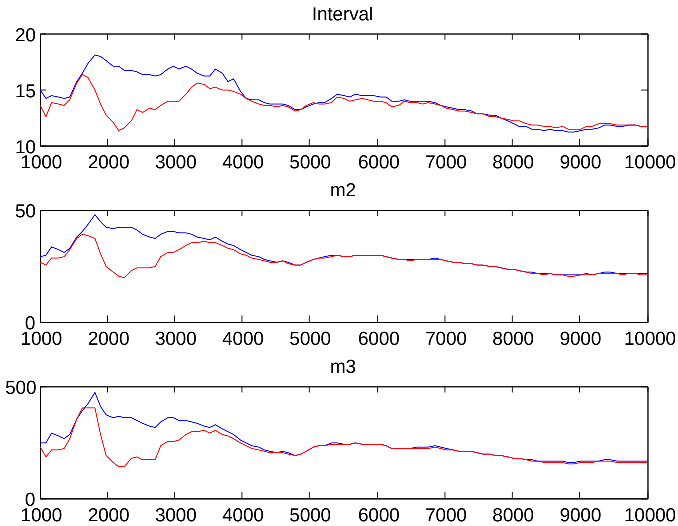
Output	y_hat	Consumer prices	pi_c
GDP deflator	pi_hat	Interest rate	R_hat
Employment	E		

with sub-indexes denoting the corresponding country (we use ISO 3166 Alpha-2 codes ®) or region.

2.5.1 Estimation on the NAFTA region

The first estimation corresponds to the region comprising the members of the North American Free Trade Agreement (*NAFTA*). This estimation achieves a fair degree of convergence even after a relatively modest number of MCMC replications as shown in Figure 2.5.1.

Figure 2.5.1: Multivariate convergence diagnostic, NAFTA region.



Priors and posteriors from the estimation are shown in Appendix D. After the adjustments made possible by the information provided though the estimation of the model (see the results in Appendix D.2), we perform the simulation of key shocks of interest for macroeconomic policies. The new parameterisation represents an important improvement towards the representation of economic features at the national level which constitute the building blocks for regional and global analyses in our framework.

The model currently comprises a set of 37 stochastic shocks including country-specific as well as regional disturbances[34] (see Appendix A). In the following sections we exemplify the simulation of some of these shocks and the model's ability to provide information on their distinctive international impacts on heterogeneous economies. For this purpose we have selected a set of shocks highly relevant for the management of fiscal and monetary policies in contexts of intra and inter-regional interactions within the OECD.

[34]The way we have programmed it, the model allows for the simulation of shocks at the national and regional level when applied to a sub-sample of the *world* definition that has been selected in each exercise. Alternatively, if all the included economies are assigned to the same region, the regional shocks become *global*.

Intra-regional shocks

The first example on the simulation of shocks consists of a series of experiments on the impacts that policy-relevant disturbances in the United States have on the rest of the countries in the NAFTA region (i.e. Canada and Mexico).

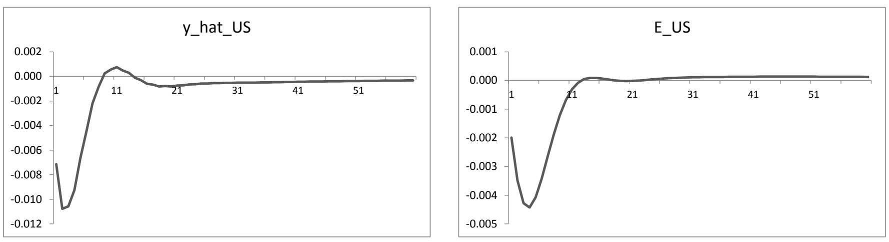
There is no doubt that the US economy is a strong force in the global economy, amounting to 35.8 per cent of the OECD's real output in 2013, as it is for the NAFTA region where it represents 83.2 per cent of the total real GDP (also in 2013). Similarly, the commercial and financial weights we have calculated indicate a strong concentration of exchanges from its regional partners for both of which it represents similar figures: 80 percent of their trade and 57 per cent of their foreign investment accounts.

In consistency with those features we set this player as an *originator* of shocks in monetary and fiscal aspects and explore the international impacts they display within the NAFTA region.

1. Monetary policy shock

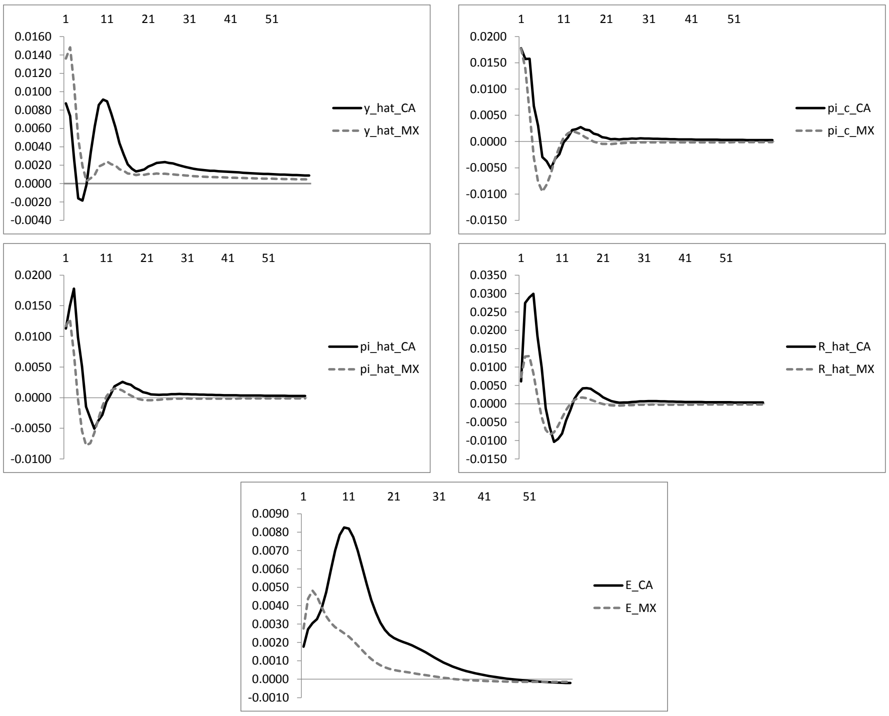
Starting with a monetary policy shock in the US ($\varepsilon^{R}_{US,t=0}$) of 1 standard error in the interest rate, we can observe in Figure 2.5.3 the international effect of the shock on selected variables in the other members of the region. This international impact reveals important features of the externalities of monetary policies applied by the Federal Reserve and, therefore, of the conditions the other central banks have to accommodate to as a result.

Figure 2.5.2: Effects of a monetary policy shock in the US.



The increase in the interest rate has a negative effect on the US levels of activity in terms of output and employment. A substitution effect is then generated by the means of which the other two economies in the region experience an increase in the US demand for imports benefiting their production and employment levels although, this being a short-term disturbance, at the cost of higher inflation and a period of increased financial costs. The latter effect is explained in terms of our model by the position held by the US interest rate as a global benchmark for risk assessments which implies that other rates follow similar trends with the addition of the applicable risk premium for each national case.

Figure 2.5.3: International effects of a monetary policy shock in the US, NAFTA region.



2. Shock to the US monetary policy target

Another type of monetary policy shock corresponds to a negative variation of the inflation target in the US ($\varepsilon^{\hat{\bar{\pi}}^c}_{US,t=0}$). This means a change in the rate of inflation that the Federal Reserve will pursue and therefore an implicit hardening of monetary policy as compared to the previous state.

Such a shock mostly represents a short-term contractionary choice until the new policy stance is assimilated by other economic agents. Both output and prices fall, making the monetary rule to start a downward trend of adjustments on the interest rate. This subsequent easing of the monetary policy (through its automatic-response components) improves the conditions for a recovery in output while the impact on prices dissipates. Employment displays a neutral response in the aftermath of the shock but, as output recovers, it also exhibits a considerable positive deviation. All the selected variables show a very gradual return to equilibrium levels in the US, spanning for the most part of our simulation horizon.

Figure 2.5.4: Effects of a monetary policy target shock in the US.

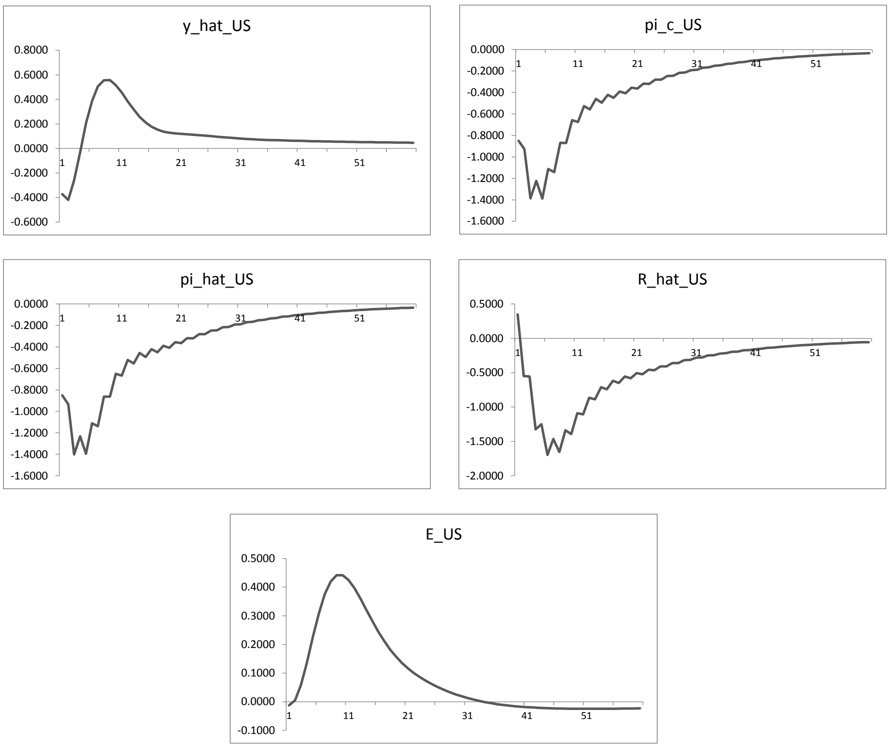
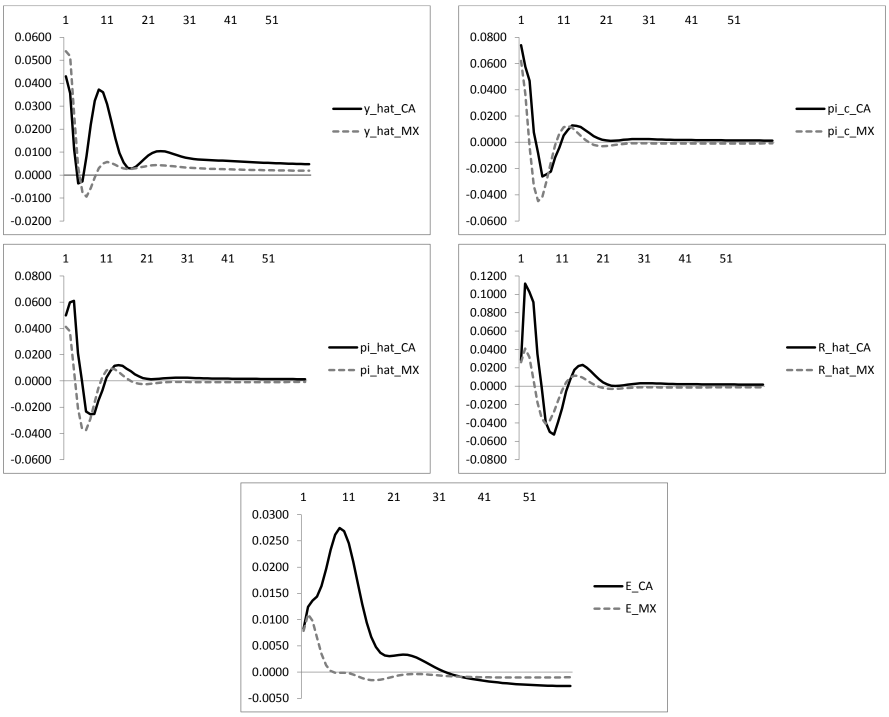


Figure 2.5.5: International effects of a monetary policy target shock in the US, NAFTA region.



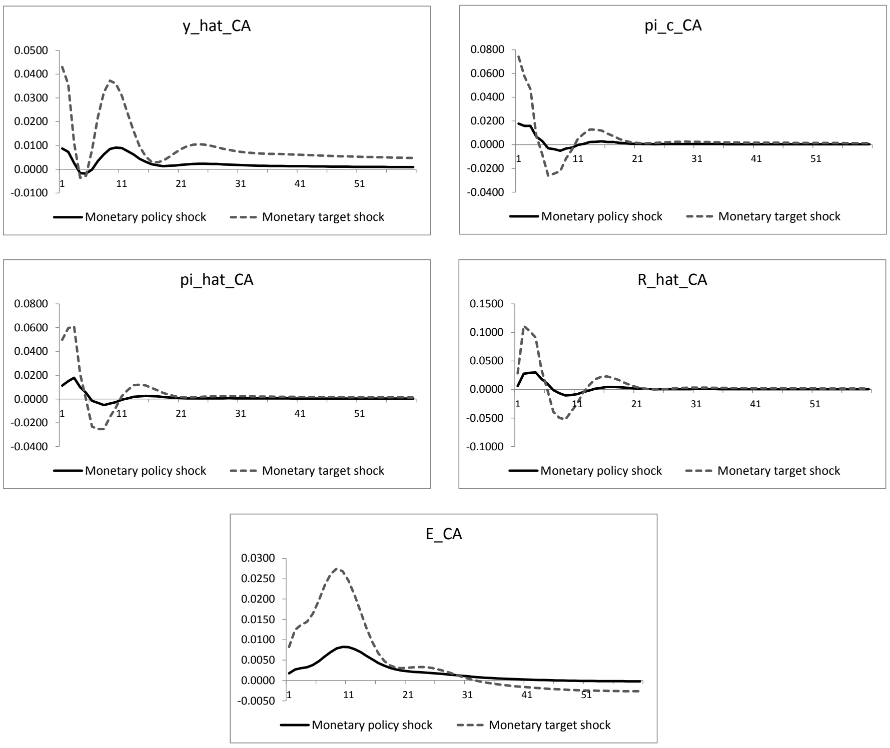
A substitution effect in the US economy induces higher demand to its partners who experience increases in output and employment. These higher demand levels from the US also pushes prices up in the rest of the region just after the shock. Both types of monetary shocks have significant implications for the monetary authorities in Canada and Mexico who receive real and nominal externalities in the form of the impacts on their levels of activity as well as on their prices and financial stability.

These externalities on output and prices, in turn, generate responses by the domestic monetary policies of Canada and Mexico which increase interest rates and, in doing so, cause the oscillation of the domestic variables.

This way, the shock generated in the US injects a degree of instability in the region where the other two countries respond to both the initial slowdown and its eventual reversal in a lagged fashion (slightly more immediate in Mexico).

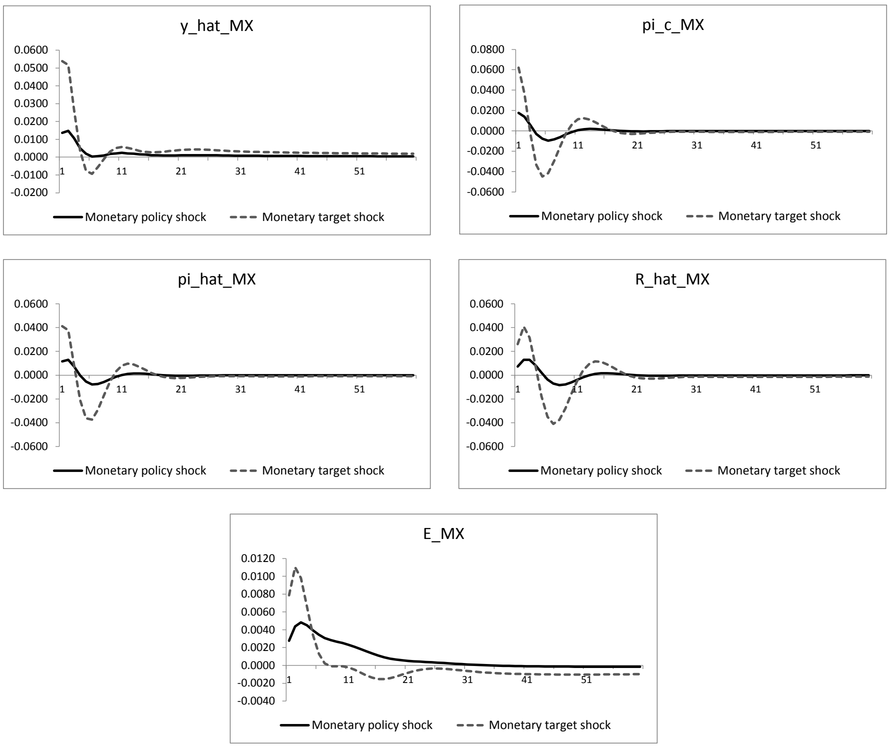
Between the two recipient countries, Canada exhibits larger sensitivity to the US shock mainly in terms of output variability, interest rate and, especially, employment.

Figure 2.5.6: International effects of a monetary policy target shock in the US, Canada.



Comparing the international effects of the two types of shocks, shown in Figures 2.5.6 and 2.5.7, it is noticeable that a target shock imposes larger disruptions to the recipients' variables. The externalities of both shocks on nominal variables, nevertheless, dissipate much faster than their equivalent direct effects in the US.

Figure 2.5.7: International effects of a monetary policy target shock in the US, Mexico.



Taking advantage of other functionalities in the Dynare© collection of computing routines, we calculated Bayesian impulse-response functions for the above shocks to evaluate the characteristics of the dispersion of posterior distributions after the estimation. Figures 2.5.8 to 2.5.11 show these functions displaying the Highest Posterior Density interval (HPD, see Hyndman (1996)) around the mean response for each variable. This is a Bayesian tool[35] for expressing the plausible range that can be inferred for each variable and, in this sense, the dispersion in the impulse-responses indicate how strongly the model is supported by the data.

We can observe that the intervals are relatively tight around the means and converge in time towards mean responses which confirms the quality of or estimations. Although the intervals are narrow in general, these graphs show a particular increase of the HPD intervals in real variables in Mexico around summits and bottoms after monetary shocks in the United States which denotes larger volatility in the estima-

[35]Note that, although there is a degree of convergence, ordinary (frequentist) and Bayesian impulse responses are not directly comparable. The difference according to Pfeifer (2014b, p. 16) is that the former are computed "at the calibrated parameter combination, while the Bayesian IRFs are the mean impulse responses (not to be confused with the IRFs at the mean)". Note too, from this explanation, the dependence of the smoothness (or lack of it) in the Bayesian impulse-responses on the number of draws used during the estimations.

tions for those variables around turning points. We do not consider, however, that this degree of dispersion compromises our results.

Figure 2.5.8: International effects of a monetary policy shock in the US, Canada (Bayesian IRF).

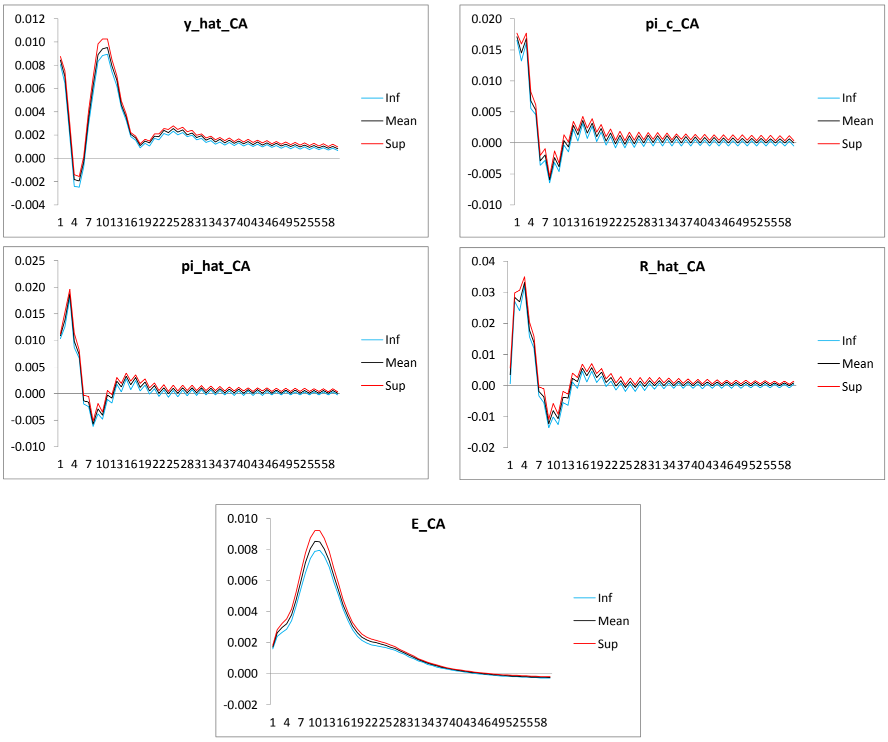


Figure 2.5.9: International effects of a monetary policy target shock in the US, Canada (Bayesian IRF).

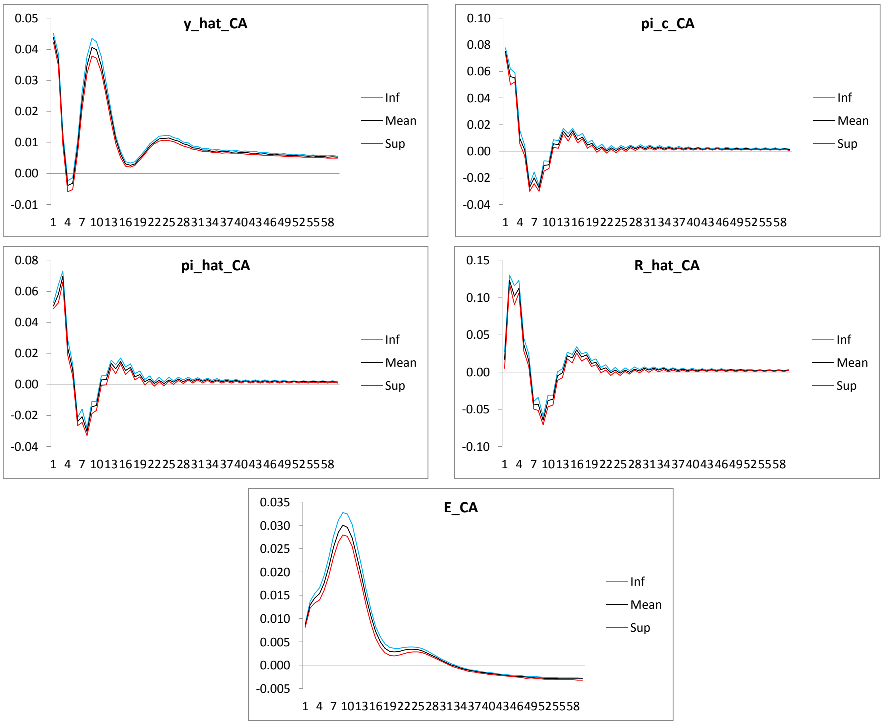


Figure 2.5.10: International effects of a monetary policy shock in the US, Mexico (Bayesian IRF).

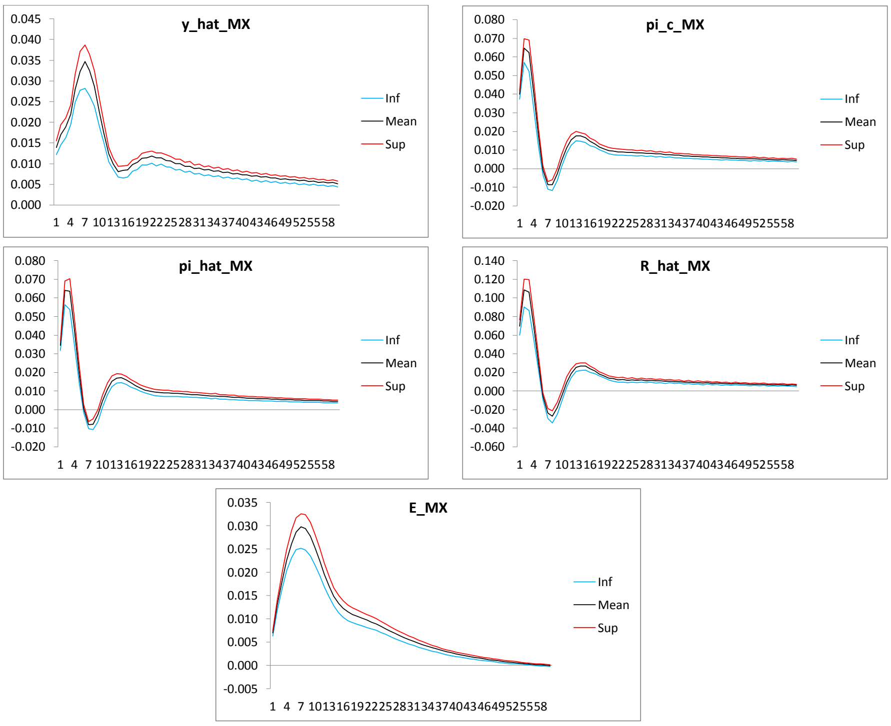
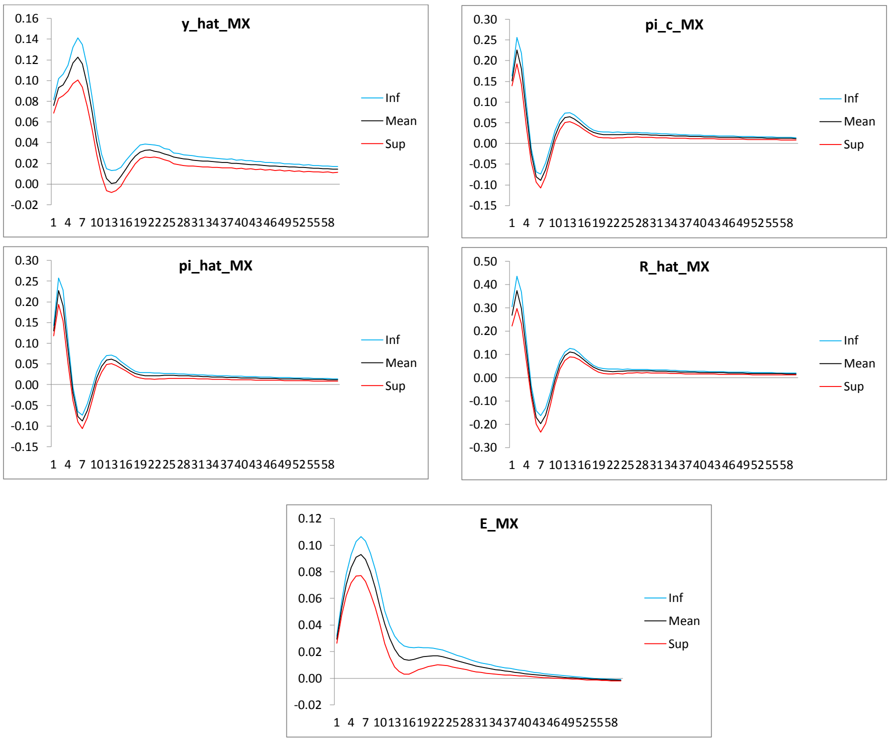


Figure 2.5.11: International effects of a monetary policy target shock in the US, Mexico (Bayesian IRF).



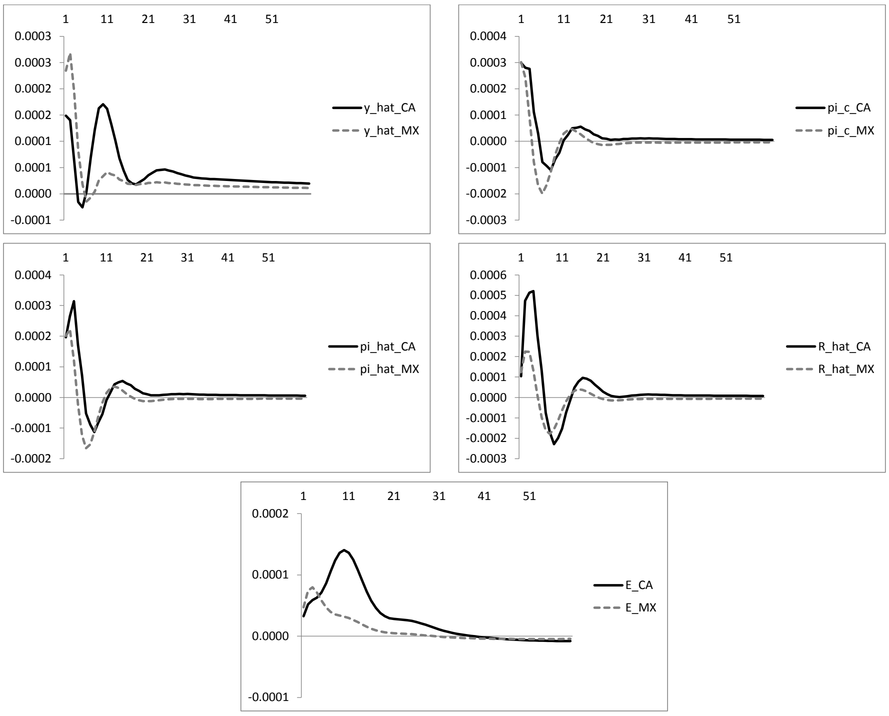
3. Shock to the US risk premium

Similarly, a shock to the risk premium of the US economy ($\varepsilon^{\tilde{\phi}}_{US,t}$) induces a parallel behaviour in the analysed variables as a monetary policy shock but the size of the deviations is comparably smaller. This is a reflection of the fact that, as our estimation shows, the US monetary policy will only partially counteract the increase in the interest rate induced by the shock to the risk premium ($\rho^{\tilde{\phi}}_{US} = -0.029$, see Table D.2). In effect, this international impact reveals a non-accelerating mechanism of contagion between linked economies.

The response to this externality also reflects into both the real and nominal conditions of the partner economies although output instability and employment variations appear more accentuated in Canada. Elements like a larger insertion of financial services[36] may have a role in this comparatively higher exposure to nominal instability.

[36] Our approximation in terms of the proportion of wages financed by working capital, for example, puts Canadian firms in a less resilient position when facing increases in the interest rate: $\nu^{w}_{CA} = 0.8 > \nu^{w}_{MX} = 0.6$.

Figure 2.5.12: International effects of a shock to the US risk premium, NAFTA region.



4. Nominal externalities of fiscal policy

In addition to the intra-regional outcomes of monetary policies shown above, we are also interested in analysing the cross-policy international externalities resulting from shocks on fiscal variables. For this purpose we look into the international nominal repercussions derived from fiscal shocks in the US.

A negative shock to the income tax in the US ($\epsilon^{fpy}_{US,t=0}$), for example, brings a degree of nominal instability in both countries with mostly immediate increases in their inflation levels and interest rates. Mexico seems to display the most immediate responses while Canada presents slightly lagged reactions in comparison.

In our framework, this shock operates through its effect on real wages and, therefore, on the patterns of consumption and investment in the US. The shock liberates disposable income, a fraction of which reflects into an increased demand for imports and international bonds explaining the rise in prices and interest rates both in Canada and Mexico

Canadian variables return to the equilibrium neighbourhood much faster than their Mexican equivalents. This means that instabilities in the second country tend to display a more permanent nature.

This distinction is important since it provides information for the discussion on the comparative *Ricardian* features that specific countries may exhibit. Recalling that both types of fiscal shocks we have applied would also lead to an increase in the US government indebtedness or, in the shorter run, an increase in its primary deficit (as it is described in the model) with latter repercussions on the households' resource constraint. It is this second impact which will ultimately lead to readjustments towards the previous equilibrium in the US.

Figure 2.5.13: International nominal effects of a fiscal policy shock (income tax) in the US, NAFTA region.

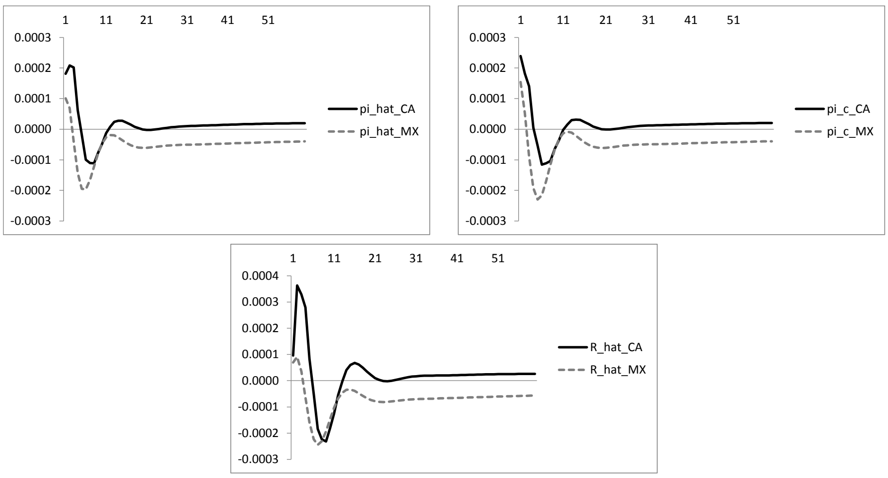
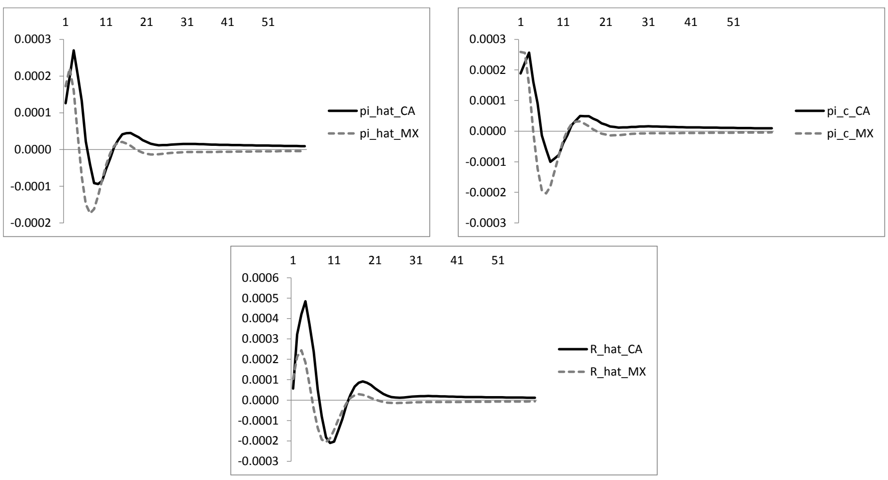


Figure 2.5.14: International nominal effects of a fiscal policy shock (government spending) in the US, NAFTA region.

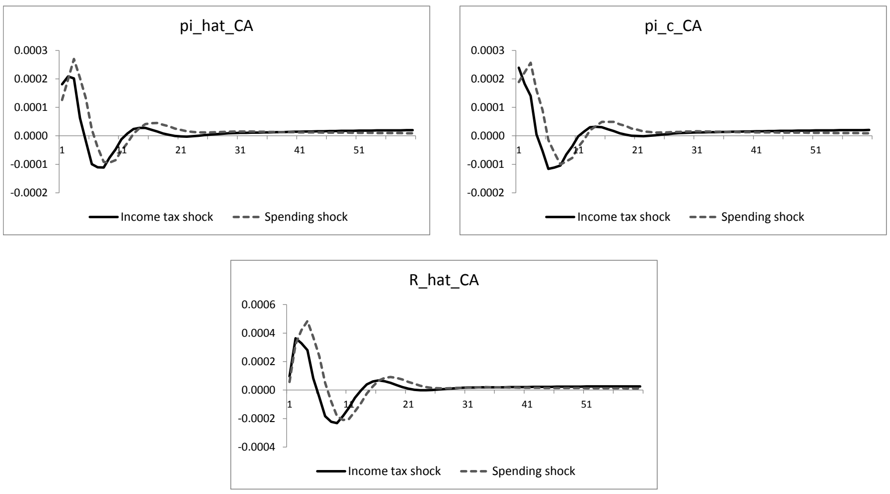


In a less *Ricardian* fashion (towards the US fiscal policy), Mexico displays an over-compensation after the tax shock in the US which eventually brings the nominal variables below their previous equilibrium levels.

Interestingly, a shock to the US government spending ($\epsilon^{fpg}_{US,t=0}$) generates very similar responses in Canada's and Mexico's nominal variables when compared to the previous one although, this time, without significant displacements from the long-term equilibrium in both countries. There is a small difference in the size of the responses (keep in mind that variables have been transformed as differences of logarithms) when both shocks are compared. This is more tangible in the case of interest rates in Canada, we argue that this is a result of a comparative higher degree of reliance on working capital (in our framework expressed by $\nu^{w}_{CA} = 0.8 > \nu^{w}_{MX} = 0.6$) so that firms facing a higher foreign demand also put increased pressure on the local credit markets.

We also observe in Figures 2.5.15 and 2.5.16 that a shock on US spending generates later responses than a shock on income tax rates.

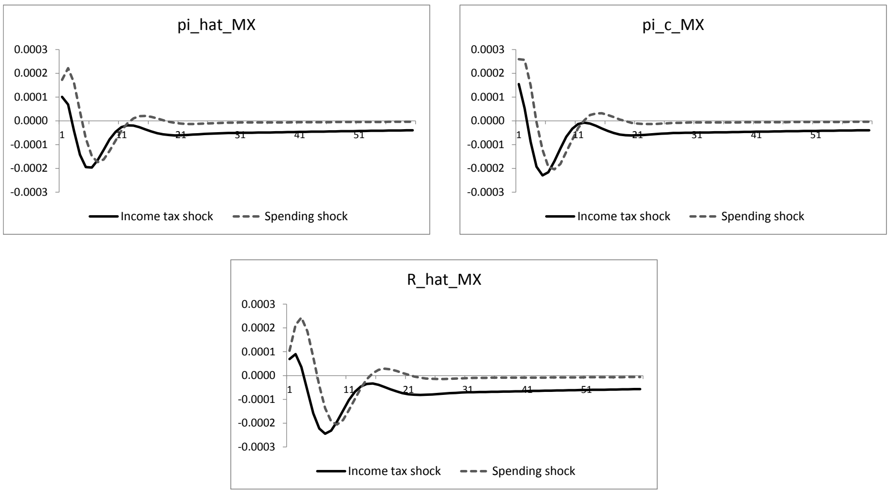
Figure 2.5.15: Comparative international nominal effects of fiscal policies in the US, Canada.



This exercise has allowed us to verify the distinctive presence of cross-policy international externalities in the NAFTA region. The resulting implications mainly fall upon the design of monetary policies in Canada and Mexico, both of which are subject to these effects and, therefore, would have to adjust their stances accordingly, especially in the cases where, as we have seen, the responses to shocks show long-term displacements.

The overall conditions for the management of their monetary policies are modified by fiscal shocks in the US not only in terms of the variables they target (overall and/or consumption inflation) but also of the instruments they use since interest rates are susceptible to considerably lasting instability after such disturbances.

Figure 2.5.16: Comparative international nominal effects of fiscal policies in the US, Mexico.



Regional shocks

In this section we exemplify the application of a regional-level shock, that is, a shock that simultaneously affects all the economies in a region. The differences in the responses that this kind of shocks generate depend both on the characteristic features of the individual economies comprised in our model (including their commercial and financial openness towards other members of the region and outside it as well as the corresponding elasticities) and on the linkages they have both with their regional partners and with the rest of the world.

The shocks depict a common disturbance in the rest of the world or, more precisely in our case, in the rest of the OECD countries. This type of shocks aims to represent events of relatively generalised turmoil in the international context of regions and, particularly, the consequences for the transmission of such impacts from a set of heterogeneous economic features and interconnections in the international sphere.

Emblematic events in the recent economic history show that, even when originally sparked in a single economy, shocks can be transmitted within broader geographic regions (see Chudik and Fratzscher (2011), Degryse, Elahi and Penas (2010) and Fry-McKibbin, Hsiao and Tang (2014) for the analysis of key historical examples).

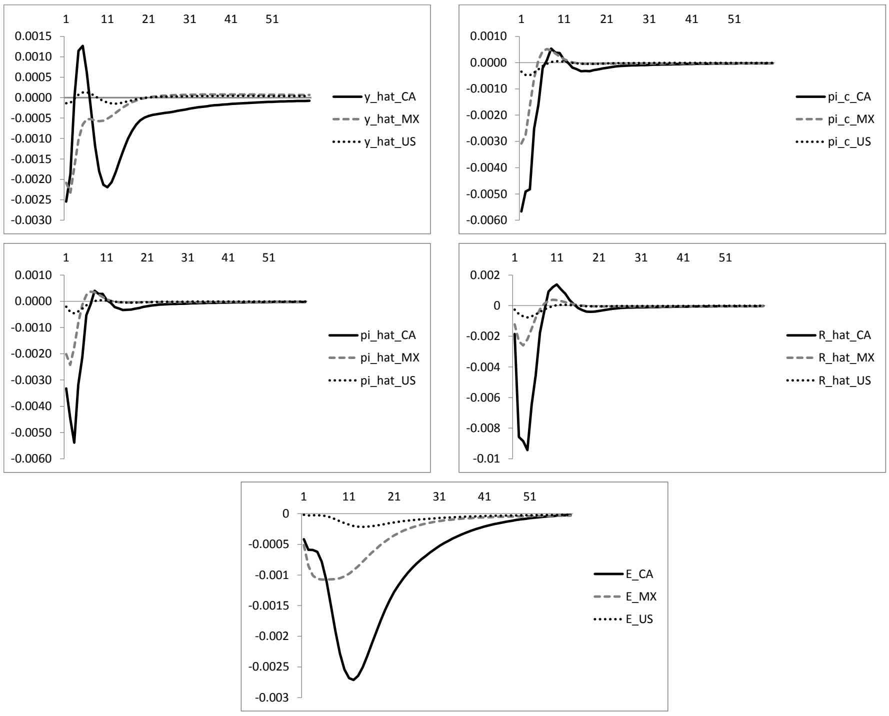
We adopt an approach that visualises economic regions as networks between which there is a continuous transmission of impulses but where, at the same time, the repercussions for individual economies are dissimilar.

1. Output shock in the rest of the world for NAFTA countries

We first examine a shock with a high likelihood of occurrence after a major international disruption as the recession that followed the 2007-2009 financial crisis. Supposing that the rest of the OECD economies experience a recovery trend amounting to a positive shock of one standard error in their aggregate GDP. The implications of this shock ($\epsilon^{\hat{y}^*}_{r,t=0}$) are shown in Figure 2.5.17.

Figure 2.5.17: Comparative effects of external shocks on the NAFTA region.

External output shock



They provide evidence of the variations generated in the levels of economic activity as well as in the nominal conditions in each of the three *recipient* economies.

It is noticeable that output levels are subject to a prolonged period of variation in the US and Canada although the latter is the more affected in terms of its own size. The succession of trends corresponds to the substitution effects during each phase of the external recovery. In the early stages, just after the shock, the regionally-foreign growth represents a competitive effect consisting of a relative saturation of the markets (also recall that our resource constraint in Equation 2.3.119* binds for global production.) and, therefore, prices and production fall in all three countries.

Secondly, the external recovery also implies an increase in the requirements for supplies and financial resources from the economies in the region explaining the second-phase upward trend although the distinctive degrees of commercial and financial integration make these responses to vary within the region. According to our commercial and financial weights the OECD economies excluding the NAFTA countries represent 54.7 (trade) and 87.8 percent (finance) of the US exchanges while the equivalent figures are 18.0 and 42.0 percent for Canada and 16.3 and 39.7 percent for Mexico meaning that the latter is in a comparatively less favourable position to benefit from a recovery occurring outside the NAFTA region.

The third-phase downturn provides an indication of the duration of the productive cycle in the rest of the OECD and the decline in their demand for supplies before returning to equilibrium levels[37] most noted in Canada and the US. This explanation is supported by the fact that, unlike the first phase (when, under our argument, the main effect is market-saturation) domestic prices are not significantly affected during the third phase.

The Canadian economy displays the largest vulnerability to this shock both in terms of the size of its impact and of the length of the period of instability it generates. Variables like output and employment exhibit long-lasting (although not permanent) deviations from steady state levels. This is particularly marked when compared with the impacts on Mexican variables which responses describe a considerably faster recovery towards equilibrium.

The impacts on the US economy are clearly small in comparative terms, similar in dynamics as those on Canada. These two countries share a considerably delay in the response in employment reaching the largest downturn deviation 12 quarters after the initial impact in Canada and after 14 quarters in the US while in the case of Mexico the maximum deviation is reached in the fifth quarter.

2. Comparison with a price shock in the rest of the world for NAFTA countries

The next regional shock we analyse corresponds to a disturbance on the rest of the OECD's prices ($\epsilon^{\pi^*}_{r,t=0}$). An interesting feature of this shock is that it does not only generate nominal variations but also instability in real variables in the receiving countries. In fact, the behaviour of the responses in the selected variables has qualitatively similar dynamics as the effect of an external productive shock as described above.

In order to assure comparability between these two shocks, both of them correspond to a disturbance of one standard error. The degree of real and nominal

[37]The US seems to experience a higher long-term equilibrium output after the shock.

Table 2.5.1: Differences in the effects of external price vs external output shocks on the NAFTA region.

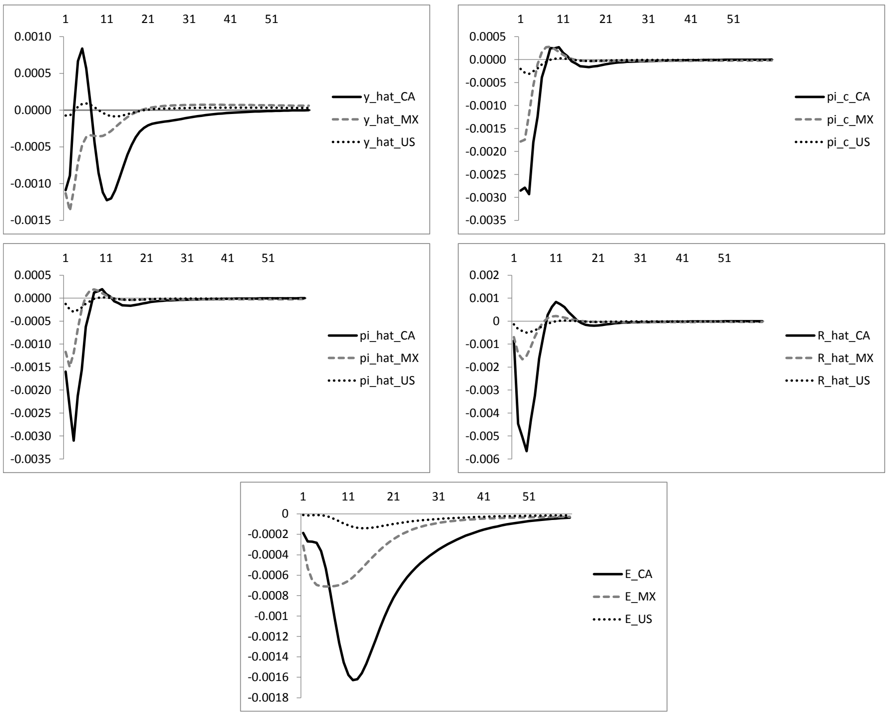
Variable	CA		US		MX	
	Initial impact	Maximum deviation	Initial impact	Maximum deviation	Initial impact	Maximum deviation
Interest rate	-54.0	-40.0	-45.5	-35.1	-42.9	-36.2
Domestic prices	-51.8	-42.5	-40.3	-35.7	-42.1	-38.3
Consumer prices	-49.7	-48.3	-39.3	-34.7	-42.2	-42.2
Real output	-57.2	-51.9	-44.9	-37.5	-45.7	-41.1
Employment	-55.1	-40.0	-46.3	-34.7	-39.2	-33.9

Figures as comparative percentage to the shock on external output.

instability generated by the regional shock on external prices, however, is less severe in the recipient countries than that of a productive shock as can be perceived in Figures 2.5.19 to 2.5.19.

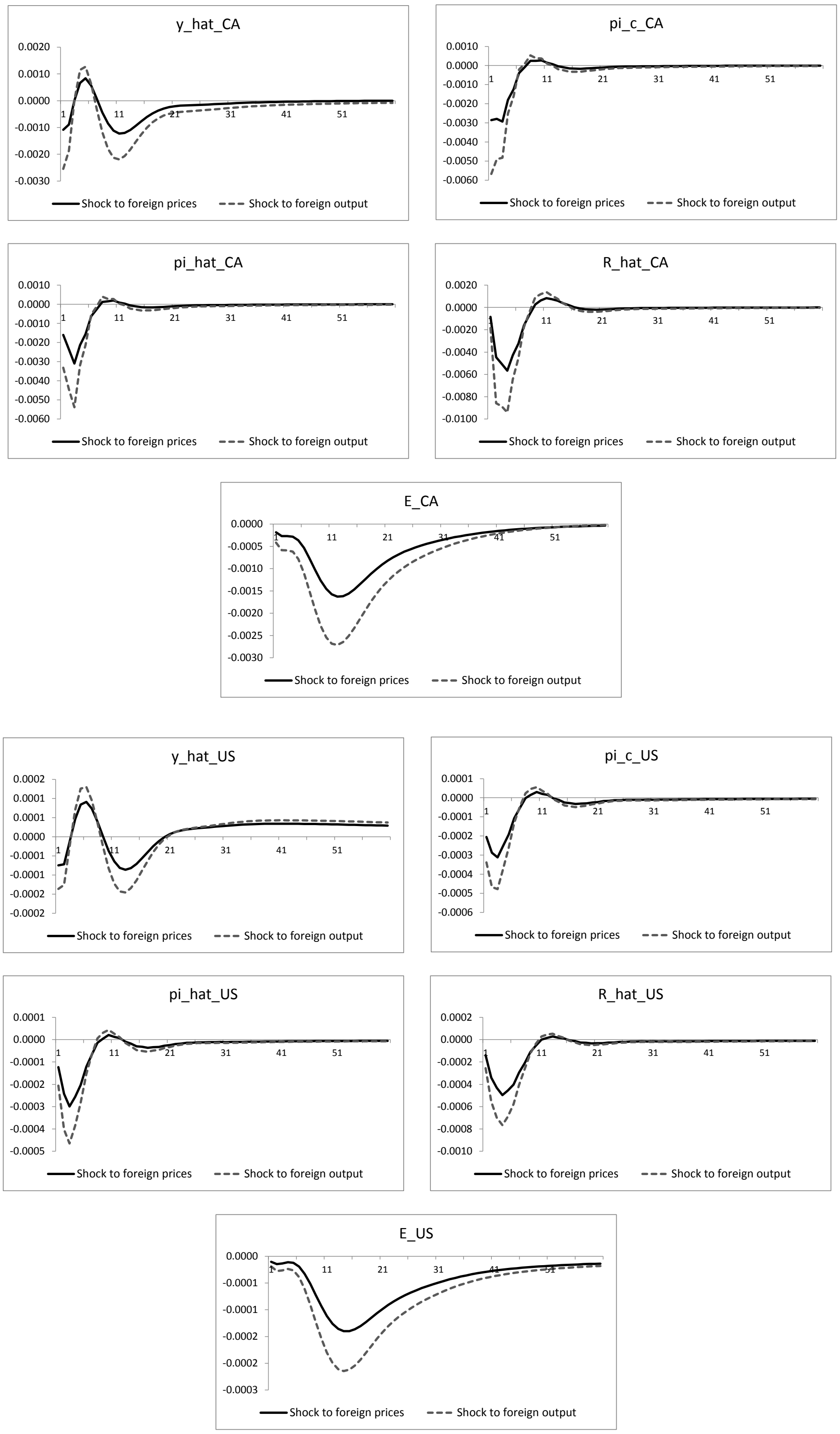
Figure 2.5.18: Comparative effects of external shocks on the NAFTA region.

External prices shock



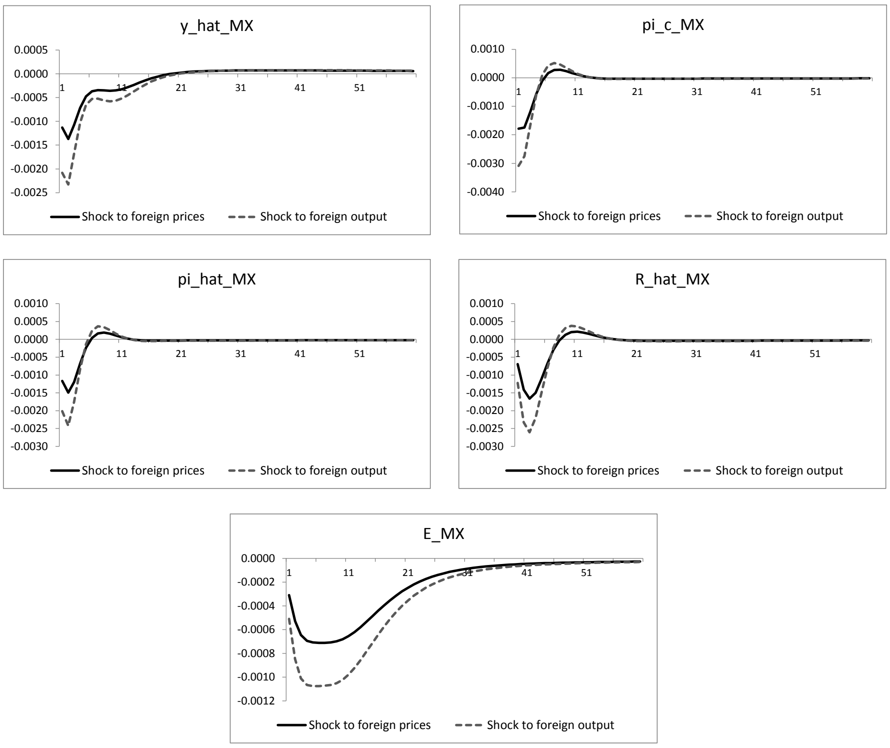
The contrasts are evident in key measurements as the differences between the initial impacts and the maximum deviations generated by each type of shock (see Table 2.5.1). For example, for Canada's output the impact of an extra-NAFTA shock in prices generates an initial response 57.2 per cent lower than the one from a shock in extra-NAFTA aggregate OECD output. The figures show similar characteristics in the case of other responses: the initial impact on the interest rate from a shock in external prices is 54 per cent lower than its equivalent from an external production shock while the difference is 55.1 per cent lower in the case of employment.

Figure 2.5.19: Regional effects of external shocks on the NAFTA region.



As we can see, the conditions in terms of prices out of the NAFTA region and, by consequence, the stance of the external policies in charge of their control, are relevant for each of the countries in the region.

Figure 2.5.19: Regional effects of external shocks on the NAFTA region (cont'd.).



Also, it is important to highlight from the comparison of the effects of the shocks that the preferences the external authorities display in terms of their own weightings on output and inflation do matter. As we have shown, the balance of their choices between inflation conservatism and output stabilisation will bring about different externalities to the economies they are related to.

In line with the main purpose of this investigation we make the relevant distinctions attending to the heterogeneous nature of the impacts received by each individual economy. In comparative terms, Canada's variables display a considerably higher vulnerability to out-of-NAFTA shocks, followed by Mexico. A consolidated higher degree of integration to international markets relative to the size of its economy (see Table 2.5.2.) also implies that, out of the countries in the NAFTA region, Canada exhibits a larger exposure to external fluctuations.

We must note too the fact that for Canada and Mexico this extra-NAFTA shock has a composite total effect including both the direct impact of the shock (i.e. the effect propagated through their own linkages with non-NAFTA economies) as well as an indirect effect consisting of the impact they receive through linkages with the US economy (the main commercial and financial partner for both countries).

Table 2.5.2: Trade openness in the NAFTA region

Average of total exports and imports as a percentage of GDP

Country	2000	2008	2009
Canada	42.7	34.5	29.6
Mexico	29.1	29.2	28.4
United States	13.0	15.4	12.6

Source: OECD Science, Technology and Industry Scoreboard 2011. OECD, 2011.

Conversely, the US economy displays a considerably higher degree of resilience (in terms of its own size) to the extra-NAFTA shocks. Our weighting matrices also contribute to provide a rationale behind this feature: given that the US (normalised) trade weights of NAFTA countries add up to 45.3 per cent and the equivalent financial weights add up to 12 per cent of the total US exchanges with OECD economies we can argue that the main effects on the US economy of the two regional shocks we have analysed operate through trade links (which have an intrinsically larger association with output and price disturbances) and, therefore, a substantial fraction corresponds to indirect effects from the impacts received by its largest commercial partners in the OECD.

This way, the overall design of our model has allowed us to make specific distinctions on the asymmetric consequences of common shocks for the participants of a region displaying significant heterogeneities.

By the analysis of regional common shocks across the OECD, it emerges that extra-regional policies that assign a greater weight to output stabilisation in comparison to price stabilisation would increase welfare in the receiving regions given that the impacts resulting from output shocks are larger than those from price shocks.

With this quantification of the countries' exposure to the production and inflation conditions of the external economy we can also measure their relevance for the design of appropriate policy-responses to external shocks of these types, a component rarely found in the literature and research on macroeconomic policy[38].

2.5.2 Estimation on the Euro-zone region

Another important region in the world economy is the one formed within the sphere of the European Monetary Union. The interactions within this group are charac-

[38] The textbook notion of policy responses is generally restricted to responses to the conditions of the domestic economy.

terised by the use of a single monetary policy. In our model this is described by Equation 2.3.111* and its regional components.

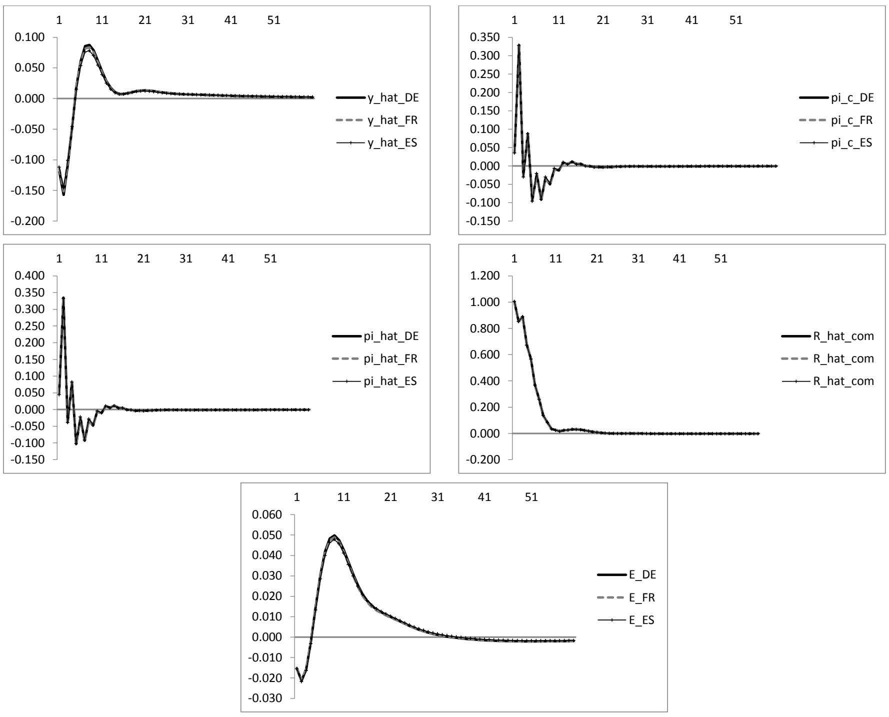
Given its relevance for the whole region, this estimation was modelled including the United States' economy. As for the Euro-zone, France, Germany and Spain were included given that their economies added to 61 per cent of the Euro-zone's aggregate GDP in 2013.

Intra-regional shocks

1. Monetary policy shock

The effects of a simulated monetary policy shock are shown in Figure 2.5.20. They display homogeneous responses across the region where the monetary shock has an immediate downward impact on each country's output of such a scale that, in fact, it creates an inflationary response (through an inelastic demand) especially marked in quarter 2.

Figure 2.5.20: Effects of a monetary policy shock in the Euro-zone.



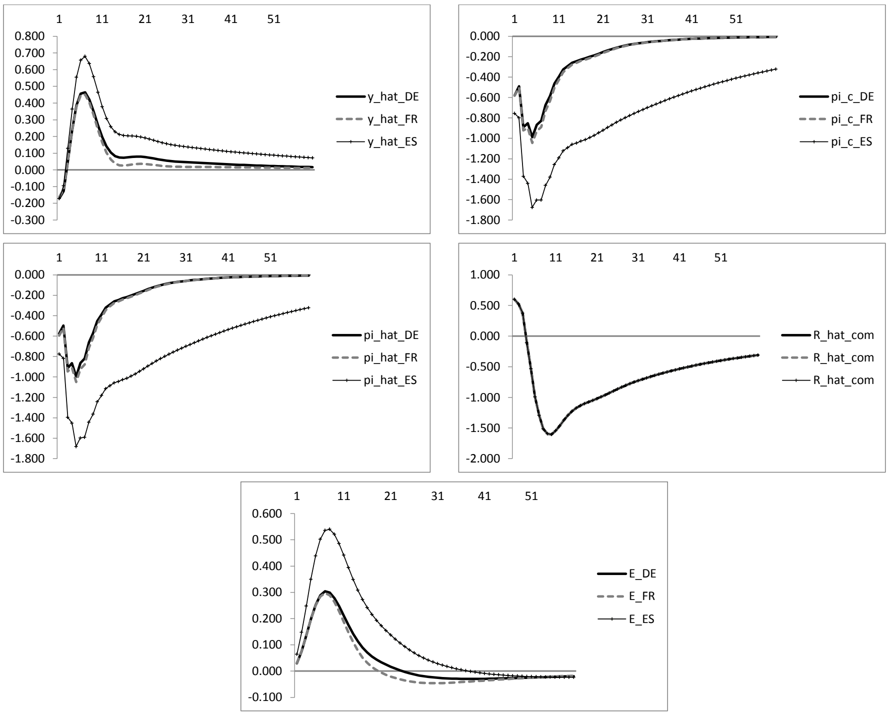
The subsequent decline of the regionally-common interest rate sets the pace of output's recovery which, given the features of the model in terms of persistence, eventually turns into a positive deviation with its main strength between quarters 5 and 8.

Employment also declines during the immediate aftermath of the shock although it displays greater downward rigidity while, by contrast, the upward adjustment that accompanies the phase with output's growth is significantly larger and lasting (extending its reach up to the middle of our simulation horizon). This asymmetric rigidity in employment also fits in the inflationary account given above.

2. Shock to the Euro-zone's monetary policy target

A shock to the monetary policy target, in turn, displays differentiated responses between countries, especially in the case of the Spanish economy, which appears to be substantially more sensitive to a policy shift of this type[39] (see Figure 2.5.21).

Figure 2.5.21: Effects of a monetary policy target shock in the Euro-zone.



The pattern of the responses in the individual countries are, on the other hand, considerably homogeneous, particularly when compared to the intra-regional dis-

[39]Recall that, in order to compare with a monetary policy shock, which implies a contractionary stance, we use in these sections *negative* shocks to the policy targets so that they also describe a hardening in relation to monetary policies. The extent of the shocks in this case, however, are regional, involving all the countries representing the Euro-zone.

similarities found in NAFTA and the Asia-Pacific region when they are exposed to equivalent shocks.

As in the previous scenario, we notice the presence of asymmetric real rigidity although in this case it is present in both output and employment. This way, the initial decline in output, for example, is over-compensated by a subsequent recovery. The after-shock increase in output is enhanced by lower interest-rate conditions which, in turn, reflect the common monetary policy response to the earlier falls in regional prices and output. In comparative terms, the asymmetric rigidity is also shown by the fact that, although all three countries experienced the same initial fall in output, intra-regional differences only emerge during and after the recovery stages.

In addition, despite the immediate negative effect on output, this shock does not negatively affect employment in the region which, starting from a minor positive initial impact, displays a positive response to the declining interest rate and increasing production. The return to equilibrium levels of employment is significantly slower than output's as is the interest rate's given that the larger impact of the shock on Spanish prices takes a long period to dissipate.

Comparing the implications of these shocks for the region's constituent economies in Figures 2.5.22-2.5.24, we notice that the monetary target shock exhibits the most significant responses in our selected map of representative variables.

Figure 2.5.22: International effects of a monetary shocks in the Euro-zone, Germany.

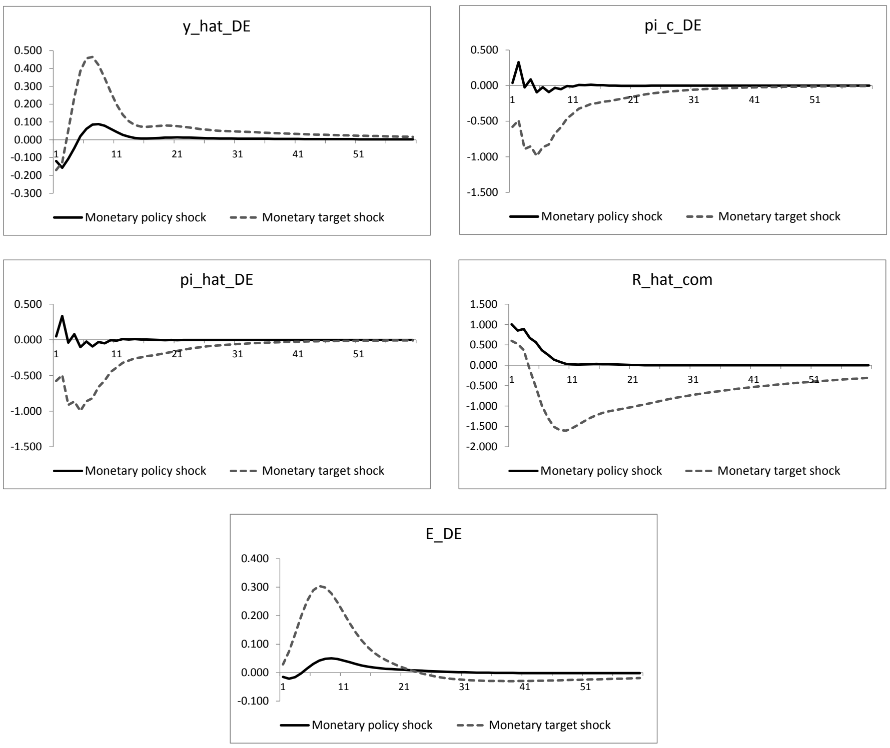


Figure 2.5.23: International effects of a monetary shocks in the Euro-zone, France.

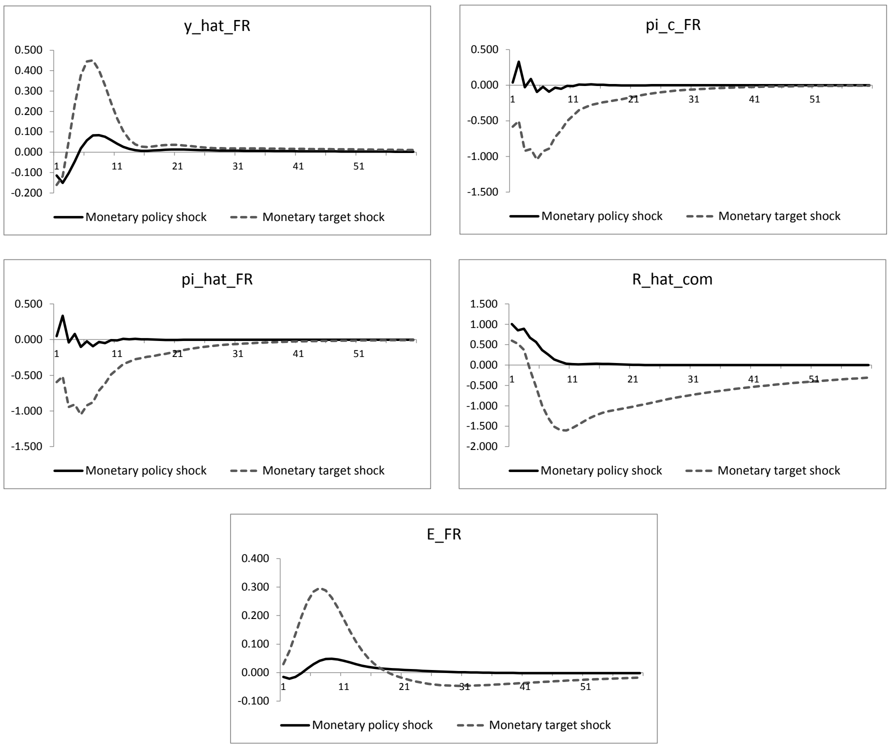
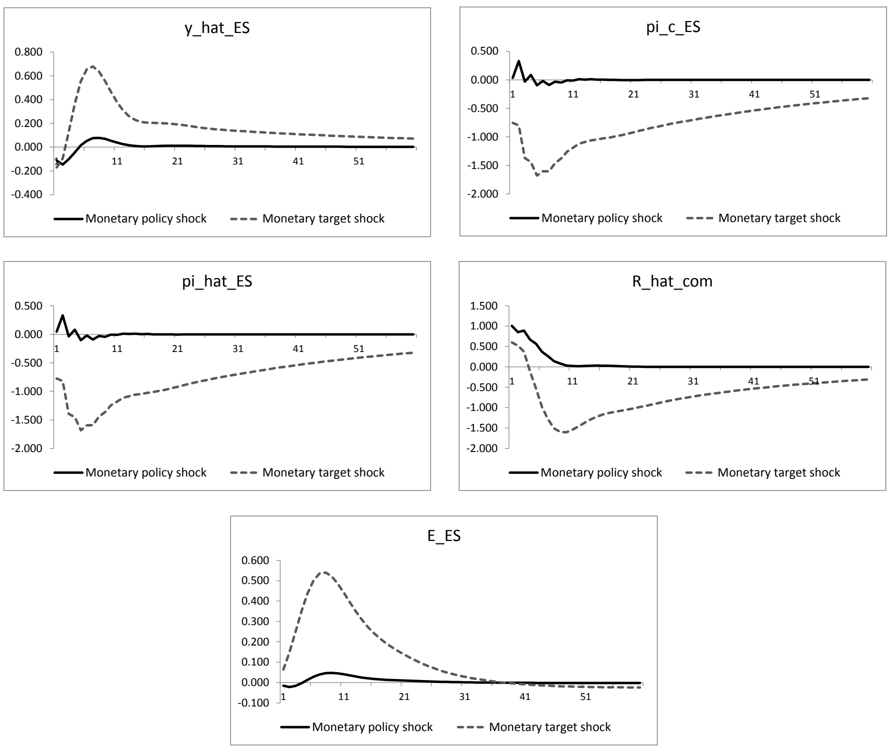


Figure 2.5.24: International effects of a monetary shocks in the Euro-zone, Spain.



This shows the comparative extent and features with which, even a transitory impact on a variable expressing the longer-term commitment of the monetary authority, as is the inflation target, generates larger disruptions than policy shocks with a shorter temporary perspective by design.

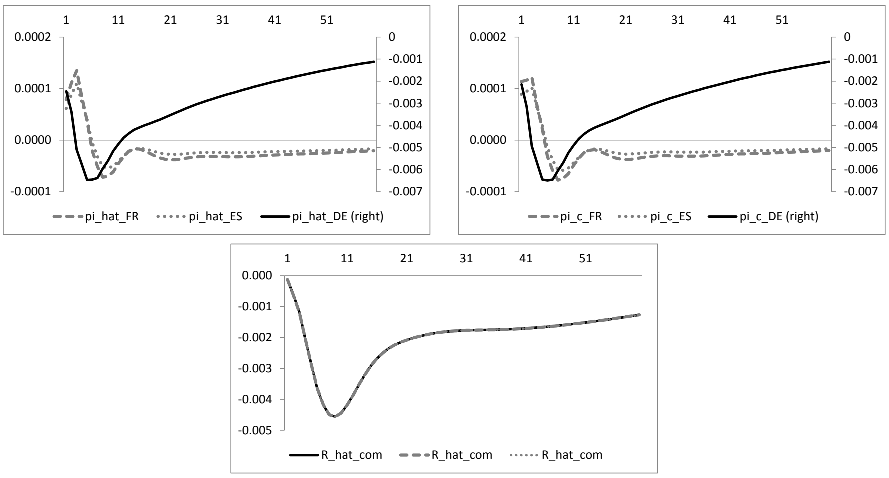
Moreover, we can distinguish the similarities (as those between Germany and France) and heterogeneities in the responses at country-level (noticeably in Spain) to these monetary disturbances. In this particular case, all of them are relevant to the common regional monetary authority.

3. Nominal externalities of fiscal policy

In this section we compare the responses within the Euro-zone region of fiscal policy shocks, in particular from a negative income tax shock ($\varepsilon^{fpy}_{DE,t=0}$) and a positive government spending shock ($\varepsilon^{fpg}_{DE,t=0}$) in Germany as the leading regional economy.

In line with our approach on macroeconomic policy interactions we are specifically interested in evaluating the nominal repercussions of such developments in fiscal policy given that those effects modify the space of action available to the common monetary authority.

Figure 2.5.25: International nominal effects of a fiscal policy shock (income tax) in Germany, Euro-zone.

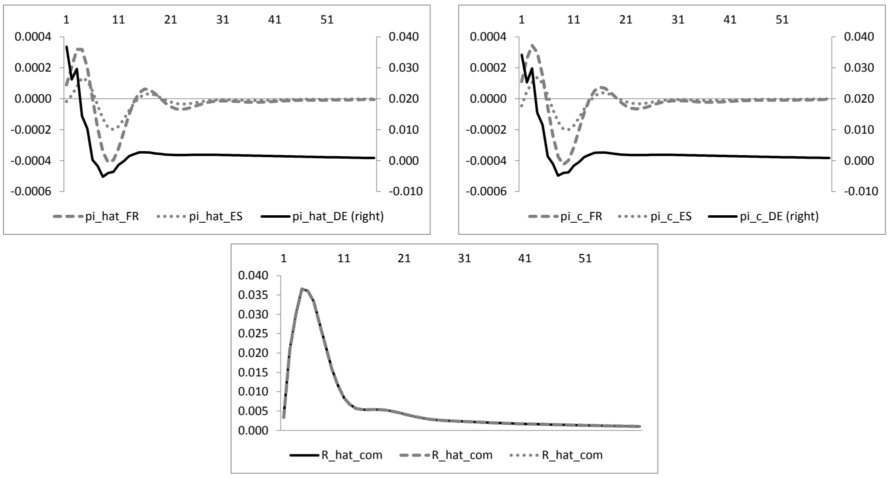


First, we observe in Figure 2.5.25 that fiscal spillovers from a negative shock to income tax within the region (left scale) are relatively small. The spillovers to France and Spain share a similar dimension and follow the direct effect of the shock in Germany with a delay of three quarters.

The direct and indirect effects of the policy shock are mostly described by an inflationary episode in these economies which, however, is not important enough to generate an increase of the common interest rate. On the contrary, the interest rate exhibits a minor negative response to the shock.

In turn, in Figure 2.5.26 we see that larger nominal spillovers (left scale) appear after a government spending shock in Germany which imposes the largest spillovers on France. The international effects of this shock are of a broadly similar size as their equivalents in the NAFTA region and larger than those in Asia-Pacific.

Figure 2.5.26: International nominal effects of a fiscal policy shock (government spending) in Germany, Euro-zone.



Importantly, this fiscal disturbance generates a positive deviation of the common interest rate with its largest effect during the first year. This nominal effect reflects the size of the adjustment that the monetary authority will be forced to perform in order to accommodate its own policy programme to the circumstances created by the national fiscal shock. For individual economies, the spillovers from fiscal shocks (shown in Figures 2.5.27 - 2.5.29) represent a prolonged period of price-instability, especially after a German spending shock to which France's consumer prices display the highest sensitivity.

Figure 2.5.27: Comparative international nominal effects of fiscal policies in the Euro-zone, Germany.

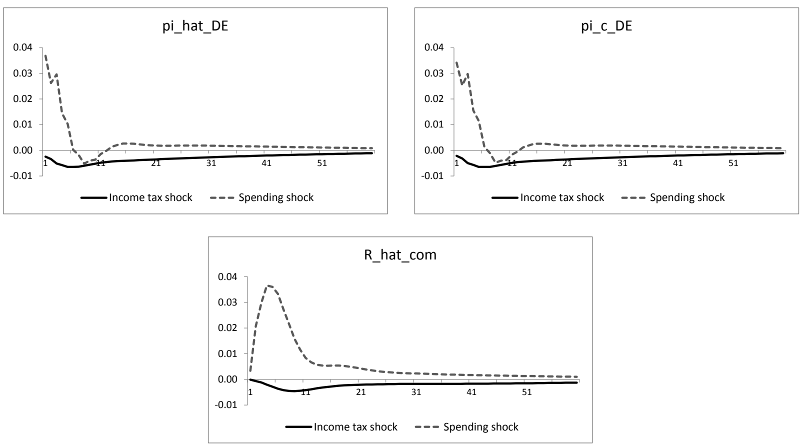


Figure 2.5.28: Comparative international nominal effects of fiscal policies in the Euro-zone, France.

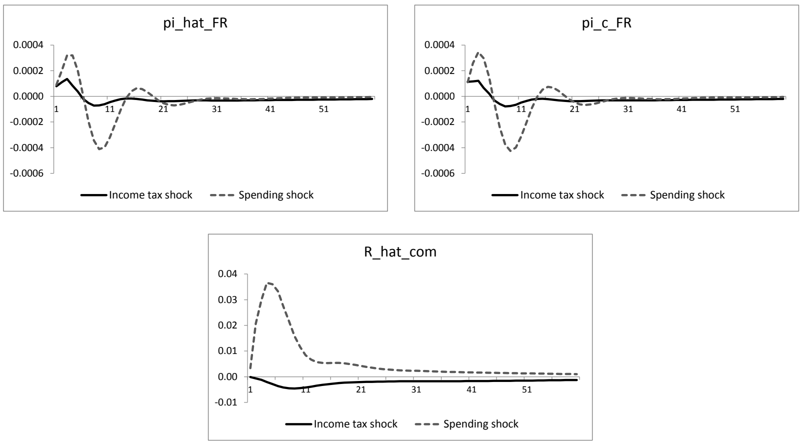
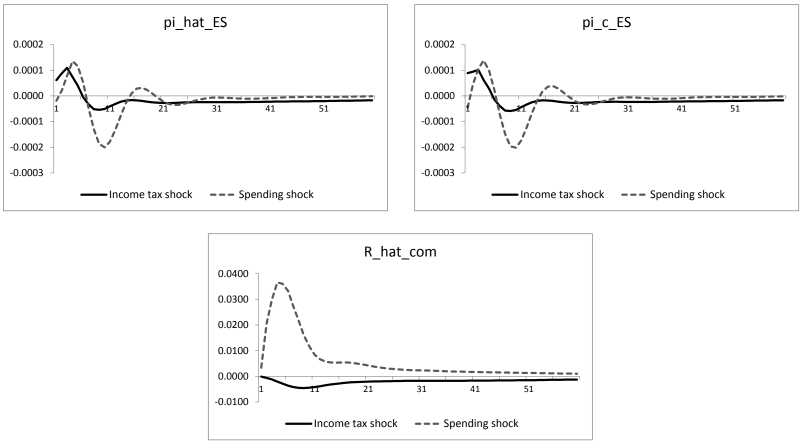


Figure 2.5.29: Comparative international nominal effects of fiscal policies in the Euro-zone, Spain.

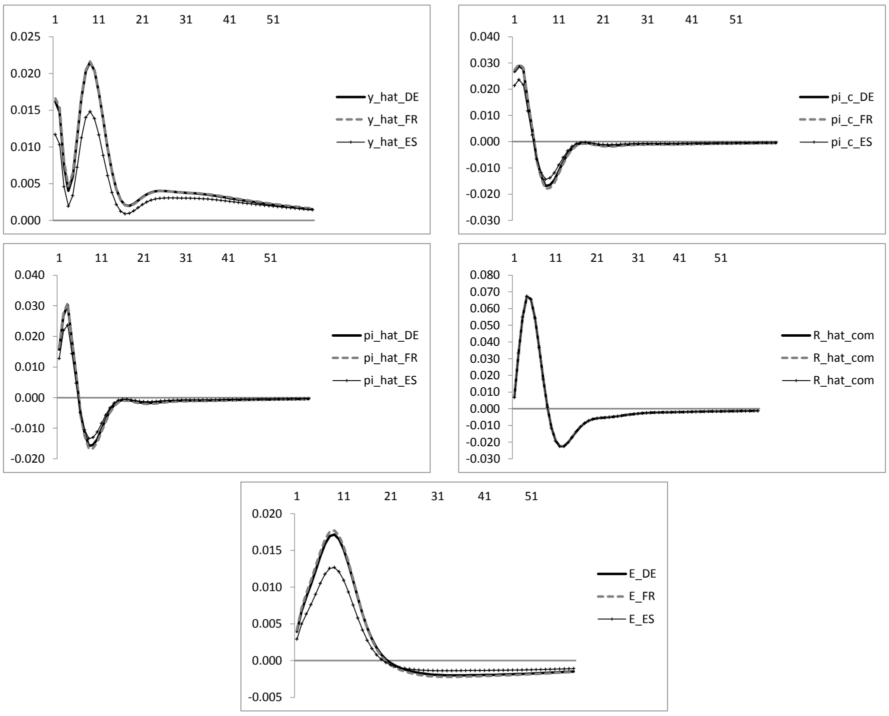


Regional shocks

1. Shock to the Euro-zone risk premium

Figure 2.5.30 shows the effects on the three Euro-zone countries of a region-level shock to the risk premium, $(\varepsilon^{\tilde{\phi}}_{EUR,t=0})$. The dominant feature of the responses to this shock is a higher degree of homogeneity between countries with Spain displaying a slightly higher resilience mainly in real variables. This difference is likely to be a reflection of a lower Spanish exposure to the impacts of variations in the risk premium owed, in turn, to a more discrete degree of integration to the international bonds markets.

Figure 2.5.30: International effects of a shock to the risk premium in the Euro-zone.



The shock initially creates inflationary deviations in the region accompanied by productive expansions. Both of these effects generate a strong response from the monetary authority rule's automatic components increasing the interest rate. Once this overheating is reversed (around quarter 3) the interest rate starts to rapidly decline too, stimulating a second phase of output growth although prices keep falling (in this respect, the shock seems to operate on the supply-side of the economy).

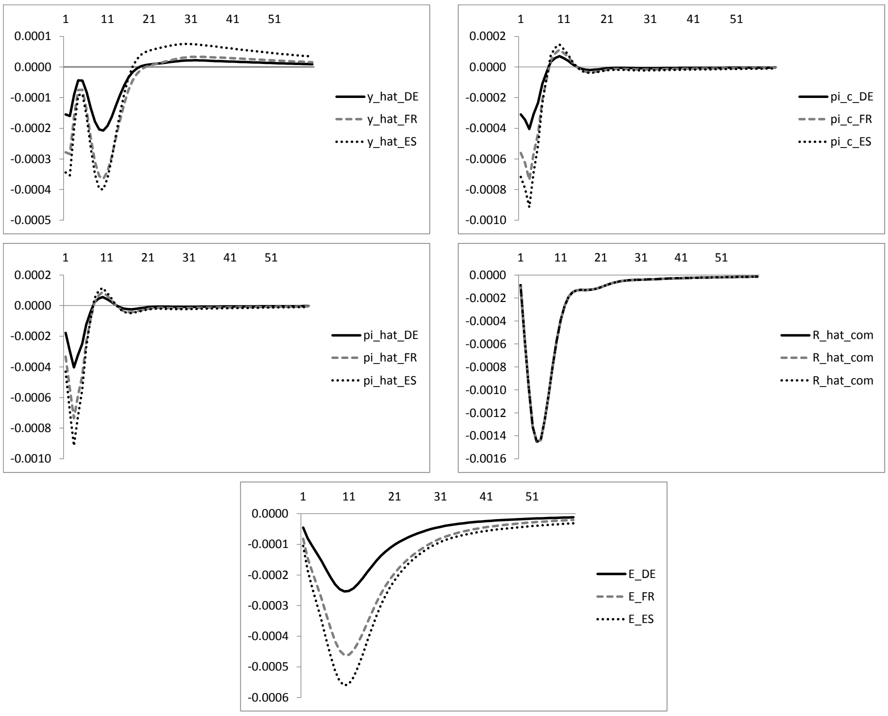
Once again, employment displays higher levels of rigidity while accompanying the productive expansions but in this case the return to pre-shock levels is comparatively faster that in other scenarios. After quarter 20, however, a minor downward displacement is registered in the three economies with more permanent characteristics within our horizon of analysis.

2. Output shock in the rest of the world for the Euro-zone region

The effects of a shock to the regionally-external output ($\varepsilon^{\hat{y}^*}_{EUR,t=0}$), shown in Figure 2.5.31, reflect more idiosyncratic responses given the differences in the economic structures of the countries and in their interrelationships with the rest of the world (as commercial and financial integration, for instance).

Figure 2.5.31: Comparative effects of external shocks on the Euro-zone region.

External output shock



Both output and prices experience initial downward impacts with the largest deviations in France and Spain. The monetary authority, using the features of its policy rule, starts a more than proportional reduction of the interest rate up to quarter 5. Although this is gives output a positive impulse, it is only at quarter 17 that it reaches pre-shock levels.

Among the effects of the shock, it is noticeable that, unlike other scenarios for this region, the member economies display considerable divergences from each other that are comparable to those in the other two regions we analyse.

Contrastingly, prices return to equilibrium levels and regional convergence is comparatively faster (around quarter 8). Employment negative deviations spread across most of the simulation horizon, at the end of which a certain degree of convergence towards equilibrium is also reached[40].

The largest declines of employment happened in France and Spain although all the three economies responded in a highly synchronised way.

3. Comparison with a price shock in the rest of the world for Euro-zone countries

[40] Although this is less precise than the one recorded in the NAFTA region after an equivalent shock.

Next, we contrast the effects of the shock on external output to those from a shock on extra-regional prices ($\varepsilon^{\hat{\pi}^*}_{EUR,t=0}$) shown in Figure 2.5.32.

The international outcomes of this shock share the same general patterns of the previous shock. The disruptions in all variables are, as in the other regions, smaller from a price shock in the rest of the world. Main differences between the two scenarios are reported in Table 2.5.3. For these countries an external price shock generates initial impacts around 40 per cent smaller and maximum (absolute) deviations around 34 per cent smaller than an external output shock.

Figure 2.5.32: Comparative effects of external shocks on the Euro-zone region.

External prices shock

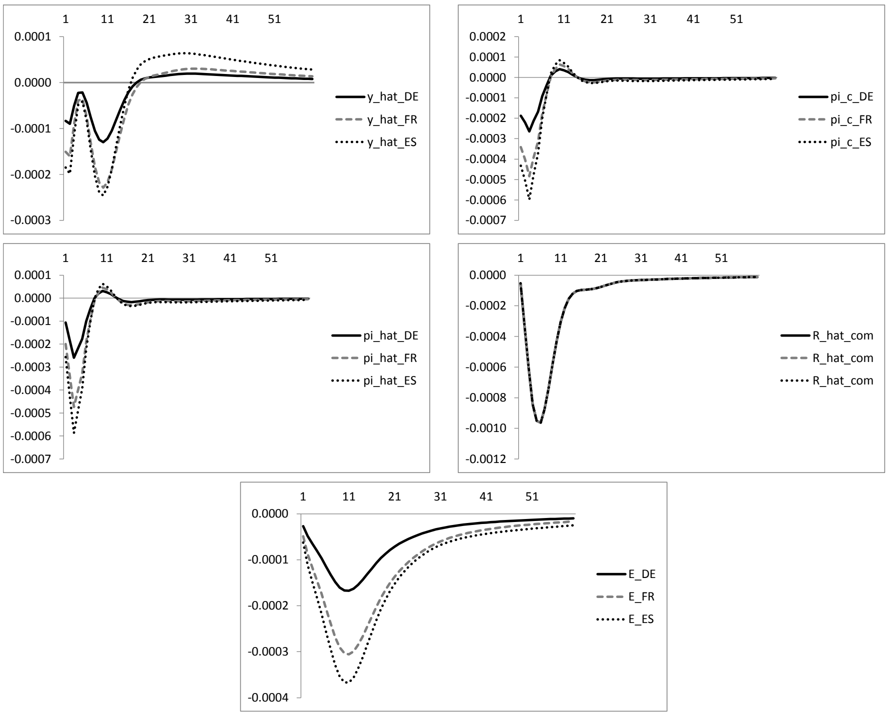


Table 2.5.3: Differences in the effects of external price vs external output shocks on the Euro-zone region.

	DE		FR		ES	
Variable	Initial impact	Maximum deviation	Initial impact	Maximum deviation	Initial impact	Maximum deviation
Interest rate	-39.6	-33.7	-39.6	-33.7	-39.6	-33.7
Domestic prices	-40.2	-35.7	-39.9	-35.5	-40.5	-35.9
Consumer prices	-39.3	-34.5	-39.2	-34.4	-39.7	-34.6
Real output	-46.2	-37.5	-45.8	-37.4	-46.3	-38.5
Employment	-40.7	-34.1	-40.5	-33.7	-40.8	-34.6

Figures as comparative percentage to the shock on external output.

Also in Table 2.5.3, we can see that these differences, although derived from larger deviations in France and Spain, are proportionally equivalent in all three economies. This allows us to verify that for the Euro-zone, shocks on extra-regional output require larger own-policy adjustments to accommodate to the resulting deviations when compared to a shock on external prices. The regional externalities of foreign output shocks are especially expensive in relation to the size of the falls in employment and the instability imposed on output.

Figure 2.5.33: Regional effects of external shocks on the Euro-zone region.

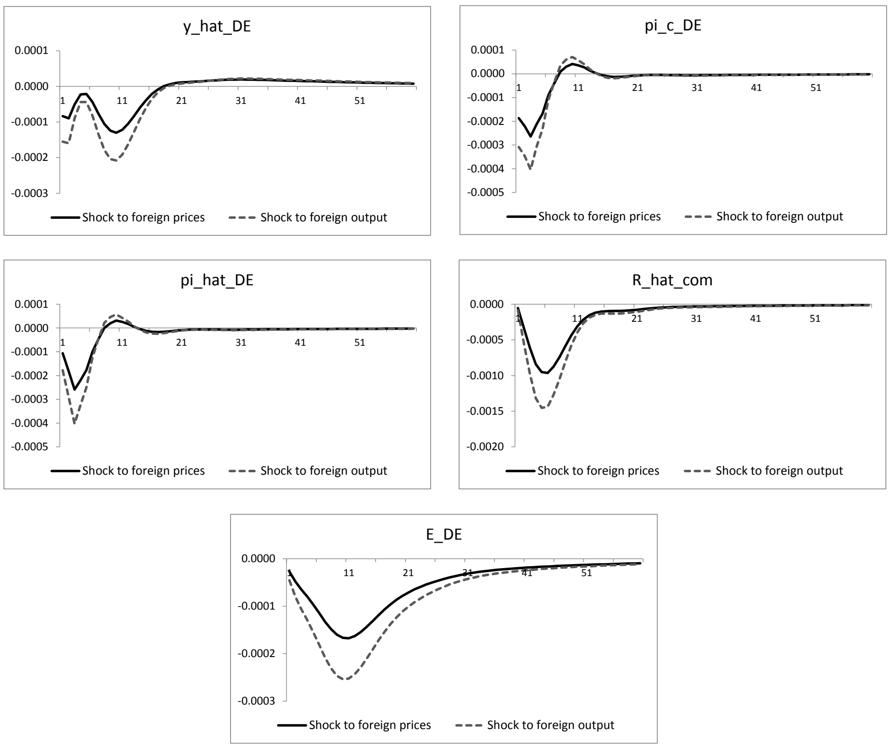
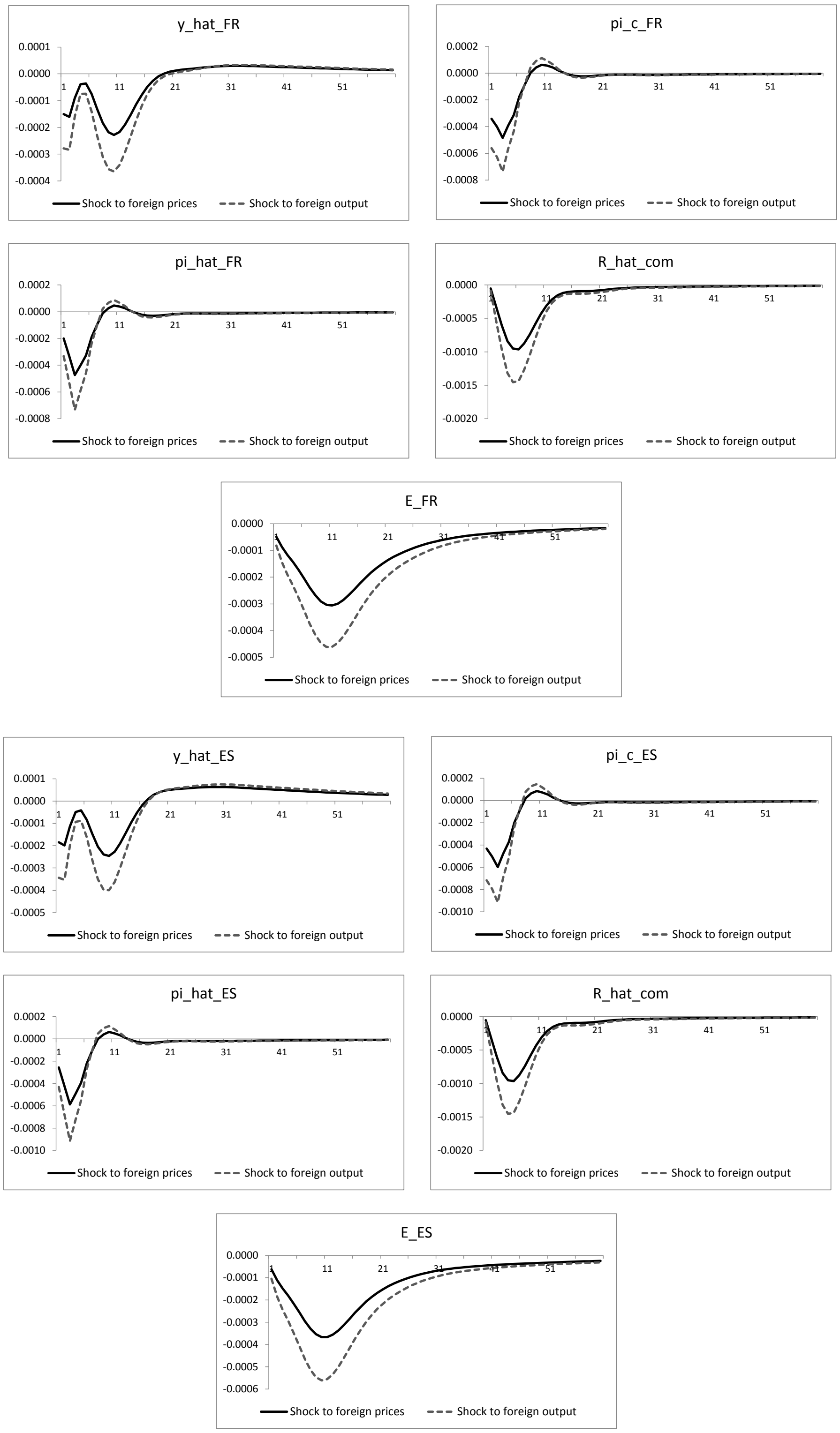


Figure 2.5.33: Regional effects of external shocks on the Euro-zone region (cont'd.).



2.5.3 Estimation on the Asia-Pacific region

The next estimation involves the major economies in the Asia-Pacific region namely, Australia, Japan and Korea[41]. Given that a large proportion of the commercial and financial links for these countries are intra-regional and the only major extra-regional counterpart is the US, we have modelled the three Asia-Pacific countries as members of one region and included the US economy as an additional counterpart outside of it.

Intra-regional shocks

Following the same experimental structure as above, the first set of simulations describe the effects resulting from disturbances in a leading regional economy as Japan. From the perspective of Korea, for example, Japan represents 28 per cent of its trade and 20.6 per cent of its FDI accounts, second only to the US which represents 30.2 per cent in both aspects. Similarly, for Australia, Japan is the third most important country in terms of FDI positions[42] (9.5 per cent) and its first commercial partner (27.7 per cent) while the US appears as first and second respectively, with 37.8 per cent in relation to FDI and 20 per cent of Australia's trade.

Therefore, for this region we assign the role of shock originator to Japan and explore the implications for Australia and Korea as receivers. The immediate impact of the monetary shock reflects into a fall in Japan's output with employment also declining during the early stages of this shock. The recovery from the initial fall is, however, relatively fast even turning into an over-compensating productive expansion in output and an increase of employment, both of them potentially associated to the depreciation in the exchange rate and the stimulus it represents to an exporting leader as Japan. This impulse on activity ends in quarter seven when both variables return to a path towards pre-shock levels[43].

1. Monetary policy shock

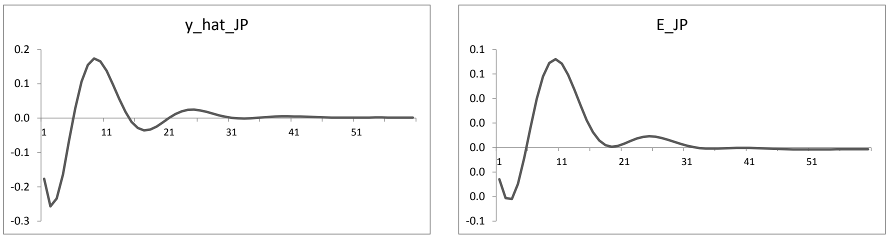
In the first scenario, a monetary policy shock is simulated for Japan ($\varepsilon^{R}_{JP,t=0}$) with a 1 standard error on the interest rate.

[41] Technically, New Zealand is also part of the region but, due to our prioritisation and to the fact that without it we are still accounting for 98 per cent of the regional economy, is not included in this estimation.

[42] The United Kingdom being the second. We did not include the UK in the model because, albeit its relative relevance for Australia and New Zealand, its participation in the exchanges are not similarly large for the region as a whole.

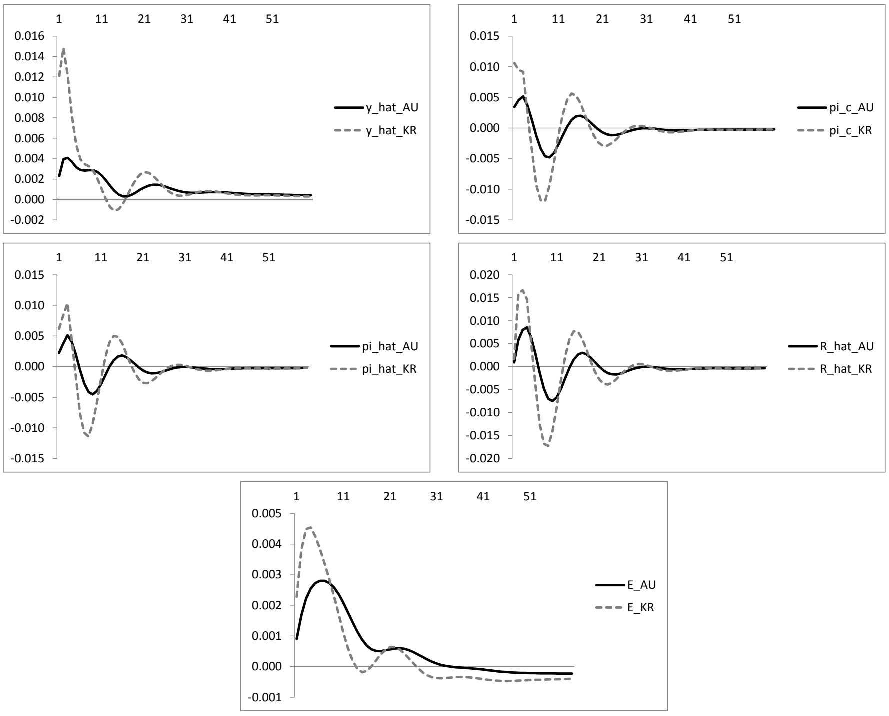
[43] The observed oscillations and slow return to equilibrium come as a result of the real rigidities operating in the model.

Figure 2.5.34: Effects of a monetary policy shock in Japan.



On the international repercussion of this shock, we can appreciate that the other two countries in the region receive a productive stimulus (rather marked in the case of Korea) during the periods of the initial contraction in Japan both of which also start to decline as soon as the Japanese recovery begins. From the impact of the shock until the appreciation of the yen has a significant effect on Japanese trade, the slowdown in Japan appears to benefit the activity levels of Australia and Korea.

Figure 2.5.35: International effects of a monetary policy shock in Japan, Asia Pacific region.

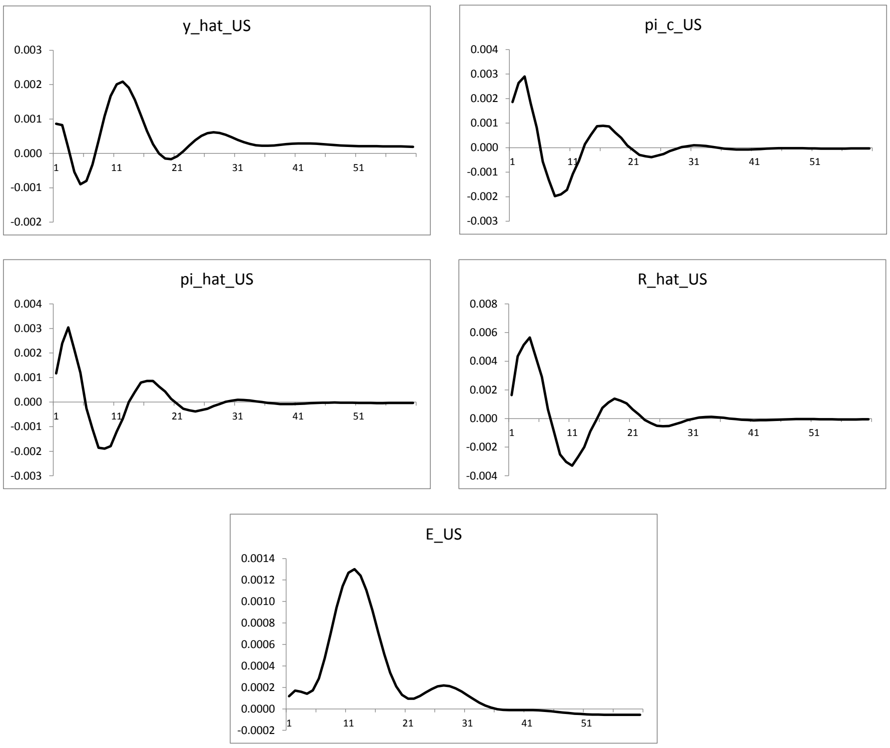


Looking for evidence on an exports shift we noticed that the US economy experiences an increase in output as the Japanese monetary shock hits and subsequently displays an antagonising cycle to Japanese real variables. At the same time, our international weights indicate that, for Korea in particular, the US is the first counterpart both in trade and finance (30.1 and 30.2 per cent, respectively) above Japan (with 28.02 and 20.6 per cent in turn). This way, the implications of the shock on the US economy and the Korean ties with it may have a significant role in explaining the dynamics in its response to the Japanese shock.

Contrastingly, for Australia, Japan is the main commercial peer (27.7 percent of its OECD trade) above the US (with 19.9 per cent) which, under this argument, would the explain the larger benefit of the first seven quarters of the shock for Korea.

Instability in Australia's and Korea's prices is also brought about by this shock with an initial increase on impact and further rises up to the fourth quarter afterwards when a sharp decline happens. Similarly, Korea experiences the largest variations with a standard deviation 125 per cent higher than Australia's in the simulated path for general prices (60 periods) after the shock and 129 per cent larger in the case of consumer prices.

Figure 2.5.36: International effects of a monetary policy shock in Japan, United States.

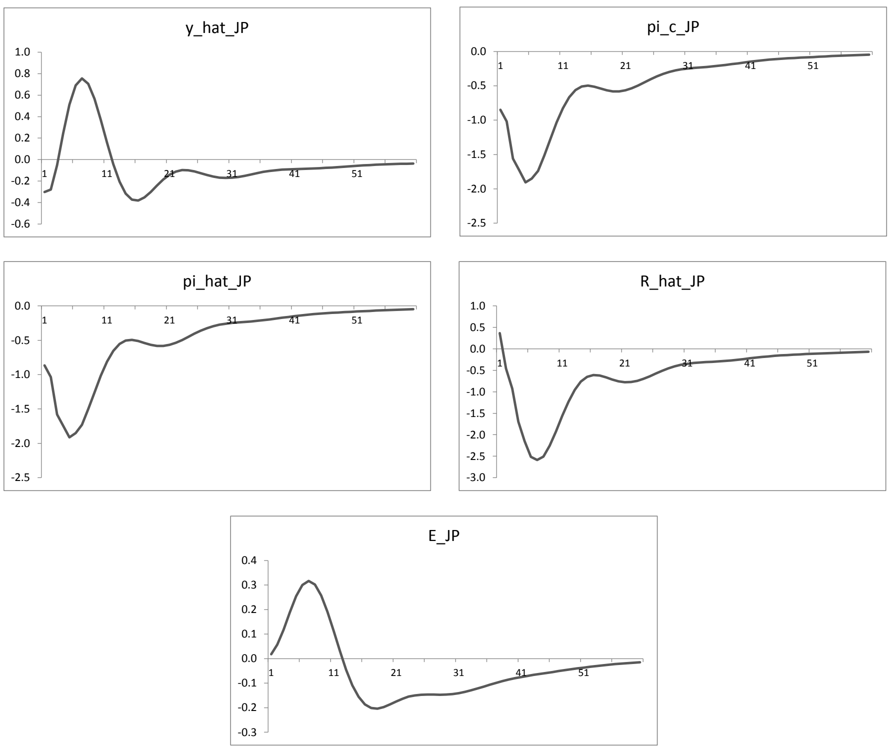


A similar outcome is found in the responses of interest rates in both countries for which the shock initially sparks rate increases but mainly a period of financial instability until its dissipation. The pronounced cyclicality of interest rates we observe is very likely an outcome of the price-rigidities depicted in the model meaning that there is a considerable factor of inertia in variables like inflation and, therefore, with the latter being part of the central banks' policy rules the adjustments of interest rates also follow an oscillating pattern.

2. Shock to Japan's monetary policy target

Subsequently, an inflation-target shock in Japan's monetary policy ($\varepsilon^{\hat{\bar{\pi}}^{c}}_{JP,t=0}$), implying a more restrictive stance, initially reflects into a small increase in the interest rate (see Equation 2.3.97*) but then a marked downward trend starts as the economic activity increases and inflation declines.

Figure 2.5.37: Effects of a monetary policy target shock in Japan.



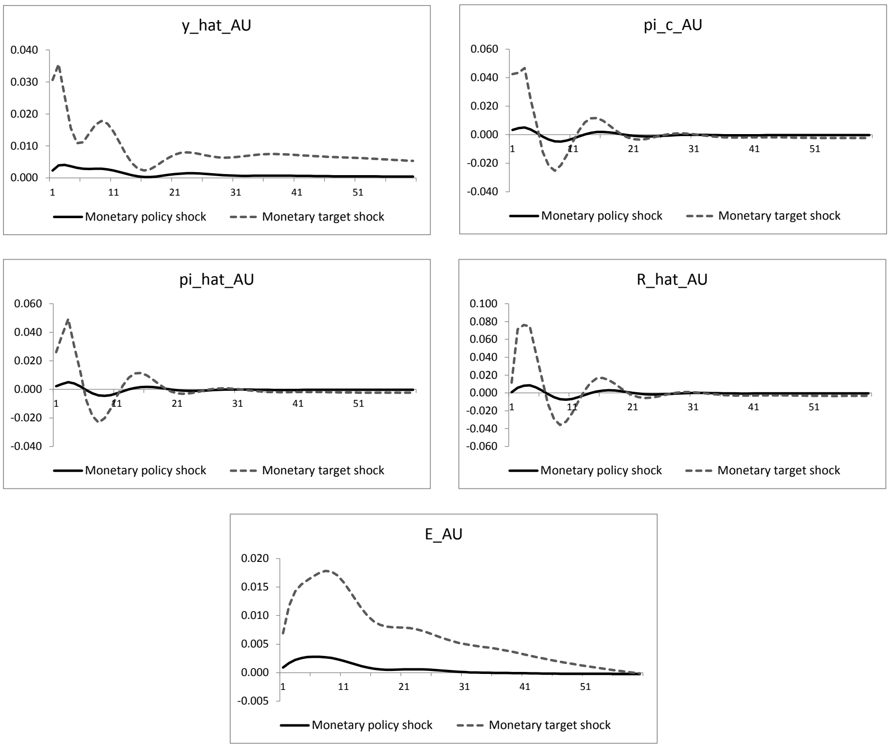
The hardening of monetary policy has significant impacts on both general and consumer inflation during the first five quarters which feed back into the monetary policy function pushing the interest rate down favouring, by doing so, a recovery in production and employment which lasts until quarter seven. Employment closely follows the same dynamics although, similarly to the US, it does not display a negative effect at the start of this type of shock.

For the other members of the region, the monetary target shock has distinctive consequences mainly in real terms. This time Australia shows the largest variations as a result of its comparatively higher interdependence towards the Japanese economy. This is evident in the case of output and employment which display long-lasting effects after the shock. In the case of Korea the initial increase in output rapidly declines and similarly the employment gains are over-compensated by the fast decay in activity.

On the other hand, the nominal instability that results from this shock is approximately of the same order in both countries.

In comparative terms, a Japanese target shock implies considerably larger disturbances to the regional partners' variables (see Figures 2.5.38 and 2.5.39) than a monetary policy shock with Australia especially influenced by the international effects of the former (Figure 2.5.40).

Figure 2.5.38: International effects of a monetary policy target shock in Japan, Australia.



Out of the two types of shocks (monetary and target) with the same dimension (1 standard error) a monetary policy shock generates lower externalities to the region both in terms of their size and of the resulting variability. This is especially clear in the case of Australia where, the local authorities will face considerably larger disruption in their own policies by the occurrence of a target shock.

Figure 2.5.39: International effects of a monetary policy target shock in Japan, Korea.

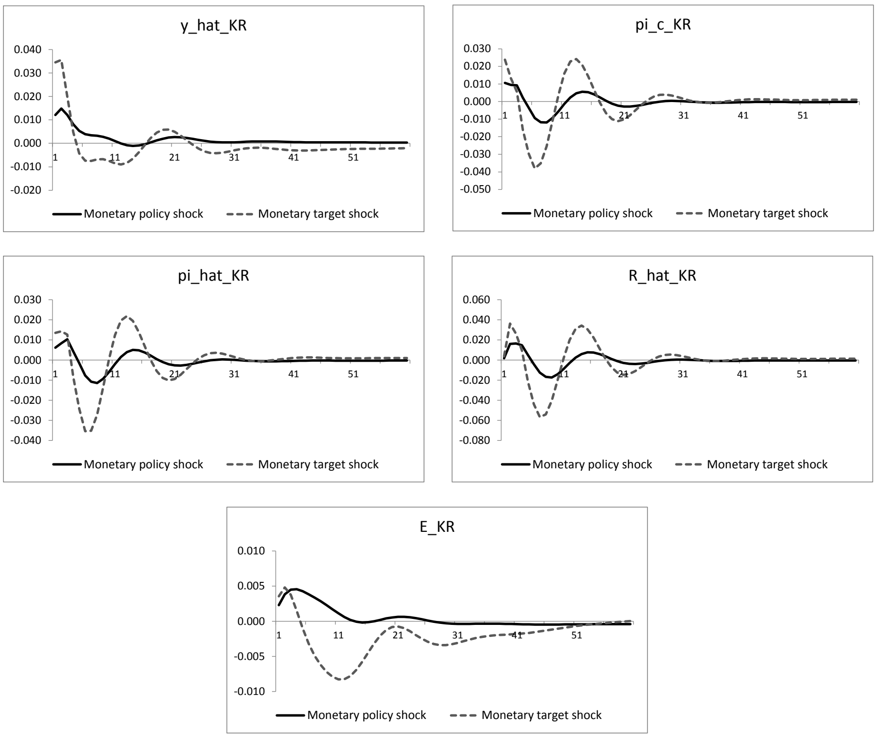
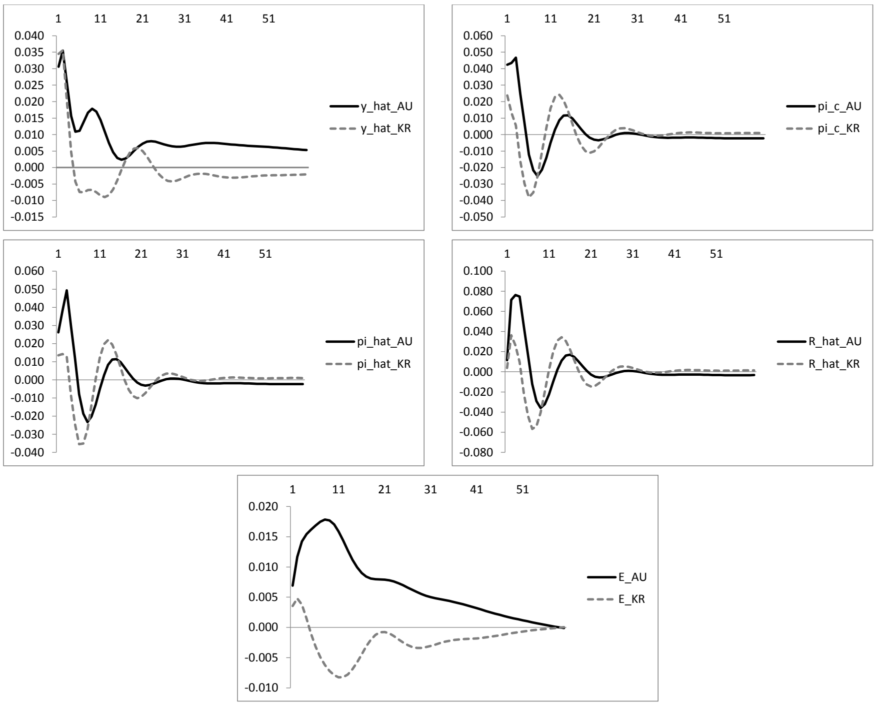


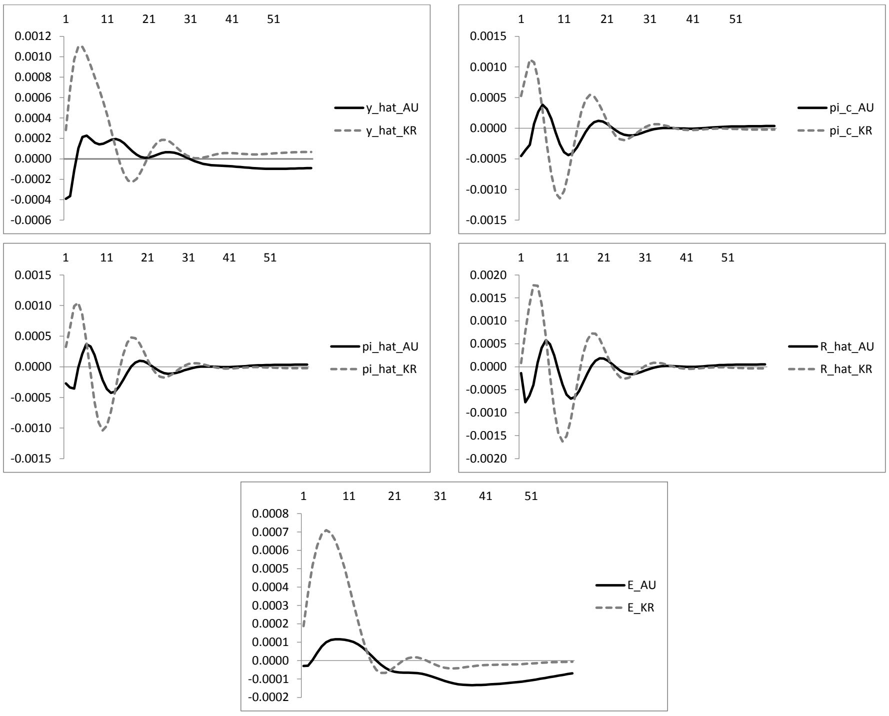
Figure 2.5.40: International effects of a monetary policy target shock in Japan, Asia Pacific region.



3. Shock to Japan's risk premium

A shock to Japan's risk premium ($\tilde{\phi}_{JP,t=0}$) sets off distinctive patterns in the responses of the region's members. Asynchronous and dissimilar paths are followed by Australia's and Korea's key macroeconomic variables with the second displaying the most dramatic variations in each one of them.

Figure 2.5.41: International effects of a shock to Japan's risk premium, Asia Pacific region.



Firstly, we notice from our estimations that the Japanese monetary policy seems to actively counteract financial instability as represented by the spreads between the prevailing lending interest rate and the US three month Treasury bills rate ($\rho_{JP}^{\tilde{\phi}} = -0.0167$, see Table F.2) although this mitigation effort is comparatively small.

Next, unlike other regions, we perceive a mixed picture in terms of the contagion occurring towards the countries in this area where Australia's interest rate also falls while Korea's increases after the shock.

The large participation of the US in Korea's international exchanges (meaning that Korea effectively has two economies acting as leading generators of shocks) seem to favour a distinctive dynamic pattern for this economy, showing the effects of an economic stimulus after what implicitly means an expected appreciation of the yen.

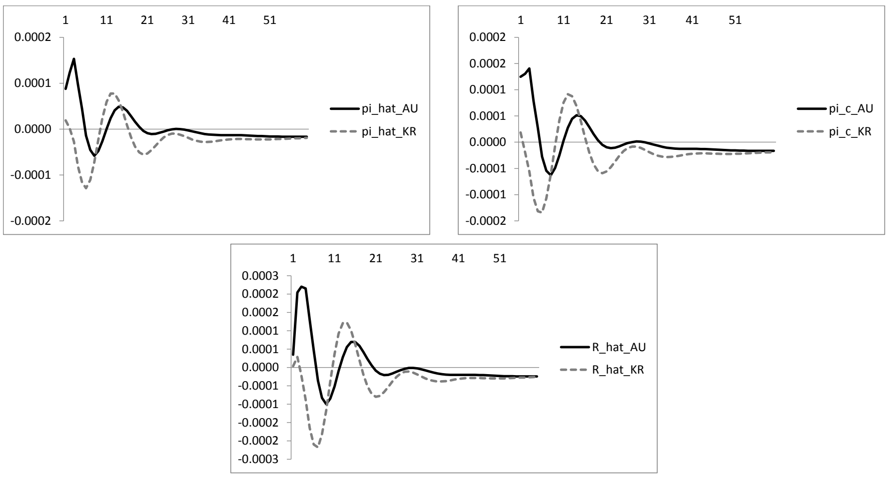
Using more structural premises, a competitive standing between Japan and Korea seems to be behind these antagonistic variations. This clearly comes as a contrast whit the relationships we found in regions like NAFTA, where a leader-follower style of interdependence dominates the international effects of economic shocks.

4. Nominal externalities of fiscal policy

Turning to international cross-policy shocks originated from fiscal policies, a negative shock to the income tax in Japan ($\epsilon^{fpy}_{JP,t=0}$), also transmits nominal externalities to its regional peers with Australia experiencing the largest increases in inflation as well as in the interest rate immediately after the shock. For standardisation purposes, we used a one standard error shock.

The results are clearly distinct for each of the receiving countries, this way the Reserve Bank of Australia would need to consider the largest adjustments to its own policies right after such a fiscal event in Japan.

Figure 2.5.42: International nominal effects of a fiscal policy shock (income tax) in Japan, Asia Pacific region.



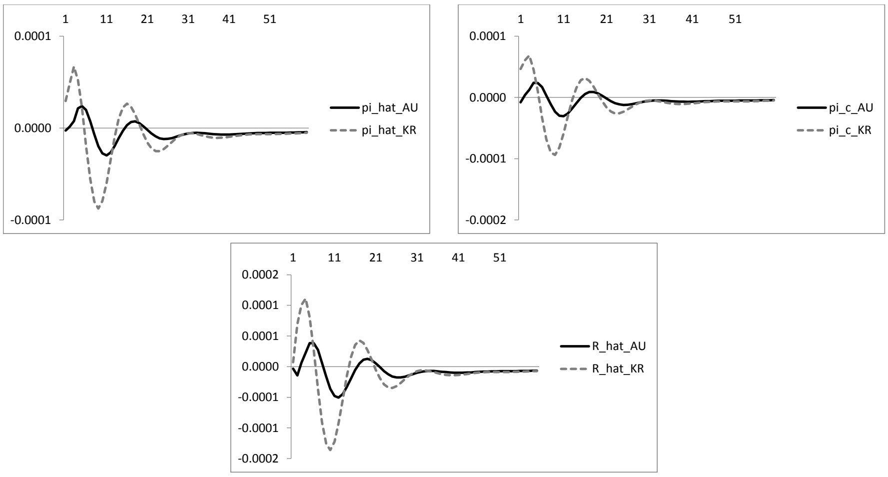
General and consumer prices display a considerably higher increase in Australia, as an increased demand for imports is fuelled in Japan by the rise in disposable income. Contrastingly, this effect does not appear in Korea[44]. These increases in Australia's inflation generate upward pressure on the interest rate until quarter 3 when the international externality on inflation loses momentum.

Although the shock brings the same degree of instability to their interest rates ($6x10^{-5}$ as standard deviation of the path followed by the interest rate in both cases) the direction of the necessary adjustments in each country are different with Australia's monetary policy being forced to temper an inflationary externality while Korea faces a deflation process at the same time.

[44]Further details are required in relation to the nature of the exchanges between Japan and Korea, in order to understand why the last one does not receive the effects of an increased demand in a scenario of lower taxes in Japan.

By contrast, a shock to Japan's government spending ($\epsilon^{fpg}_{JP,t=0}$) creates a disturbance process which is more noticeable in Korea with its inflation and the interest rate displaying the largest effects from this externality (generating a standard deviation 172 per cent higher in Korea's interest rate path against Australia's.). However, although there is a slight comparative lag in Australia's response, the nature of the nominal externalities is the same in both cases.

Figure 2.5.43: International nominal effects of a fiscal policy shock (government spending) in Japan, Asia Pacific region.



Comparing the international effects of these two shocks, we can appreciate that for this region an income tax shock in the originating economy generates a larger disruption in the nominal context of the receiving economies when contrasted with a spending shock, especially in the case of Australia.

In a similar way as in the NAFTA region, in this case the effects of a spending shock also display a relative lag in time of around three quarters in relation to a tax shock.

Figure 2.5.44: Comparative international nominal effects of fiscal policies in Japan, Australia.

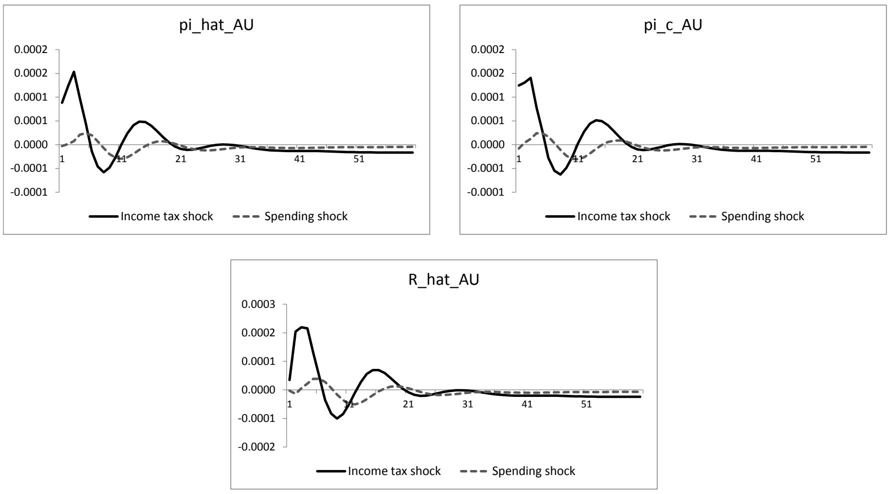
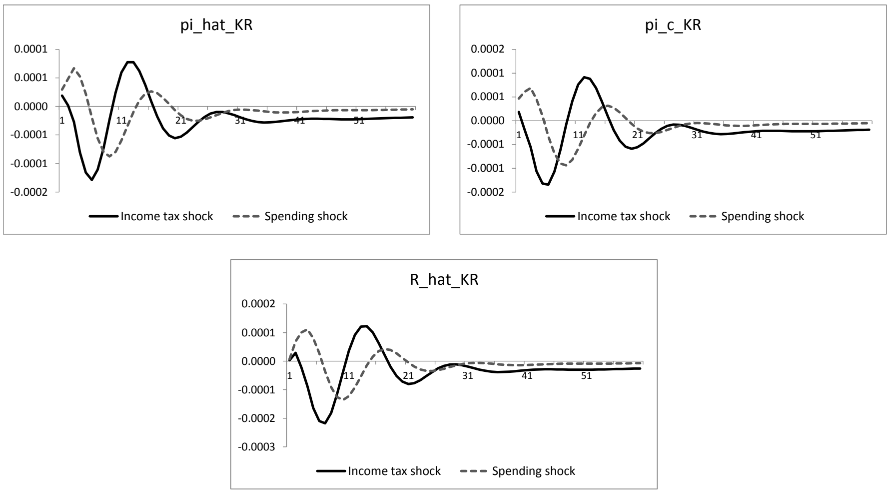


Figure 2.5.45: Comparative international nominal effects of fiscal policies in Japan, Korea.



Regional shocks

This section describes the implications of two relevant shocks on key macroeconomic extra-regional variables, as are output and inflation, for the performance of the region's member economies. Again, the aim is to expose the economies in the Asia-Pacific region to a common set of disturbances in order to analyse the particular effects they have on each one.

1. Output shock in the rest of the world for the Asia-Pacific region

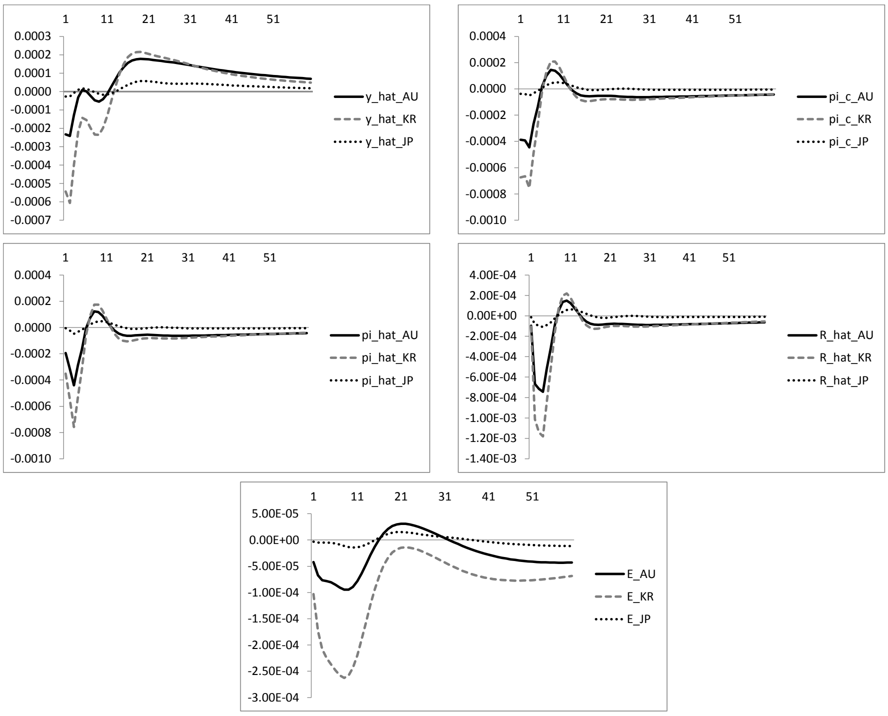
Replicating the exercises performed on other regions, we now study the outcomes of a simulated shock on the external output, that is, an expansion in the production of the rest of the OECD countries from the perspective of Asia-Pacific ($\epsilon^{\hat{y}^*}_{r,t=0}$, with r =Asia-Pacific). This shock has impacts on the macroeconomic performance of the region as we can see in Figure 2.5.46. The external recovery also implies an effect of market saturation depressing output, employment, prices and the interest rate in all three countries.

Nevertheless, significant heterogeneities appear between those responses. The external recovery, for example, seems to affect Korea's insertion in the rest of OECD markets and, with this effect, the country is subject to the largest productive slowdown in the region (150.9 per cent lower than the maximum fall in Australia's output) and also the largest falls in employment (177 per cent lower than Australia's) and prices (72.3 per cent lower).

The comparative exposure of Japan to this shock shows contrasting results. Being at the opposite side of the scale, the external impacts seem to have little impact on the overall performance of the Japanese economy. Our perspective on these features in the information obtained from the model points towards the low participation of imports in both Japanese consumption and investment (see Appendix C) as the main reason of its comparative resilience.

Figure 2.5.46: Comparative effects of external shocks on the Asia Pacific region.

External output shock



2. Comparison with a price shock in the rest of the world for Asia-Pacific countries

If a shock occurs in relation to regionally-external prices (that is, in the inflation of the rest of the OECD countries) instead, the resulting impacts and variability transmitted to the three economies are comparatively smaller. As described in Table 2.5.4, the main contrasts appear in the case of Japan's overall inflation, with an initial impact 68.5 per cent smaller than its equivalent from an external output shock and, similarly, a fall in employment 46.2 per cent smaller.

Also for Australia, a shock to external inflation is 45.6 per cent less severe in its impact on real output than an external output shock and 44.8 per cent smaller in the case of employment. In the same way, the maximum impacts of the shock on external inflation are 43.1 per cent and 46.2 per cent smaller respectively, than the corresponding outcomes from the external output shock.

In the case of Korea (the most affected economy), the variations in its indicators after the external inflation shock are also lower when compared to the resulting ones from an external output shock. This is especially notorious in terms of lower falls in output and employment.

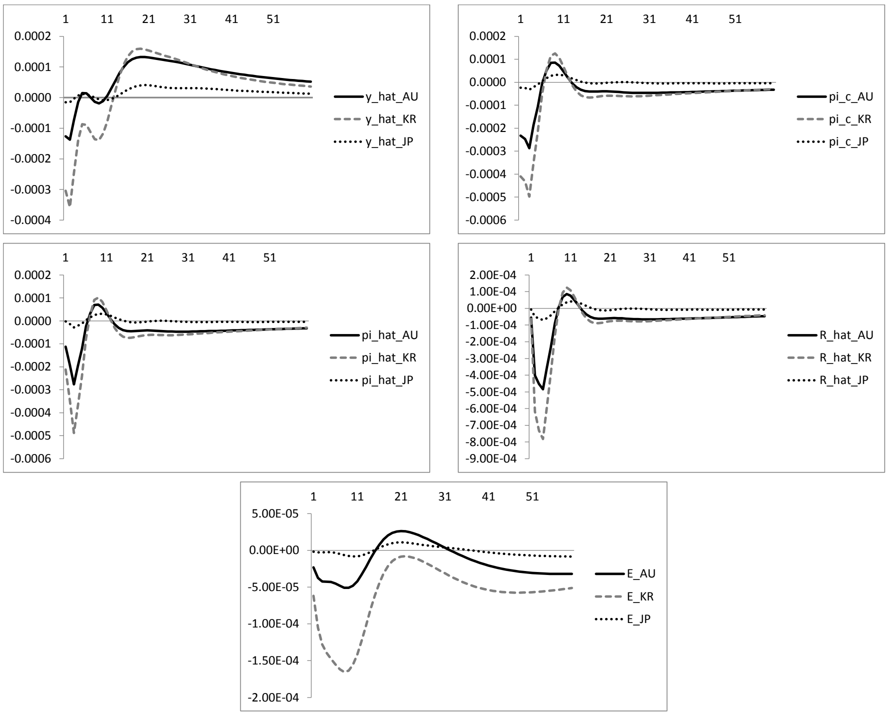
Table 2.5.4: Differences in the effects of external price vs external output shocks on the Asia Pacific region.

Variable	AU		KR		JP	
	Initial impact	Maximum deviation	Initial impact	Maximum deviation	Initial impact	Maximum deviation
Interest rate	-42.8	-34.9	-39.3	-33.8	-42.0	-36.0
Domestic prices	-42.3	-37.1	-39.7	-35.6	-68.5	-33.9
Consumer prices	-40.0	-35.5	-39.1	-33.9	-39.2	-35.3
Real output	-45.6	-43.1	-44.1	-41.0	-43.9	-29.3
Employment	-44.8	-46.2	-40.2	-37.0	-46.2	-27.9

Figures as comparative percentage to the shock on external output.

Figure 2.5.47: Comparative effects of external shocks on the Asia Pacific region.

External prices shock



The occurrence of either of these external shocks would, therefore, bring about different implications for the local authorities and require specific adjustment plans confirming, again, that foreign policy-preferences are relevant for the domestic macroeconomic management. Real variables (output and employment) generally show the largest contrasts when the two scenarios are compared.

Figure 2.5.48: Regional effects of external shocks on the Asia Pacific region, Australia.

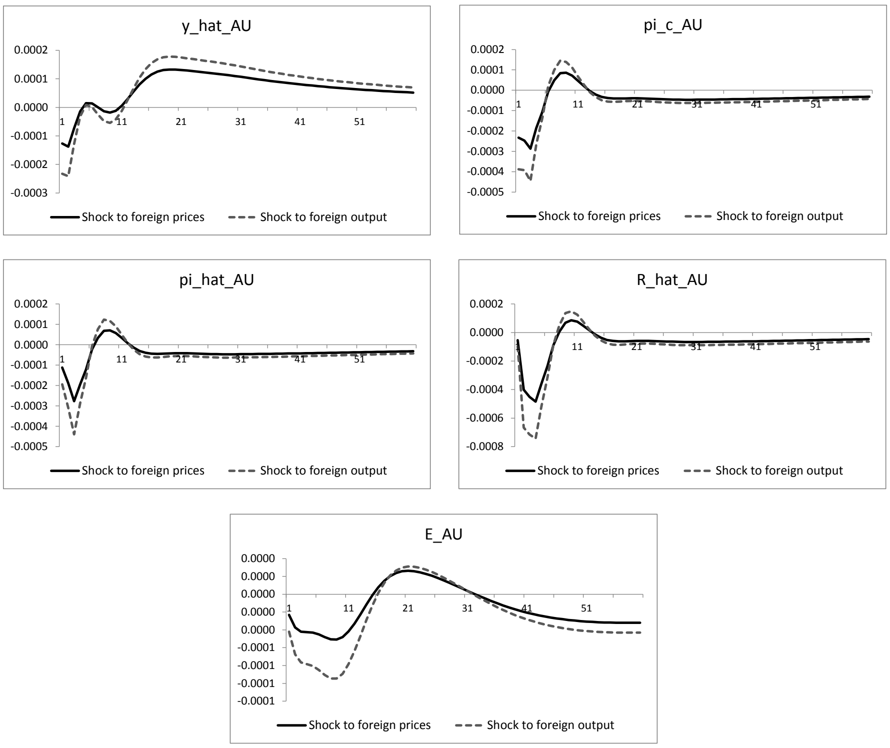


Figure 2.5.49: Regional effects of external shocks on the Asia Pacific region, Korea.

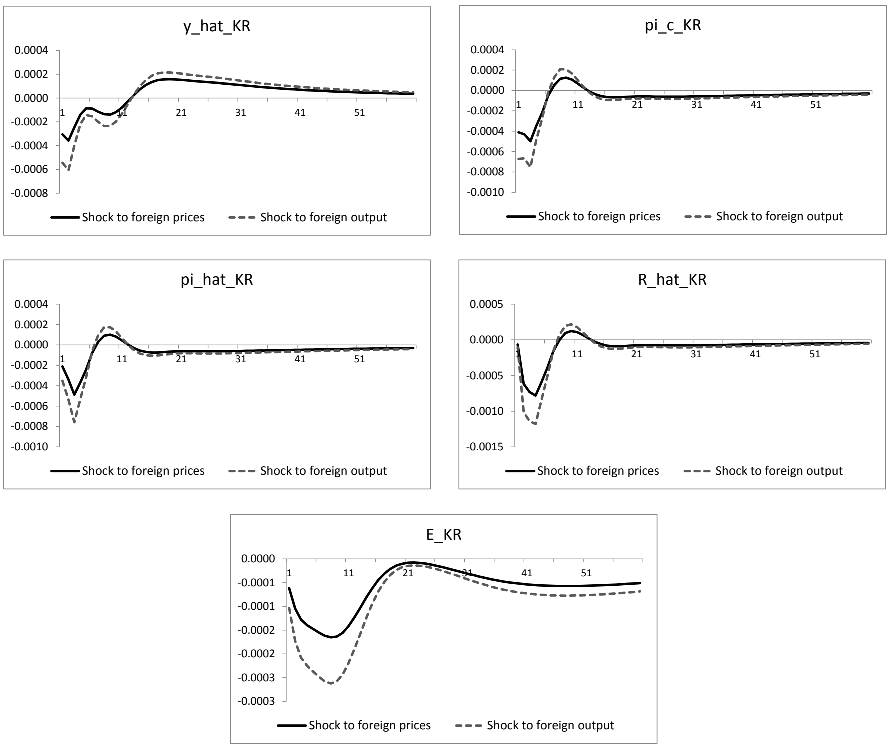
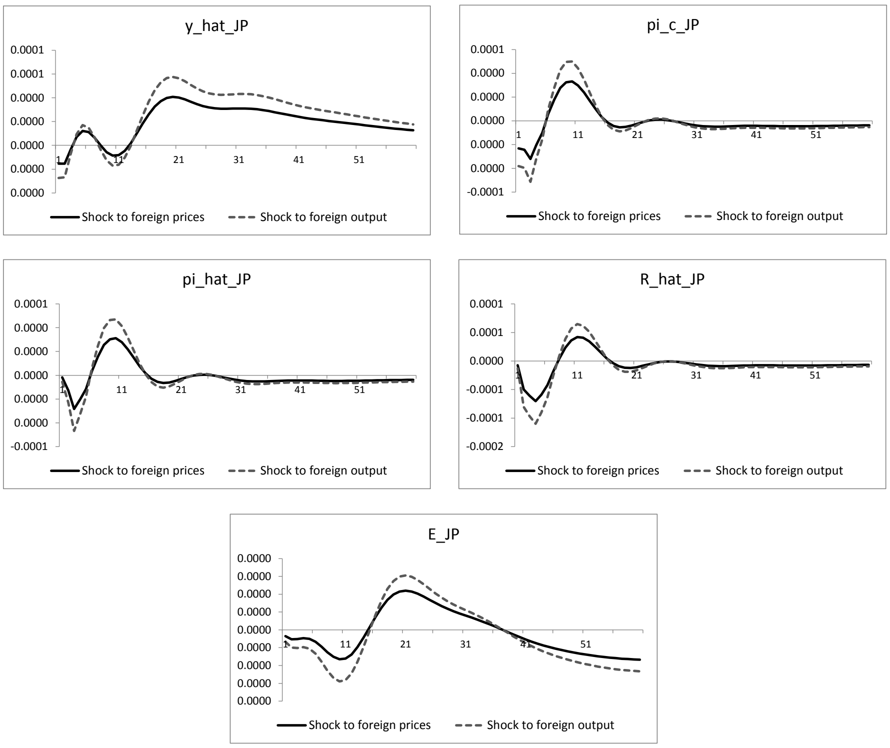


Figure 2.5.50: Regional effects of external shocks on the Asia Pacific region, Japan.



2.6 Conclusions

In this Chapter we have developed and applied a new macroeconometric multi-country DSGE platform for the analysis of the international effects of macroeconomic shocks as well as of monetary and fiscal policy externalities in a context of international networks in trade and finance.

Given the limitations found in previous DSGE literature in addressing these internationally interactive aspects, the platform in itself constitutes a significant contribution of our research. Our multi-country expansion of Adolfson et al. (2005, 2007) with selected contributions from Smets and Wooters (2003), Fernandez- Villaverde (2010), Taylor (2008) and Akitobi and Stratmann (2008), results in a tool for macroeconomic analysis which in addition to their original advantages, as the inclusion of nominal and real rigidities, is able to characterise, through a network-based depiction of international components, key features of the specific linkages between economies and the particularities of international impacts of disturbances generated at the national, regional and global level.

An innovative structure of commercial, financial and size weights embedded in the model contributed to achieve a precise representation of the relationships between economies and enabled it to calculate country-specific foreign variables for each experimental setting[45] in our exploration of international interactions. This reflected in our measurements of the impacts of international shocks and the diverse degrees of exposure to them displayed by dissimilar but closely linked economies. This way, we also contributed to close the gap in previous literature in relation to the simultaneous assessment of the impacts of shocks on heterogeneous economies linked within commercial and financial networks.

By the means of our empirical application to three regions within the OECD, we explored the international consequences of macroeconomic, fiscal and monetary international externalities in a variety of policy-relevant contexts not restricted to the conditions of monetary unions. We used the outcomes of estimations on 9 leading economies in North America, the Euro-zone and Asia-Pacific and, as a result, obtained a wide, precise parameterisation in the model for those economies although there is still ample room for more parameters to be individualised though subsequent estimations.

In terms of its extent and complexity, our study sits above other multi-country investigations in the DSGE applied arena as Taylor (1993), Coenen and Wieland (2002) and Razafindrabe (2016) but still below Kumhof et al. (2010) and, nevertheless, is able to combine precise descriptions of international phenomena as regional and global shocks with concrete depictions of the heterogeneous national responses that arise as a result.

The depiction of national and regional economic features contained in our set of individualised parameters is of great value for a better-informed simulation of shocks, relevant to both monetary and fiscal policies, that we performed with particular focus on the international aspects of their impacts.

Unlike previous modelling which evaluated international shocks from the perspective of either a monetary union, large economies or national scopes, our extended framework embracing all those possible profiles proved valuable for the assessment of a richer set of interactions within and between wider international networks as represented in our regional settings.

Among those interactions, we analysed cross-policy effects transmitted between the economies in our sample. In particular, we looked into the comparative regional effects of fiscally-originated shocks on the nominal conditions (as represented by prices and interest rates) of the economies receiving such impacts. Although we are not aware of previous research applied to the same extent, the assessment of

[45]The computing programme in which the model resides is able to adapt to the researcher's specifications of the countries included, the regional membership, the presence (and regional consequences) of a monetary union and the geographic coverage of the shocks to be simulated. It is equally flexible to include additional parameters at the national level and common parameters related to a monetary union as they become available to the researcher.

those shocks is considered to be highly relevant for monetary policy-makers given that it provides concrete information on the scale and persistence of international fiscal externalities and, with, them, of the potential adjustments they would have to perform in the design of their own policies operating in an open-economy context.

The results confirm the presence of international fiscal externalities and show important differences between regions. In North America, tax and spending shocks generate very similar international nominal responses with only a relative slight delay in time in the case of the responses to spending shocks. In turn, for the Eurozone and Asia-Pacific regions the contrasts between the two profiles of responses are marked. The first region is more sensitive to foreign spending shocks while the second is to foreign tax shocks. This kind of empirical contrasts have not been addressed in previous studies but are, nevertheless, important to consider from national, regional and global-macroeconomics points of view.

Our model was also able to integrate an international perspective to long-standing debates in the context of macroeconomic policy as the *rules versus discretion* discussion. On the monetary side, our study of international externalities found that shocks to the inflation targets pursued by regionally-leading monetary authorities (which, therefore, act as shock-originators) display larger and more persistent effects on macroeconomic variables of shock-receiving economies in contrast to comparable discretionary monetary shocks. Shocks involving the monetary rules generated larger disruptions in the welfare set (as defined by output, consumer and general prices, the interest rate and employment in each economy) for all three regions when compared to shocks to the discretionary component of monetary policies.

These findings provide additional information and support to the literature on international policy coordination in the form of specific measurements of vulnerability to the foreign setting of macroeconomic policies. This is particularly relevant in a context where large and small economies interact given that, in a leadership game (as Stackelberg, for example), the latter would find valuable considering these developments in the leader's rules into their own policy design in order to accommodate to the resulting international real and nominal externalities.

A similarly crucial discussion in the literature of macroeconomic policy and policy coordination involves the differences in preferences between policy-makers. Our platform addressed this issue by the means of contrasting the effects of regionally-common shocks to world output and world inflation. The results contribute to discern that, from a global point of view, common output shocks are considerably more disruptive to the welfare set of the member economies in each region. In this sense, the preferences displayed by foreign macroeconomic authorities in terms of the output/inflation dichotomy matter for the success of national policies. Our evidence favours the argument for giving a higher weight to output stabilisation for the benefit of the global economy as depicted in our study.

We can highlight that the NAFTA region (in particular Canada) displays the more pronounced differences between the outcomes of these two global shocks although there is a considerable degree of consistency of the results across all the three regions. The countries in the Euro-zone, in turn, exhibit the largest vulnerability to extra-regional output shocks.

This way, our description of the distinctive impacts of external disturbances among heterogeneous OECD economies offers an account of the particular adjustments that local authorities would have to consider in each of the scenarios we have studied. The confirmed international externalities of macroeconomic shocks imply that the actual space of action available for national policy makers is contingent on the actions taken by foreign authorities. This gives rise to the need to emphasise on our treatment of macroeconomic policy as a strategic body of international interactions with regional or even global implications as expressed, for example, in our concise set of representative welfare variables.

Nevertheless, as we have shown, the differences of the international impacts can be considerable between the analysed economies, both in terms of their size and their persistence in time and, in this sense, the model was also precise enough to provide specific characterisations of the exposure shown by each national economy. We consider this ability to effectively combine national, regional and global considerations to be a crucial advantage of our modelling, critically reducing home biases in macroeconomic analysis but still providing relevant information for the design of adjusted national policies.

In addition to information on the direction, size and timing of the responses to shocks, the model has provided us with important insights on the particular rigidities displayed by key variables in both real and nominal aspects of each included economy. Asymmetric features of those rigidities, in employment for example, help to distinguish the distinctive potentialities of external shocks in terms of downward or upward deviations form the steady state between the members of our regions. Common shocks in our empirical application contributed to exhibit, this way, the relative sensitivity of each economy to developments in their regional and global context.

In contrast to previous DSGE approaches to international analysis, the systemic configuration of our platform enabled us to account for the simultaneous adjustments occurring in variables of interest in the aftermath of international shocks across several economies. The analysis of additional elements of the international economic environment, as shocks to the risk premia in leading economies helped to make specific distinctions of the real and nominal repercussions faced by macroeconomic authorities within regional networks.

All the interrelations we have explored by the means of our extended DSGE platform constitute, therefore, the bases of a truly strategic component of macroeconomic policies between OECD economies which also finds expression in a set of distinctive profiles of vulnerability to international shocks within the interest of both fiscal and monetary authorities.

Chapter 3

The effects of international monetary spillovers on the supply conditions of credit in OECD countries

3.1 Introduction

3.1.1 Financial components in macroeconomic modelling

Financial markets have an undoubted participation in the transmission of shocks between economies. As previous research has pointed out, macroeconomic fluctuations are spread by financial transmission channels which can even be dominant when compared to their more conventionally studied trade counterparts (see Corsetti and Müller (2011)).

Nevertheless, the literature on the integration of financial components to macroeconomic modelling is still evolving from its early foundations and achieving more advanced stages of maturity. No true paradigm has emerged, however, as an agreed reference on these issues and there is still a considerable degree of fragmentation of interests which makes difficult to enumerate a common set of fundamental elements for the study of financial interactions.

Despite these conditions we make use of well-grounded and updated instruments in the modelling of financial intermediation and extend their application to a context where international credit also contributes to the functioning of an internationally open financial system with significant implications for the operation of domestic credit markets and, through them, for the overall macroeconomic performance of national and regional economies. In our financially-augmented framework, agents are no longer homogeneous, there are borrowers and lenders. Similarly, financial intermediaries make use of borrowing in a wholesale market.

As an extension of our multi-country DSGE framework developed on the basis of Christiano, Eichenbaum and Evans (2005) (CEE) and Adolfson, Laseén, Lindé and Villani (2007) ($ALLV$), already accounting for the effects of real and nominal frictions, we integrate the contributions of recent leading research as Gertler and Kiyotaki (2011)[1] and expand the reach of the analysed relationships to an international context where an interbank credit market provides funding to the domestic intermediaries subject to the differentiated conditions of risk in which they operate. These elements add informative interactions between heterogeneous economies and help to generate a correspondingly differentiated classification of vulnerabilities to financial shocks.

Until recent years, simplifying elements such as the use of a single interest rate in the economy or the assumption of complete markets with permanent access that allow agents to be insured against all sources of risk[2] were persistently found as common features of macroeconomic models.

The 2007-2009 financial crisis, however, generated a reinforced alert call to the discipline about the need for an improved account of particular interrelations between business cycles and financial costs generated by market imperfections which are now generically known as *financial frictions*. A criticism was put forward by Woodford (2010) and Quadrini (2011), for example, on the inadequacy of macroeconomic models which do not account for financial frictions to depict the current *institutional realities*[3] of the financial system and, therefore, they claimed that a more adequate framework of analysis of the links between financial intermediation and macroeconomics was needed.

As a response to those shortcomings and to the pressure imposed by the experience of financial turmoil, additional elements have been put forward in search of an improved depiction of the financial conditions that, importantly, also intervene in defining the operating context of macroeconomic policies. Following those lines, we aim to develop a coherent selection of financial foundations to be integrated in our DSGE framework where a significant contribution is the modelling of an international set of interactions with implications for the domestic credit markets.

[1] The original formulation of the RAMSES model (Adolfson, Laseén, Lindé and Villani (2005 and 2007)) on which our DSGE framework was based has been extended to include financial frictions on the basis of Bernanke, Gertler and Gilchrist (1999). We have preferred Gertler and Kiyotaki's model instead because of its description of the interactions between the financial intermediaries and the real economy while embracing both a *financial accelerator* effect (see below) and a more detailed account of the relevant variables in banking portfolios that determine the level of operative distress they are subject to.

[2] Which, in turn, lead to the design of models without financial frictions.

[3] Woodford, (2010, p. 21).

Pioneering references on the modelling of financial frictions are found in Bernanke and Gertler (1989), Kiyotaki and Moore (1997), Holmström and Tirole (1997) and Bernanke, Gertler and Gilchrist (1999) but the subject has received renewed attention by more recent, and more comprehensive approaches as in Gertler and Kiyotaki (2011) with a particular focus on the operative conditions of the banking sector and the resulting implications on macroeconomic fluctuations.

We internalise a similar view in our model with the objective of addressing the need for an enhanced depiction of financial phenomena within a macroeconomic model as suggested by Hördahl, Tristani and Vestin (2008). For these purposes we follow contemporaneous developments on the depiction of frictions in the operational context of credit markets as studied by Cúrdia and Woodford (2009b) and Gertler and Kiyotaki (2011).

Financial frictions and DSGE modellling

A relatively recent branch of macroeconomic research has been devoted to enhance the explanatory power of DSGE models by adding financial frictions to their framework. The 2007-2009 financial crisis presented a remarkable challenge to the DSGE school of modelling in the face of which important changes were developed relative to a representation of imperfect financial markets. As a result, financial frictions have increasingly been integrated in DSGE research, and hold especial value for those focused on policy analysis.

Involving nodal components such as credit markets, and financial intermediation in general, the impacts of financial frictions display a significant capacity to influence the economic dynamics and cyclical fluctuations not only of the involved financial institutions but also of households and firms inter-temporal decisions concerning consumption and investment by the means of their effects on the relevant resource constraints.

Recent studies have addressed the mechanisms through which these financially-originated costs are transmitted and multiplied within the broader economy and beyond. Among those transmission mechanisms, credit channels hold a central part in providing a description on how the disturbances operate. Emblematic studies like Bernanke, Gertler and Gilchrist (1999) developed a framework explaining the cumulative pattern of effects of the frictions to the non-financial sectors of the economy known as the *financial accelerator*.

For this reason, explicit representations of banking systems are characteristic of models looking into the consequences of their associated frictions. Capitalisation rates became a fairly common stress indicator in the association between financial and macroeconomic performances but, as we will show, other relevant measurements at the international level may include variations of the comparative interest rate spreads or their alternative expression as relative risks in the interbank credit markets.

Under this contextualisation, a number of sub-branches of research on financial frictions can be identified within the DSGE field[4]. Early developments on the general equilibrium-based macroeconomic theory of financial frictions are found in Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997)[5] with the subsequent alignment to the description of the financial accelerator mechanism championed by Bernanke, Gertler and Gilchrist (1999) and updated by Christiano, Motto and Rostagno (2009) within the Christiano, Eichenbaum and Evans (2005) DSGE modelling paradigm.

Subsequent advances, in turn, improved on the description of the inner workings and agency problems of financial intermediation. For this reason we are particularly attracted to the modelling of banks as in Gertler and Kiyotaki (2011) which also allowed us to incorporate additional elements impacting the stress conditions of the balance sheets in banking and revealing the macroeconomic impacts of the operational fragility in these financial intermediaries (see Brunnermeier, Eisenbach and Sannikov (2013)).

DSGE models with frictions in financial intermediation can be classified in two main groups. First, those addressing the consequences for credit markets of the presence of an external finance premium reflecting the risks in capital management (both for firms and banks, especially for the latter if an interbank market is included) as well as imperfections as asymmetric information, principal-agency problems, costly state verification, etc. Secondly, there is a variant which is based on the constraints imposed over the collaterals required for getting access to intermediated funds taking the form of loan-to-value ratios (for a contrast between these two variants see Brzoza-Brzezina, Kolasa and Makarski (2011)). In our own modelling we adhere to the first representation since it is better supported by empirical evidence and it seamlessly relates to components already operating in our multi-country framework.

3.1.2 Relevance of the banking sector

Balance sheets

In the words of Lindgren, Garcia and Saal (1996) the main functions of banks in the economy are:

[4]Among them, some groups can be highlighted as in the case of models with costly state verification, costly enforcement of contracts, models of financial intermediation and models focused on leverage cycles.

[5]Both of these papers included credit-related foundations of the frictions although they lacked a more specialised depiction of the financial sector and intermediaries as found in more recent research.

- Intermediation
- Maturity transformation
- Facilitating payments
- Credit allocation
- Maintaining discipline among borrowers

Balancing liquidity requirements among agents and risk-mitigation through diversification are important functions in a dynamic setting where banks intervene in the allocation of resources.

The inter-temporal nature of their activity, however, places them in a vulnerable condition in terms of uncertainty and market failures. Their assets are exposed (among others) to financial and operational risks while, at the same time, their liabilities are subject to the valuation of agents restricted by imperfect information and other diverse elements like emotive reactions.

Their interconnections are also features which contribute to the concerns over systemic risk with considerable implications for the broader economy. International risk valuations as The Economist Intelligence Unit's Overall risk index © include in their calculation the risk of banking crises on the basis of the assessment on banking assets and liabilities (including those with foreign entities)[6].

The importance of banks also reflects into the intrinsic risk of contagion which may spread across the financial sector and beyond. Reinhart and Rogoff (2009) present a historical analysis where banking crises are typically followed by significant declines in real and financial assets prices, output and employment as well as a sharp deterioration in public accounts as expressed by increased governmental debt.

Bank solvency, then, has wider implications for macroeconomic performance. Its most representative expression is the net worth of banks which consists of the difference between assets and liabilities at any given point in time. Net worth is also an akin indicator of capitalisation (Lindgren, Garcia and Saal (1996, Ch. 3)) and, in that sense, of the resilience banks display in the face of detrimental shocks.

As described in Brunnermeier, Eisenbach and Sannikov (2013), one of the main foundations of the theory of financial frictions is the rejection of the Modigliani-Miller theorem (Modigliani-Miller (1958)) that, in turn, gives relevance to liquidity conditions and to the balance of resources between economic agents. Under such conditions, the method of financing projects matters in the sense that external funding is typically more expensive (thanks to the state-verification and other monitoring

[6]See Bowler (2014).

costs, for example) as reflected by the spreads between lending rates and the rate of return of capital. The size of these spreads beyond some thresholds, however, also increases the risks of the banks' portfolios of loans since more productive users prefer internal funding and it is risky projects which make the most applications for credit. This phenomenon effectively constitutes a constraint on credit on the side of the costs it implies without involving any quantitative restriction on the amount of funds in the market.

The quality of the loans portfolio is an important ingredient for the operation of financial frictions. Higher proportions of defaulting loans lead to an equally higher occurrence of *fire sales* which aggregate to mutual loses in the credit market by reducing the value of private projects as well as the net worth of the banking system, effects which are susceptible to develop amplification spirals.

Banks, as counterparts in the credit markets participate in the propagation of the effects of these frictions to the wider economy and, by doing so, are key agents in driving business cycles fluctuations (see Hall (2011)). But their true role has to be understood as not only pernicious since, on the one hand, they can generate detrimental spirals (on the basis of the financial accelerator, for example) but also, on the other, they can equally take part in the mitigation of frictions especially when their accounts are observed at higher levels of aggregation.

Firstly, their pooling of assets among a diversity of credit users allows for a better management of idiosyncratic risk (including default risk). However, their exposure to external risks also brings about a degree of fragility which builds on elements like liquidity/maturity mismatch and results in the banking exposure to the risk of runs. This is a relevant component in our own framework for which we have integrated the function of banking reserves as a fraction of the deposits raised by these intermediaries.

We concentrate our attention on the *liquidity effect* fractional reserves have on the banking asset sheets. Although this is not the only function they display in actual practice. The management of compulsory reserves in the banking sector serves at least three main purposes: macro-prudential regulation, monetary control and liquidity management. Even the interests payments made to banks on reserves act as signals of the stance taken by monetary authorities which, thereby, set a *floor* reference for interest rates (see Gray (2011)).

However, in the current context of monetary management, out of those functions it is liquidity management the one that still retains a significant role. This kind of interventions has been generically represented in our model by shocks to the reserve requirements but their features can be comparable to other less regular actions which tend to appear under precarious conditions for monetary policies (e.g. when the zero lower bound for monetary policy has been reached) as the quantitative easing program in the United Kingdom where, by increasing the banking reserves, the Bank of England is *de facto* increasing their liquidity under the expectation that this will encourage the expansion of credit to the private sector.

Credit

Another way in which banks intervene in determining the final impact of financial frictions is by exerting their comparative advantage in terms of monitoring the users of credit. Monitoring and enforcement of contracts, in this context, reduces the incentives and financial conditions for default to households and firms.

In contemporaneous DSGE macroeconomic modelling, one of the main expressions of these market inefficiencies is the presence of diverse interest rates which embody the *wedges* between the returns received by capital owners and the interest payments from credit users, for example. Spreads appear between lending and deposit rates, within domestic markets and, as we will describe, between domestic and international credit rates.

Micro-foundations as asymmetric information and non-convex transaction costs in the financial context constitute the basis for the very existence of financial frictions. Moral hazard as in Gertler and Kiyotaki (2011) also stands as an explanation of the economy-wide potential costs of agents' choices in the banking system. Also, under the *financial accelerator* framework, external funding is subject to a distinctive premium between heterogeneous agents which contributes to explain macroeconomic fluctuations. In this sense we follow one of the lines pursued by Hall (2011) consisting of studying the credit transmission mechanism through the loans made to firms.

In a context where credit is included in the analysis, agents assume two types: lenders or borrowers. For our purposes, we present households as interest-acquiring depositors, firms as borrowers and banks as intermediaries with access, in turn, to an interbank credit market.

Possibilities of default in credit markets bring about financial costs and frictions to our scheme. In our framework, the possibility of default in the interbank market results in a restriction for banks to access funds whereas default in the retail credit market gives rise to the external finance premium (see Wickens, 2011, Ch. 15) which increases the financing costs of borrowers.

These frictions have macroeconomic implications since, funds-restricted banks reduce the amount of loans (a quantity dimension) made to firms impacting their ability to invest and promote growth while similar effects arise from increased financial costs to firms (a price dimension). Cumulative effects of these costs provide the basis of the financial accelerator mechanism.

The outcomes of these frictions, however, are not restricted by national borders given the nature and the extent of the current international networks in financial markets. For this reason we believe it is important to account for the international side of banking as a transcendental complement of our multi-country analysis.

The international networks of interbank credit, also display a central role in the context of the propagation and multiplication of the distortions associated to financial frictions. In more specific terms, our modelling reflects a shared interest with previous research on international contagion of shocks impacting banking assets and liabilities as in Degryse, Elahi and Penas (2010) and analyses the macroeconomic implications of incomplete repayment of loans in the international interbank credit market. As in the mentioned paper, incomplete international repayments erode the assets of banks at the national level and therefore may impinge a deteriorative spiral into the loan-originating economies.

3.1.3 Indications of financial frictions in the banking system: an empirical review

The relevance of financial frictions on macroeconomic performance is mainly owed to the obstruction they imply between savings and investments and, therefore, their impacts have consequences both in relation to short-term variables and also in terms of the long-term dynamics of investment, output and growth. The widespread transmission of these inefficiencies is a result of an increased degree of integration of the general activity with the providers of financial services. The reliance on financial intermediation of increasing sectors of economic activity sets credit markets as nodal points in the economy and, as such, as main participants in the transmission and multiplication of financial distortions.

These inefficiencies find immediate expressions in the financial context as reflected by indicators such as financial costs and the spreads between interest rates but, similarly, real variables such as output and employment are eventually affected by the cumulative effects transmitted by financial intermediation. This is especially evident under scenarios of financial turmoil as studied by Hall (2011)[7].

In the international context, the virtually global reach of financial exchanges is a key factor for the international transmission of these effects. Interconnections between financial institutions and a rapidly increased international wholesale credit

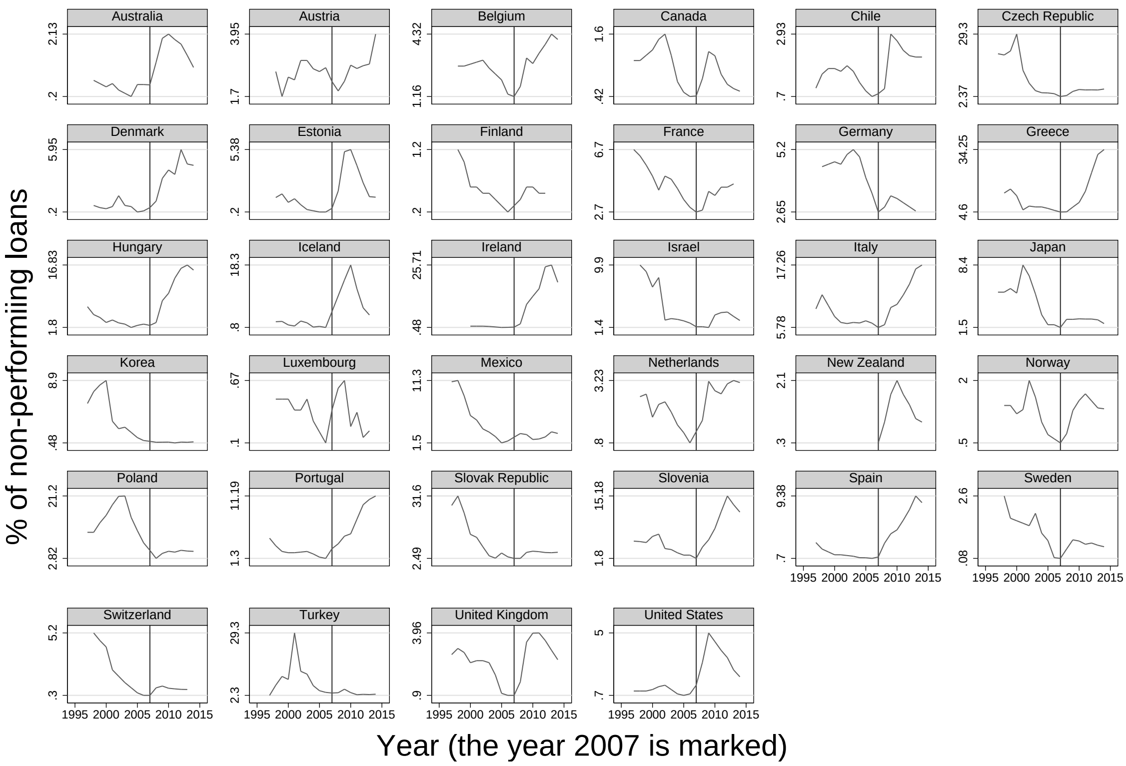
[7]Similarly, his study acknowledges the possibility of a *negative financial friction* displaying the opposite results on the macroeconomy although, on the other hand, potentially leading to the generation of bubbles.

market constitute the basis of our multi-country approach on the study of macroeconomic effects of financial frictions.

Although fundamentally based on the structure given by Gertler and Kiyotaki (2011) (*GK* henceforth), we integrate in our model complementary features which we deem contribute to a better understanding of the sources of pressure on the bank's balance sheets and operative indicators. We include, for example, the implications of the rate of default faced by commercial banks in relation to the loans they emit in the domestic retail markets as a complement of the considerations in GK on the frictions in the wholesale (interbank) credit markets.

Figure 3.1.1: Non-performing loans in the banking system by country.

(as per cent of total gross loans)



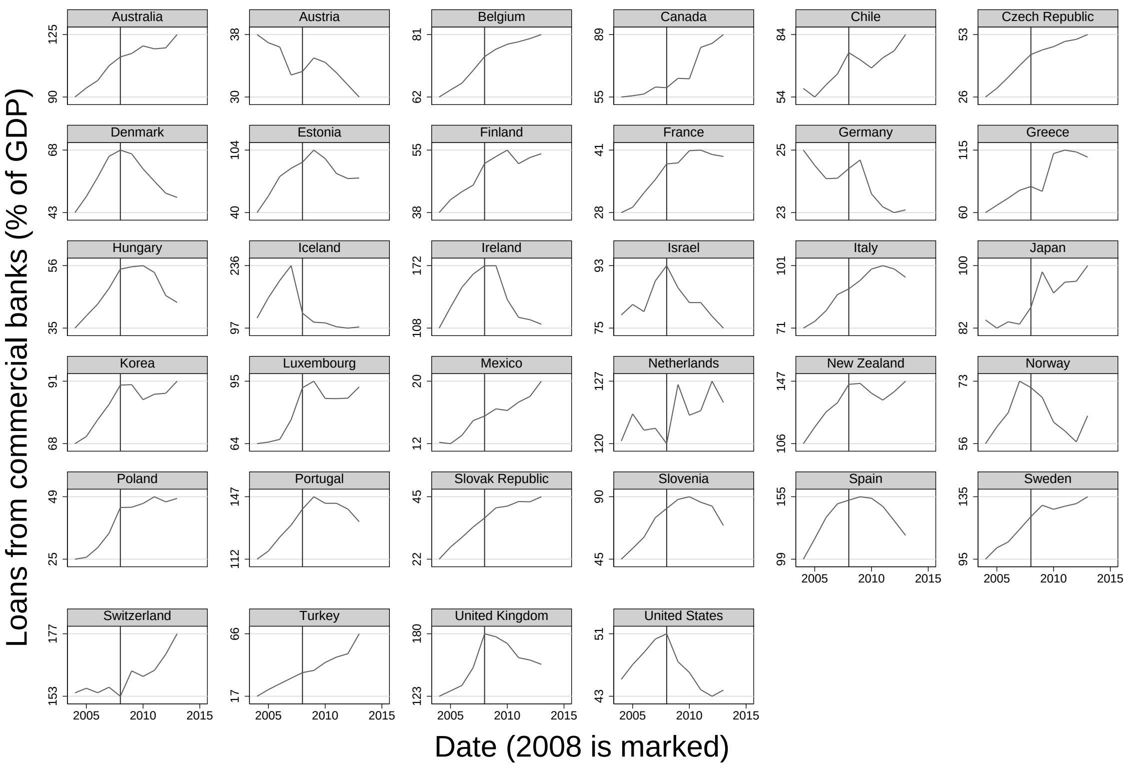
Source: World Bank, *World Development Indicators.*

On this subject, it is worth highlighting two aspects of the statistical evidence supporting the arguments on the relevance of default rates: 1) many OECD economies exhibited significant increases in the proportion of defaulting loans from 2007, that is, in the period when the financial crisis was in its building-up phase, supporting the case made by Hall (2011) on the deepening of frictions during a crisis and 2) as shown in Figure 3.1.1 this deterioration in the banking sectors' assets occurred in an almost synchronised manner, especially in Europe[8], the Pacific (Australia and New Zealand), the US, Canada and Chile.

The fact that this represented a significant decline of the banks' ability to recover loans and, therefore, a worsening of the principal-agency problems in retail credit markets is shown by Figure 3.1.2 where we can observe that most countries in the OECD were experiencing considerable increases in the amounts of loans from private banks before 2007 (so for the majority of countries the sudden increase in defaulting loans was not just a corresponding variation to higher activity as, on the contrary, may have been the case in the Netherlands) and lasted even after 2008 in some cases while, on the other hand, the surge in defaulting loans typically did not start until 2007. The steep upward trends registered in the levels of defaulting loans are indicative of a change in the nature of the relationships in credit markets and, in specific terms, they signalled a significant increase in the frictions within the system at international scale.

Figure 3.1.2: Loans from commercial banks by country.

(as per cent of GDP)



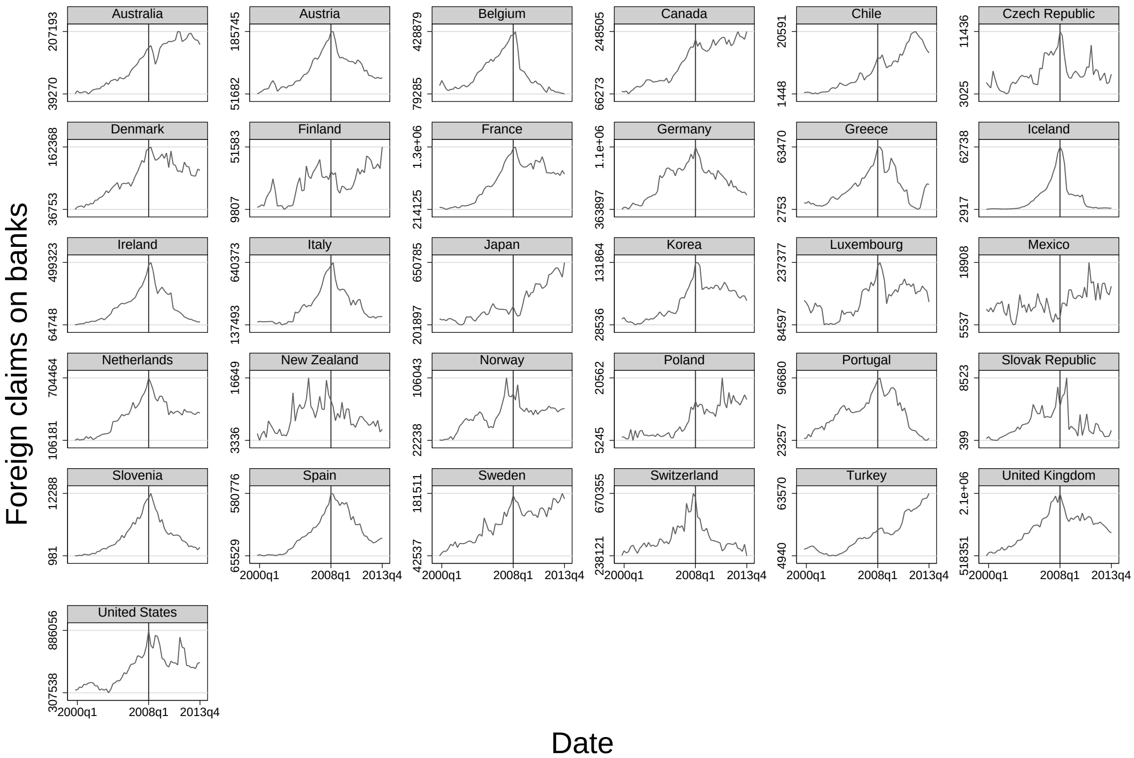
Source: IMF, *Financial Access Survey.*

[8]With Germany and Switzerland being exceptions in terms of both the extent and duration of the degradation this meant to the net worth accounts of the banking system while the Czech Republic, Poland and the Slovak Republic showed little deterioration in this respect.

A *contagion* effect is depicted by the response in transactions like those involved in international interbank credit. In Figure 3.1.3 we notice highly simultaneous patterns of considerable increases in interbank credit up to 2008 when these figures suddenly collapse in an also synchronised way[9]. The first phase, then, corresponds to a bubble in the international interbank markets with the corresponding increased exposure to the conditions in foreign banking systems which, by implication, also includes the financial frictions operating in each one of them.

Figure 3.1.3: Banking foreign claims on other banks by country.

(mill. US dollars.)



Source: BIS, *International Banking Statistics*.

Another important element that is necessary to evaluate the stress conditions in the banking balance sheets is the amount of deposits collected by commercial banks. For these institutions deposits generate a twofold pressure since, on the one hand, they represent banking liabilities and, additionally, they impose an obligation to the banks in the form of interest payments.

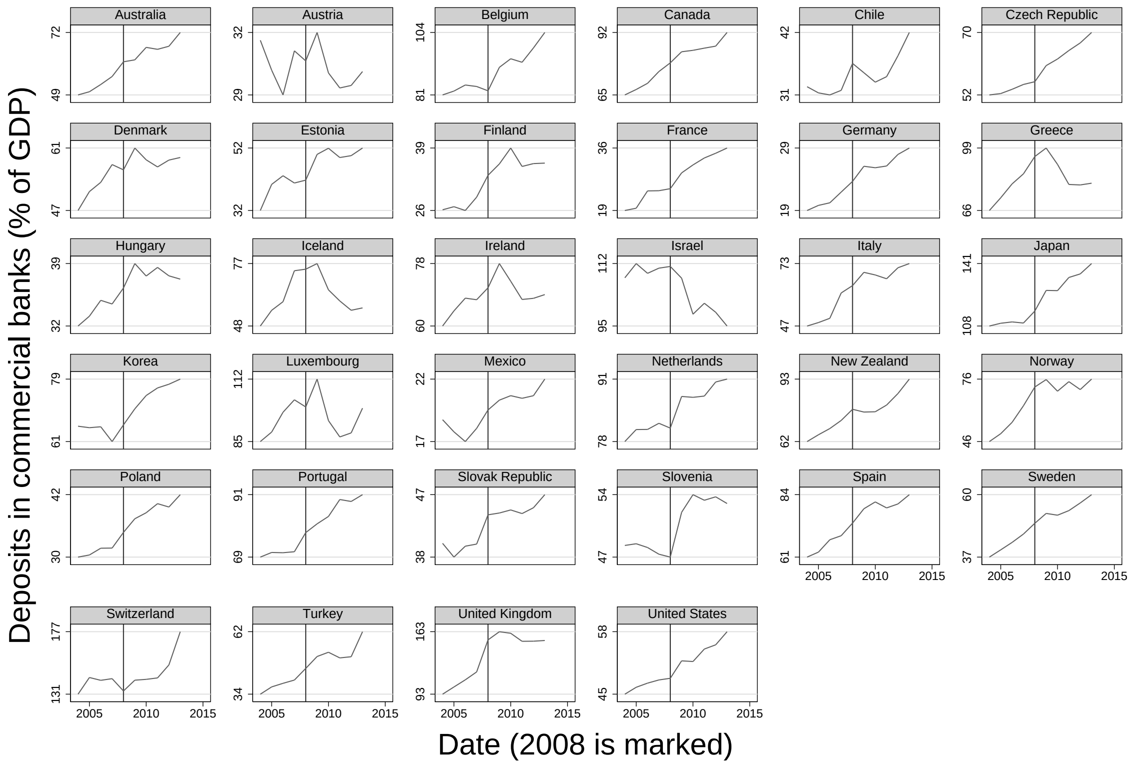
Although raising deposits is an intrinsic part of the functioning of banks, their position as liabilities implies that mounting levels bring about an increased degree of vulnerability too, unless it is balanced with a corresponding increase in assets

[9]Except for the cases of Australia, Canada, Chile, Japan, Mexico, Poland and Turkey.

or capital. In Figure 3.1.4 it is clear that banking deposits in OECD economies exhibited an important increase between 2004 and 2013.

Figure 3.1.4: Outstanding deposits in commercial banks by country.

(as per cent of GDP)



Source: IMF, *Financial Access Survey.*

3.2 Model: financial frictions and the banking sector

A review of the recent literature on the uni-directional and bi-directional transmission channels between the real and the financial sector was compiled by the Basel Committee on Banking Supervision (2011) arguing, as a result, that there are still a number of gaps in the ways macroeconomic models address their study. Among those weaknesses, they found the stylised treatment given to the banking sector in DSGE models, particularly in relation to capital constraints, the risk implications of maturity transformation and the absence of non-simultaneous changes in the borrower's and the bank's balance sheets.

Also, in the context of the studies that followed the 2007-2009 financial crisis, financial frictions (that is, the financial costs derived from asymmetric information or limited contract enforcement problems, for example) occupy an important role in the depiction of the effects of financial systems on macroeconomic performance.

According to Adrian, Colla and Shin (2012), these frictions give rise to different phenomena depending on their origin. On the one hand, demand-side financial frictions affect the creditworthiness of borrowers while frictions on the supply-side operate on the lending conditions for the intermediaries and the intrinsic impacts on the overall economy resulting from the changes they imply on credit markets.

Our analysis, in that sense, concentrates on the supply-side variant of financial frictions, focusing on the role of financial intermediaries to spread impulses through international credit markets. We assume this stance in our modelling as a way to overcome some of the deficiencies in the DSGE literature pointed out by the Basel Committee on Banking Supervision and related studies like Woodford (2010) and Quadrini (2011).

Building on the multi-country platform developed in the previous Chapter, its structure is extended by our linearization of a model based on Gertler and Kiyotaki (2011). Our transformation of their model to an international setting and its addition to our modelling scheme is an innovation that enables the resulting platform to account for key international interactions between credit markets in the presence of financial frictions in the domestic and international credit markets.

Our interest in developing these modifications also relates to recent proposals to incorporate responses to financial volatility in the definition of monetary policy rules (Taylor (2008) and Adolfson et al. (2005, 2007). In this sense, we contribute to the literature by the means of a modelling platform which describes the international transmission of monetary shocks and the resulting externalities to the nominal conditions faced by foreign banking systems.

The financial section of the model incorporates considerations from previous closed-economy models of Christiano and Ikeda (2011) and Cúrdia and Woodford (2010). Furthermore, we integrate original contributions to that previous modelling. We add, for example, novel components to Gertler and Kiyotaki's model as banking reserves with the purpose of reflecting, on the one side, the liquidity conditions of domestic banking systems (with potential impacts on the inter-temporal decisions of bankers) and, additionally, an alternative mechanism for monetary policies to operate through the management of compulsory reserves.

Unlike the previous financial models we build on, our international financially-augmented DSGE platform is able to provide contrasts in the intra and inter-regional responses to monetary shocks in heterogeneous economies participating in international credit markets. In our setting those shocks operate not only through traditional monetary instruments as interest rates but also through the liquidity of the involved banking systems.

Our model of international interactions contributes, through these innovations, to the reduction of the shortcomings indicated by the Basel Committee and previous research in relation to the modelling of financial systems within the DSGE school. It does so by the means of a comprehensive representation of banking systems describing the interactions between the financial intermediaries and the real economy, embracing both a *financial accelerator* effect (Bernanke, Gertler and Gilchrist (1999)) and a detailed account of the relevant variables in banking portfolios that determine the level of operative distress they are subject to. It also embraces the effects of financial frictions in credit markets and the study of liquidity conditions of domestic banks susceptible of being modified by monetary authorities.

In summary, we target to achieve a coherent synergy between three main modelling bodies:

1. Adolfson et al. (2010) provides a robust DSGE macroeconomic framework accounting for nominal and real rigidities in an open-economy context,

2. Gertler and Kiyotaki (2011) complement that setting with a deeper description of financial intermediation with financial frictions and detailed banking portfolios, and

3. Our multi-country extension which takes the strengths of the previous two to an international, interactive environment with heterogeneous economies and international policy-externalities.

3.2.1 Households

A number of economic agents (entrepreneurs, bankers, mutual funds) can be incorporated in this type of modelling in order to account for the financial mechanisms (and frictions) operating in the economy. However, for the sake of simplicity and focus, our main interest is on integrating only a sector of f bankers as a complementary fraction of 1-f workers within each unit-sized household, all sharing the same level of consumption.

Each banker owns a single financial intermediary (i.e. a bank identified by the subscript b) which transfers non-negative dividends $\Pi^b_{h,i,t}$ to the household who maximises expected discounted utility:

$$E_0^h \sum_{t=0}^{\infty} \beta_i^t \left[\zeta_{i,t}^c \ln \left(C_{h,i,t} - b_i C_{h,i,t-1} \right) + A_q \frac{\frac{Q_{h,i,t}}{z_{i,t} P_{i,t}}^{1-\sigma_i^q}}{1-\sigma_i^q} - \zeta_{i,t}^l A_L \frac{\left(l_{h,i,t} \right)^{1+\sigma_i^L}}{1+\sigma_i^L} \right] \tag{3.2.1}$$

subject to:

$$
\begin{aligned}
&M_{h,i,t+1} + \widetilde{S}_{i,t}B^*_{h,i,t+1} + P^c_{i,t}C_{h,i,t}(1+\tau^c_{i,t}) + P^i_{i,t}I_{h,i,t} + P_{i,t}\left(a(u_{h,i,t})\overline{K}_{h,i,t} + P^k_{i,t}\Delta_{i,t}\right) \\
&= R^d_{i,t-1}(M_{h,i,t} - Q_{h,i,t}) + Q_{h,i,t} + (1-\tau^k_{i,t})\Pi^T_{h,i,t} + (1-\tau^y_{i,t})\frac{W_{h,i,t}}{1+\tau^w_{i,t}}l_{h,i,t} \\
&\quad + (1-\tau^k_{i,t})R^k_{i,t}u_{h,i,t}\overline{K}_{h,i,t} + R^*_{i,t-1}\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right)\widetilde{S}_{i,t}B^*_{h,i,t} \\
&\quad - \tau^k_{i,t}\Bigg[\left(R^d_{i,t-1} - 1\right)\left(M_{h,i,t} - Q_{h,i,t}\right) \\
&\qquad\qquad + \left(R^*_{i,t-1}\Phi\left(\frac{A_{i,t-1}}{z_{i,t-1}}, \tilde{\phi}_{i,t-1}\right) - 1\right)\widetilde{S}_{i,t}B^*_{h,i,t} + \left(\widetilde{S}_{i,t} - \widetilde{S}_{i,t-1}\right)B^*_{h,i,t}\Bigg] \\
&\quad + TR_{h,i,t}
\end{aligned}
\tag{3.2.2}
$$

Households earn domestic interests $R^d_{i,t}$ on their bank deposits, which in this context are defined as:

$$d_{h,i,t} = (M_{h,i,t} - Q_{h,i,t}). \tag{3.2.3}$$

Ownership of banks implies that there is an additional source of profits such that total profits are defined as $\Pi^T_{h,i,t} = \Pi_{h,i,t} + \Pi^b_{h,i,t}$ where the second component equals the net transfers paid by banks.

3.2.2 Banks

Banks provide financial intermediation between domestic households (lenders) and domestic firms (borrowers). The financial institutions are assumed to participate in a competitive market receiving domestic households deposits[10], $d_{i,t}$, issuing domestic loans, $s_{i,t}$, borrowing in the interbank market $b_{i,t}$ and holding reserves in the central bank $H_{i,t}$. They incur in country-specific homogeneous unitary costs of intermediation, $\Xi_{i,t}$ and loses from non-recovered loans, $\theta^{def}_i s^h_{i,t}$. Then the cash flow for a financial intermediary is given by:

$$
\begin{aligned}
CF_{b,i,t} = d_{b,i,t} + b_{b,i,t} + R^H_{i,t}H_{b,i,t-1} + (1-\theta^{def}_{b,i})R^l_{b,i,t}Q_{b,i,t-1}s_{b,i,t-1} \\
-(Q_{b,i,t} + \Xi_{i,t})s_{b,i,t} - \Delta H_{b,i,t} - R^d_{b,i,t}d_{b,i,t-1} - R^{ib}_{b,i,t}b_{b,i,t-1}
\end{aligned}
\tag{3.2.4}
$$

with $R^H_{i,t}$ as the interest rate received from the reserves held at the central bank, $R^l_{b,i,t}$ as the lending rate charged by banks, $R^d_{b,i,t}$ the gross interest paid on the deposits raised from households and $R^{ib}_{b,i,t}$ the rate charged in the interbank credit market.

Financial constraints make bankers to accumulate earnings until the former are no longer binding. On the other hand, in order to avoid an indefinitely continuous

[10] A common practice is to assume that the probability of a household to make deposits in its own bank is infinitesimal and therefore negligible.

path of accumulation for bankers, GK modelled a type-switching i.i.d. probability $1-\sigma^b$ of bankers becoming workers by exiting the bank and transferring all the closing proceeds to the household (the non-defaulting closure) while, simultaneously, the same number of workers become bankers (thus keeping f constant). When $(1-\sigma^b)f$ new bankers appear, they are endowed by the household with a starting-business transfer as a fraction of the assets of exiting banks $\xi^b/(1-\sigma^b)$.

There is also a flow of interbank borrowing $b_{i,t}$. In line with our transformation of the model into an international system, interbank credit operates at the international level[11] with banks having access to foreign funds charged with a rate of interest $R^{ib}_{i,t}$ which is country-specific since it depends not only on the external conditions reflected by the relevant calculation of foreign interest rate $R^*_{i,t}$ but also on the risk premium, $\widetilde{\phi}_{i,t}$, that is applicable to each country:

$$\widehat{R}^{ib}_{i,t} = \widehat{R}^*_{i,t} + \widehat{\widetilde{\phi}}_{i,t} \tag{3.2.5}$$

We assume that in this international interbank market there are no quantitative restrictions (banks have access to any amount of funding which may be optimal for them according to their own maximising behaviour solutions). The risk premium follows the process:

$$\widehat{\widetilde{\phi}}_{i,t} = \rho^{\widehat{\widetilde{\phi}}}\widehat{\widetilde{\phi}}_{i,t-1} + \varepsilon^{\widetilde{\phi}}_{i,t} + D^i_r \varepsilon^{\widetilde{\phi}}_{r,t} \tag{3.2.6}$$

where $\varepsilon^{\tilde{\phi}}_{i,t}$ and $\varepsilon^{\tilde{\phi}}_{r,t}$ are country-specific and regional shocks, respectively, and D^i_r is a dichotomous variable which indicates whether country i belongs to region r.

Loans $s_{i,t}$ can only be made against the future profits of non-financial firms located within the same country of the bank and are priced by $Q_{i,t}$ which is expressed in terms of the returns from each unit of present capital the non-financial firms ($Q_{i,t} = P^k_{i,t}$, see CEE and ALLV for further details on this variable). This price is contingent on the total volume of investment opportunities available in the context of the bank. These loans are charged a rate $R^l_{i,t}$ in the retail credit market.

Each bank's resource constraint implies that, at any given period, the value of total loans, $Q_t s_{i,t}$, must equate the sum of the bank's net worth, $n_{i,t}$, interbank borrowings, $b_{i,t}$, and its deposits, $d_{i,t}$ minus the compulsory reserves it holds at the Central Bank, $H_{i,t}$:

$$Q_t s_{i,t} = n_{i,t} + b_{i,t} + d_{i,t} - H_{i,t}. \tag{3.2.7}$$

Our interest on integrating a fractional reserves scheme mostly relates to the

[11] Implicitly, a domestic interbank market is assumed to be subject to the same conditions as the domestic retail market and, therefore, obtaining funds from domestic banks carries the same marginal costs as raising deposits. This assumption may be relaxed for future developments of the model.

analysis of the implications of interventions on the liquidity of banks so, in fact, this component really aims to embrace a broader generic range of policies from regulatory stances to *quantitative easing* (see Joyce M., Tong, M. and Woods, R. (2011) and Cúrdia and Woodford (2009 and 2011)) in our experimental setting. The reserves kept in the Central Bank earn the interest rate $R^H_{i,t}$ subject to policy shocks, $\varepsilon^{R^H}_{i,t}$:

$$\widehat{R}^H_{i,t} = \rho^{R^H}_{i,t} \widehat{R}^H_{i,t-1} + \varepsilon^{R^H}_{i,t} \tag{3.2.8}$$

The amount of reserves is calculated according to a simple rule based on the level of deposits at any given point in time (see Wickens (2011, p. 478)):

$$H_{i,t} = \theta^{bres}_{i,t} d_{i,t} \text{ or, log-linearised: } \widehat{H}_{i,t} = \widehat{\theta}^{bres}_{i,t} + \widehat{d}_{i,t} \tag{3.2.9}$$

with $0 \leq \theta^{bres}_{i,t} \leq 1$ being exogenously determined as a discretionary element of monetary policy:

$$\widehat{\theta}^{bres}_{i,t} = \rho^{br}_i \widehat{\theta}^{bres}_{i,t-1} + \varepsilon^{bres}_{i,t} \tag{3.2.10}$$

In the case of joint determination of the reserves policy in a region (as in the Euro-zone), the discretionary shock applies to all members of the relevant region:

$$\widehat{\theta}^{bres}_{i,t} = \rho^{br}_m \widehat{\theta}^{bres}_{m,t-1} + \varepsilon^{bres}_{m,t} \tag{3.2.11}$$

with m denoting regionally-common variables and parameters.

This way, equations (3.2.7) and (3.2.9) condense into:

$$Q_{i,t} s_{i,t} = n_{i,t} + b_{i,t} + (1 - \theta^{bres}_{i,t}) d_{i,t} \tag{3.2.12}$$

Net worth at a given period t, equals:

$$n_{i,t} = [Z_{i,t} + (1-\delta) Q_{i,t}] (1 - \theta^{def}_i) s_{i,t-1} - R^{ib}_{i,t} b_{i,t-1} + (\theta^{bres}_{i,t} R^H_{i,t} - R^b_{i,t}) d_{i,t-1} \tag{3.2.13}$$

where $Z_{i,t}$ is the dividend payable for the loans made in the previous period and θ^{def}_i measures the fraction of loans issued to firms which is not recovered (due to firms' default).

We can express the banking lending rate, $R^l_{i,t}$, as:

$$R^l_{i,t} = \frac{Z_{i,t} + (1-\delta) Q_{i,t}}{Q_{i,t-1}} \tag{3.2.14}$$

where $Z_{i,t}$ is the marginal product of capital, calculated as:

$$Z_{i,t} = \frac{\alpha Y_{i,t}}{\bar{K}_{i,t-1}\gamma_{i,t}^{cd}} \tag{3.2.15}$$

Profits from banks are transferred to the households when the former close. Since the workers/bankers ratio f is kept constant, new starting endowments, $n_{i,t}^{y}$, must be transferred to bankers resulting in net transfers to households as:

$$\begin{aligned}\Pi_{i,t}^{b} = \left[(1-\delta)Q_{i,t-1} - \Xi_i - \theta_i^{def}\right] s_{i,t-1} + (R_{i,t}^{H} - 1)H_{i,t-1} \\ -R_{i,t}^{b}d_{i,t-1} - R_{i,t}^{ib}b_{i,t-1} - n_{i,t}^{y}\end{aligned} \tag{3.2.16}$$

provided the banker does not default on his liabilities.

However, for the purpose of designing an incentive constraint governing banking default we focus instead on the expected value of the future flow of dividends at the end of period t:

$$V_{i,t} = E_{i,t}\sum_{s=1}^{\infty}(1-\sigma^b)(\sigma^b)^{s-1}\Lambda_{i,t,t+s}n_{i,t+s} \tag{3.2.17}$$

where $\Lambda_{i,t,t+s}$ is a stochastic discount factor equivalent to the inter-temporal rate of substitution of the representative household between periods t and $t+s$.

Following GK, bankers face the choice of ending their banking activity according to a probabilistic rule and handing over all their net assets to the household (no default option) or, alternatively, to default on their banking liabilities and *abscond* with a fraction θ^{bdef} of the bank's assets.

A restriction on the resources flowing to the banks arises from the possibility they have to divert funds to their own households, which is known by the creditors who will, therefore, limit the banks' access to their resources. Diverting funds implies defaulting and closing the bank, leaving a fraction $(1-\theta^{bdef})$ of funds to be reclaimed by creditors. In addition, the *divertable*[12] amount of funds consists of the total gross assets minus a system-wide fraction ω of interbank borrowing, then divertable funds are: $\theta^{bdef}(Q_{i,t}s_{i,t} - \omega b_{i,t})$.

The parameter $0 \leq \omega \leq 1$ reflects the comparative efficiency of banks to recover interbank loans in relation to the depositors' ability to recover their funds ($\omega = 1$ means complete recovery of interbank loans while $\omega = 0$ implies the same rate of recovery as non-financial creditors) and is therefore an indicator of the prevailing relative efficiency in the international banking system.

[12]As opposed to non-divertable funds such as banking reserves which are out of reach for all bankers. This restriction, as we will show later, will impact the banker's valuation of the benefits from defaulting.

Only if $\omega = 1$ frictions in the interbank market would be completely absent and bankers are not able to divert funds borrowed from other banks.

Given this set-up, an incentive constraint governing a banker's decision to divert funds is described as:

$$V_{i,t}(s_{i,t}, b_{i,t}, d_{i,t}) \geq \theta^{bdef}(Q_{i,t}s_{i,t} - \omega b_{i,t}) \tag{3.2.18}$$

where $V_{i,t}(s_{i,t}, b_{i,t}, d_{i,t})$ is the maximised value $V_{i,t}$ given the asset/liability configuration $(s_{i,t}, b_{i,t}, d_{i,t})$[13] and it is given by:

$$\begin{aligned} V_{i,t-1}(s_{i,t-1}, b_{i,t-1}, d_{i,t-1}) = \\ E_{i,t-1}\Lambda_{i,t-1,t}\sum_h \theta^h \Big\{(1-\sigma^b)n_{i,t} \\ + \sigma^b \max_{d_{i,t}} \Big[\max_{s_{i,t},b_{i,t}} V_{i,t}(s_{i,t}, b_{i,t}, d_{i,t})\Big]\Big\} \end{aligned} \tag{3.2.19}$$

Equation (3.2.18) implies that, for a banker to stay in business, the total value of the bank in terms of $V_{i,t}$ has to be greater than the amount obtained from absconding and transferring to the household the divertable resources.

In order to solve the bank's decision problem, GK assume a linear value function:

$$V_{i,t}(s_{i,t}, b_{i,t}, d_{i,t}) = \nu^s_{i,t}s_{i,t} - \nu^b_{i,t}b_{i,t} - \nu_{i,t}d_{i,t} \tag{3.2.20}$$

with $\nu^s_{i,t}$ as the marginal value of assets, $\nu^b_{i,t}$ as the marginal cost of interbank debt and $\nu_{i,t}$ as the marginal cost of deposits.

The optimisation problem is expressed as the Lagrangian:

$$\mathcal{L} = V_{i,t} + \lambda_{i,t}\left[V_{i,t} - \theta^{bdef}\left(Q_{i,t}s_{i,t} - \omega b_{i,t}\right)\right] = (1+\lambda_{i,t})V_{i,t} - \lambda_{i,t}\theta^{bdef}\left(Q_{i,t}s_{i,t} - \omega b_{i,t}\right) \tag{3.2.21}$$

Maximising the value function subject to the incentive constraint (3.2.18) yields the following first order conditions with respect to $d_{i,t}$, $s_{i,t}$ and $\lambda_{i,t}$:

$$(\nu^b_{i,t} - \nu_{i,t})(1 + \bar{\lambda}_{i,t}) = \theta^{bdef}\omega\bar{\lambda}_{i,t} \tag{3.2.22}$$

$$\left(\frac{\nu^s_{i,t}}{Q_{i,t}} - \nu^b_{i,t}\right)(1+\lambda_{i,t}) = \lambda_{i,t}\theta^{bdef}(1-\omega) \tag{3.2.23}$$

$$\left[\theta^{bdef} - \left(\frac{\nu^s_{i,t}}{Q_{i,t}} - \frac{\nu_{i,t}}{1-\theta^{bres}}\right)\right]Q_{i,t}s_{i,t} - \left[\theta^{bdef}\omega - \left(\nu^b_{i,t} - \nu_{i,t}\right)\right]b_{i,t} \leq \nu_{i,t}n_{i,t} \tag{3.2.24}$$

[13]Recall that the amount of banking reserves depends on private deposits.

with $\lambda_{i,t}$ being the Lagrangian multipliers for (3.2.18) which average to $\bar{\lambda}_{i,t} = \sum_h \theta^h \lambda_t^h$ across regions/countries.

As described in GK, the general case where $0 < \omega < 1$ implies that the marginal cost of borrowing is greater than the marginal cost of deposits ($\nu_{i,t}^b > \nu_{i,t}$)

A leverage ratio, $\phi_{i,t}^b$, is calculated as:

$$Q_{i,t}s_{i,t} - b_{i,t} = \phi_{i,t}^b n_{i,t} \tag{3.2.25}$$

with:

$$\phi_{i,t}^b = \frac{\nu_{i,t}^b - \theta^{bdef}\omega}{\theta^{bdef}(1-\omega) - \left(\frac{\nu_{i,t}^s}{Q_{i,t}} - \nu_{i,t}^b\right)} \tag{3.2.26}$$

$$V_{i,t}(s_{i,t}, b_{i,t}, d_{i,t}) = E_{i,t}\Lambda_{i,t,t+1}\Omega_{i,t+1}n_{i,t+1} \tag{3.2.27}$$

where the marginal value of net worth at period $t+1$ is:

$$\Omega_{i,t+1} = 1 - \sigma^b + \sigma^b\left(\nu_{i,t+1} + \phi_{i,t+1}^b\mu_{i,t+1}\right) \tag{3.2.28}$$

By the means of the method of undetermined coefficients:

$$\nu_{i,t}^b = R_{i,t+1}^{ib}E_{i,t}\Lambda_{i,t,t+1}\Omega_{i,t+1} \tag{3.2.29}$$

$$\nu_{i,t} = R_{i,t+1}^d E_{i,t}\Lambda_{i,t,t+1}\Omega_{i,t+1} = \frac{R_{i,t+1}^d}{R_{i,t+1}^{ib}}\nu_{i,t}^b \tag{3.2.30}$$

$$\nu_{i,t}^s = E_{i,t}\Lambda_{i,t,t+1}\Omega_{i,t+1}\left[Z_{i,t+1} + (1-\delta)Q_{i,t+1}\right] \tag{3.2.31}$$

given that:

$$\mu_{i,t}^s = \left(\frac{\nu_{i,t}^s}{Q_{i,t}} - \frac{\nu_{i,t}^d}{1-\theta^{bres}}\right) \tag{3.2.32}$$

shows the excess value of assets over liabilities, and using (3.2.29), (3.2.30), (3.2.31) as well as the definition in (3.2.14) we have:

$$\mu_{i,t}^s = \nu_{i,t}^b\left[\frac{R_{i,t+1}^l}{R_{i,t+1}^{ib}} - \frac{R_{i,t+1}^d}{(1-\theta^{bres})R_{i,t+1}^{ib}}\right] \tag{3.2.33}$$

3.2.3 Banking sector aggregates

Given the described probabilistic type-switching mechanism within households, each period there are both old and young banks which aggregate the sector's net worth as:

$$N_{i,t} = N_{o,i,t} + N_{y,i,t} \tag{3.2.34}$$

with upper case variables reflecting the national sum of banking indicators ($N_{i,t} = \sum_b n_{b,i,t}$, for example) and o denoting old banks and y young banks.

Recalling there is a survival rate for banks given by σ^b, each period the net worth for old banks consists of their earnings on assets discounting their debt payments:

$$N_{o,i,t} = \sigma^b \left\{ [Z_{i,t} + (1-\delta)Q_{i,t}] \, S^b_{i,t-1} + (\theta^{bres}_{i,t} R^H_{i,t} - R^d_{i,t}) D_{i,t-1} - R^{ib}_{i,t} B^{ib}_{i,t-1} \right\} \tag{3.2.35}$$

In turn, the initial net worth of young banks is given by a fraction $\frac{\xi^b}{1-\sigma^b}$ taken from the closing net assets of exiting banks and transferred to them by households:

$$N_{y,i,t} = \xi^b \left\{ [Z_{i,t} + (1-\delta)Q_{i,t}] \, S^b_{i,t-1} \right\} \tag{3.2.36}$$

Therefore, the (national) aggregate amounts to:

$$\begin{aligned} N_{i,t} = {} & R^l_{i,t}(\sigma^b + \xi^b) Q_{i,t-1}(1-\theta^{def}_i) S^b_{i,t-1} \\ & - \sigma^b \left[(R^d_{i,t} - \theta^{bres}_{i,t} R^H_{i,t}) D_{i,t-1} + R^{ib}_{i,t} B^{ib}_{i,t-1} \right] \end{aligned} \tag{3.2.37}$$

Aggregation of assets and liabilities for the banking sector yields:

$$Q_{i,t} S^b_{i,t} = N_{i,t} + (1-\theta^{bres}_{i,t}) D_{i,t} \tag{3.2.38}$$

indicating the total capacity of the banking sector to issue loans in the national retail market.

3.2.4 The Central Bank

Central banks exogenously decide on the interest rate paid on banking reserves $R^H_{i,t}$ and the overnight funds interest rate $\widehat{R}_{i,t}$, the latter according to a spread-adjusted Taylor rule defined on the basis of responses to deviations of inflation, output, the exchange rate and interest rate spreads.

$$\begin{aligned} \widehat{R}_{i,t} = {} & \rho^R_i \widehat{R}_{i,t-1} + (1-\rho^R_i) \left(\widehat{\overline{\pi}}^c_{i,t} + r^\pi_i \left(\hat{\pi}^c_{i,t-1} - \widehat{\overline{\pi}}^c_{i,t} \right) + r^y_i \hat{y}_{i,t-1} + r^e_i \hat{e}_{i,t-1} \right) \\ & + r^{\Delta\pi}_i \Delta\hat{\pi}^c_{i,t} + r^{\Delta y}_i \Delta\hat{y}_{i,t} + r^{\widehat{\widetilde{\phi}}}_i \widehat{\widetilde{\phi}}_{i,t} + \varepsilon^R_{i,t} + \sum_{r=1}^{G} D^r_i \varepsilon^R_{r,t} \end{aligned} \tag{3.2.39}$$

Additionally, as regulatory bodies, they set the proportion of deposits to be held as compulsory reserves, $\theta^{bres}_{i,t}$. This feature of the model gives us the opportunity to look into the effects of the monetary authority's intervention on the liquidity of banks which constitutes a generic example of policies adopted by central banks when the zero-lower-bound has been reached.

Our modified configuration of the monetary policy rule finds its origins in Taylor (2008) who suggested to adjust for what constitutes a specific market measure of financial stress in the U.S. as the difference between the London interbank offer rate (LIBOR) and the overnight federal funds rate (overnight index swap, OIS). The reasoning behind the inclusion of such element into the non-discretionary component of monetary policy relies on the impact of counterparty (default) risks in the financial sector on aggregate spending and represents a link between monetary policy and the prevailing financial conditions.

Given our open, international framework, we chose an internationally-common reference instead and compare the macroeconomic leading rate[14], $\widehat{R}_{i,t}$ to the United States 3-month Treasury Bills.

3.3 Empirical assessment

In order to assess the international impacts of policy shocks implying variations in the conditions of banking systems in heterogeneous countries we perform simulations of the model with the parameterisation obtained in Chapter 1 via regional estimations and additional relevant data. In these exercises we make use of the same regional definitions within the OECD in an attempt to make the most of the information and estimations on their heterogeneities.

Keeping a supply-side focus on the credit markets, we mainly study the outcomes of shocks in terms of their effects on relevant interest rates and banking operative indicators. These elements are useful for the evaluation of the prevailing conditions faced by intermediaries both at the domestic and the international fronts. This constitutes an innovative framework

3.3.1 Solution approach and data

In line with our empirical application in the previous Chapter, we make use of a partial information approach to the solution and simulation of the model. For the financially-extended framework, however, we add to the list of observable variables given in Chapter 2, commercial banks loans $\widehat{S}^{b}_{i,t}$, liabilities with non-banks $\widehat{D}_{i,t}$ and

[14]In contrast to other analysed rates which behaviour is associated to the conditions in the banking system, this rate relates to the actual productivity of capital in the economy and is therefore closer to the relevant macroeconomic developments.

interbank liabilities $\widehat{B}^{ib}_{i,t}$. This way, the group of variables that defines the *observable* information set at period t for households, firms and bankers, $\mathbf{\Omega}^{PF}_{i,t}$, is:

$$\mathbf{\Omega}^{PF}_{i,t} = \left\{ \widehat{\pi}_{i,t},\ \widehat{w}_{i,t},\ \widehat{c}_{i,t},\ \widehat{i}_{i,t},\ \widehat{E}_{i,t},\ \widehat{y}_{i,t},\ \widehat{\pi}^{c}_{i,t},\ \widehat{\tilde{\phi}}_{i,t},\ \widehat{S}^{b}_{i,t},\ \widehat{D}_{i,t},\ \widehat{B}^{ib}_{i,t} \right\}$$

The additional data consists of:

- Bank lending to the private sector, index 2005Q1=100 (`loans`)

$$\widehat{S}^{b}_{i,t} = \Delta \ln \left(\texttt{loans}_{i,t} \right)$$

  Data from national central banks via Datastream©.

- Outstanding Bank liabilities to non-banks, index 2005Q1=100 (`dep`)

$$\widehat{D}^{b}_{i,t} = \Delta \ln \left(\texttt{dep}_{i,t} \right)$$

  Data from Bank for International Settlements via Datastream©.

- Outstanding Bank liabilities to banks (international bank positions, all BIS reporting countries), index 2005Q1=100 (`ib`)

$$\widehat{B}^{b}_{i,t} = \Delta \ln \left(\texttt{ib}_{i,t} \right)$$

  Data from Bank for International Settlements via Datastream©.

We assume the domestic observability of these additional variables as highly feasible on the basis of their inclusion in the banking balance sheet accounts such that other bankers and private agents can have access to the financial conditions they depict. They are also valuable for providing a succinct assessment of the prevailing stress-conditions of each national banking system in their interaction with both domestic and foreign agents within the regional systems we analyse.

All series have been seasonally adjusted by the means of the US Census Bureau's X-12-ARIMA algorithm (see Ladiray and Quenneville (2001)).

The parameters for private default, θ^{def}_{i}, were calculated using data on the percentage of non-performing loans out of total gross private bank loans between 1997 and 2014 (the full list is in Appendix I). The information source is World Bank, *World Development Indicators*.

3.3.2 Shock simulation: NAFTA

In this set of exercises we study the comparative outcomes of policy shocks on nominal indicators reflecting the operative conditions of the respective banking sectors.

Unlike the main emphasis in GK, where the interbank frictions are either full ($\omega = 0$) or absent altogether ($\omega = 1$), in our model's variant the solution and empirical applications present a non-extreme case for the frictions. This means the banks operate in the context of partial *divertability* of interbank loans ($0 < \omega < 1$).

In addition to being a more realistic scenario, our simulations benefit from such a setting in that the impacts of shocks are adjusted for the presence of both domestic frictions (θ^{bdef}) as well as those related to the international credit market (ω)[15].

Unlike the vast majority of parameters in the model, which are treated as country or regional-specific, a single measurement is used for all the countries ($\omega = 0.10$) in an attempt to reflect the global conditions in the international financial markets. This decision is better understood as the setting of a common standard for the self-regulation imposed by interbank markets in the form of loan-recovery discipline.

Similarly, θ^{bdef} is also set at a common level with the intention of concentrating on the heterogeneities contained in the macroeconomic and financial sections of the model. This avoids unnecessary confusion during the international comparison of results and, most importantly, allows to focus on the cross-sectional heterogeneities between the relative valuations of banking assets and liabilities[16].

Spillovers of a monetary policy shock

In first instance, we evaluate the international repercussions on the conditions of credit markets in Mexico and Canada of a one standard error monetary policy shock in the US ($\varepsilon^{R}_{US,t}$). As is characteristic of models with financial intermediation the variety of interest rates implies that domestic monetary policies face the pressure from privately-set dynamic adjustments and, equally, from their associated variability given the eventual impact on the patterns of consumption and investment.

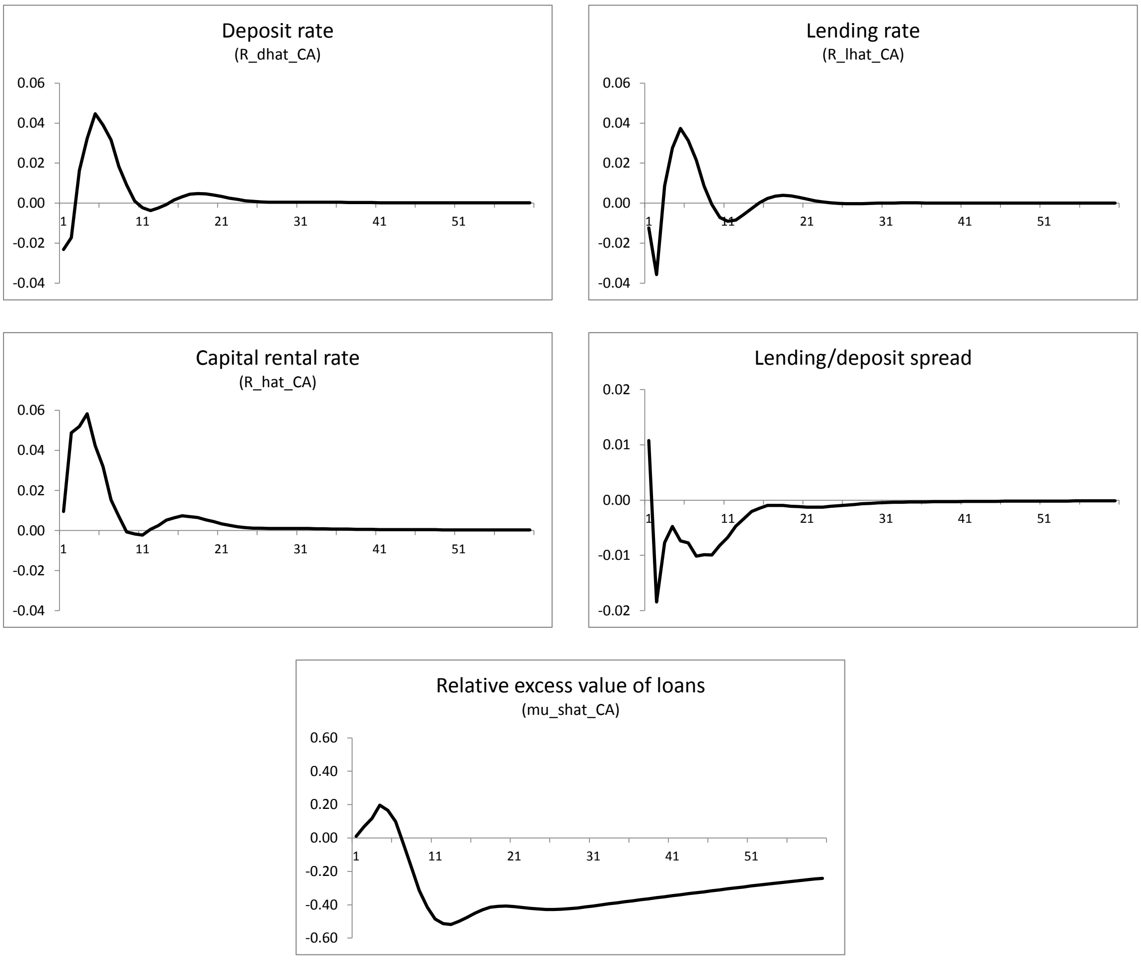
In addition to the description of the externality-effects on the main rates we include a summary indicator in the form of the lending/deposit spread which provides a measurement of the net consequences of the shocks which also translates into implications for the variations in liquidity between agents.

The international outcomes of the shock are described in Figures 3.3.1 and 3.3.2. For Canada, despite some periods of initial decreases in the deposit and lending rates, the main effect of the shock is an increase in the considered rates as in the relative excess value of loans over deposits and interbank loans (represented by $\mu^{s}_{i,t}$).

[15]Recall that banks mainly have access to funds from either domestic deposits or international banking loans.

[16]In this case, the implications of a common parameter are that bankers are homogeneous across countries in their defaulting technologies (or mechanisms). In other words, our model does not account for international differences in the efficiency of bankers to divert funds.

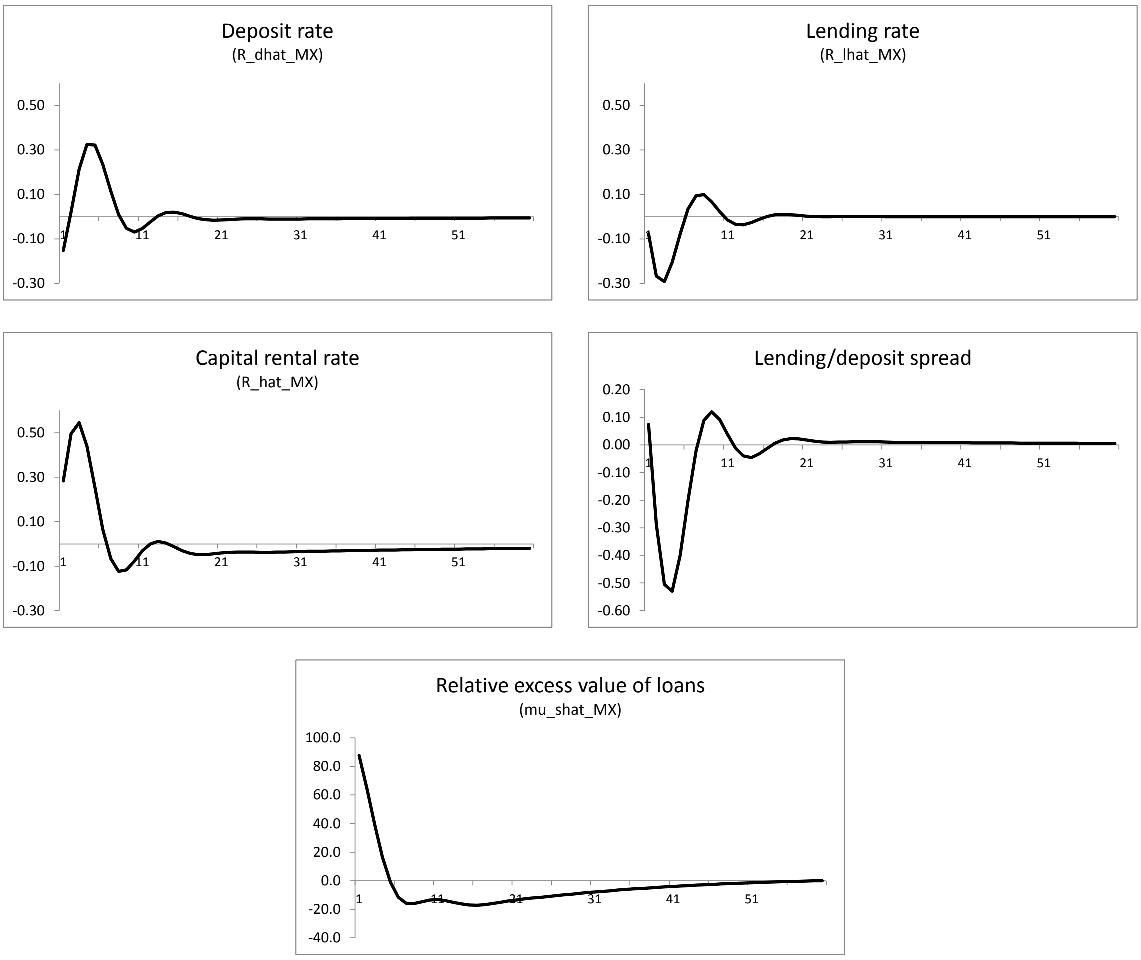
Figure 3.3.1: International effects of a monetary policy shock in the US, Canada



From the point of view of Canadian banks, loans become attractive in the immediate aftermath of the shock in the US (as revealed by the increase of their relative excess value) but, as the effects between rates diverge, the spread becomes negative and the relative value of loans follows a substantial decline. The implications for the Canadian banking system, then, are reflected in the incentives to contract the levels of private credit in the economy.

In comparative terms, Mexican rates show a much larger responsiveness to the shock and, particularly, a greater dissimilitude between the effects on the deposit and lending rates which leads to a heavy plunge of the spread counteracting the initial increase of the relative value of loans. The main impact on Mexican banks is concentrated over a shorter period but is undoubtedly deeper imposing, therefore, a substantial tightening of the domestic credit conditions.

Figure 3.3.2: International effects of a monetary policy shock in the US, Mexico

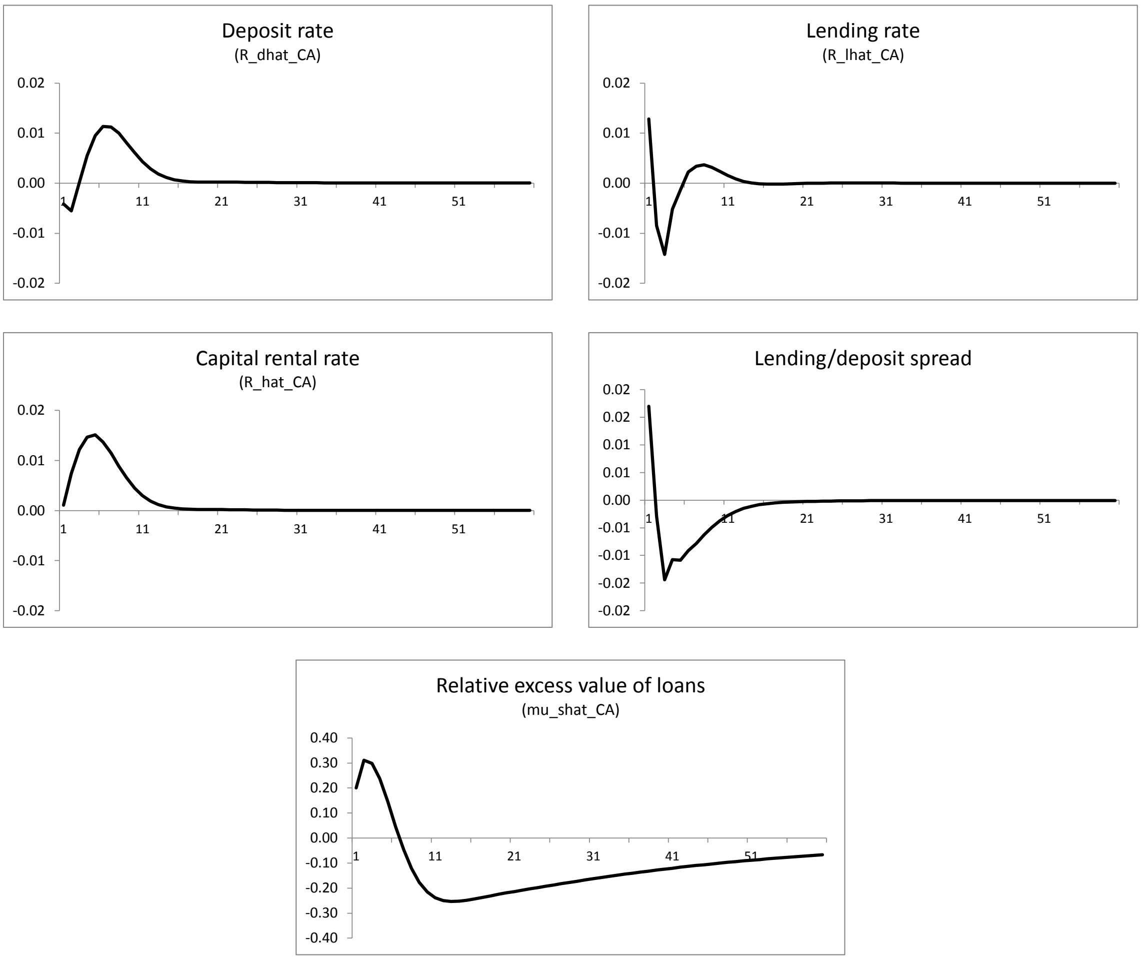


Fractional reserves shock

With the purpose of analysing the effects of policies operating through changes in the liquidity of banks, we explore the international effects of a one standard error shock to the amount of compulsory reserves in the United States ($\varepsilon^{bres}_{US,t}$). This shock effectively represents a *quantitative* restriction on the available resources for banking loans but, at the same time, its effect is akin to a re-capitalisation of the intermediaries reflected by an increase in their net worth (see Eq. (3.2.7)).

From Figures 3.3.3 and 3.3.4 we confirm the presence of an international effect in the sense that the interest rates in both Canada and Mexico display spillovers of the policy adopted in the US. The specific outcomes for each country are dissimilar mainly in terms of their comparative magnitude and, therefore, of the conditions of credit availability each one experiences after the quantitative foreign shock.

Figure 3.3.3: International effects of a shock to compulsory reserves in the US, Canada

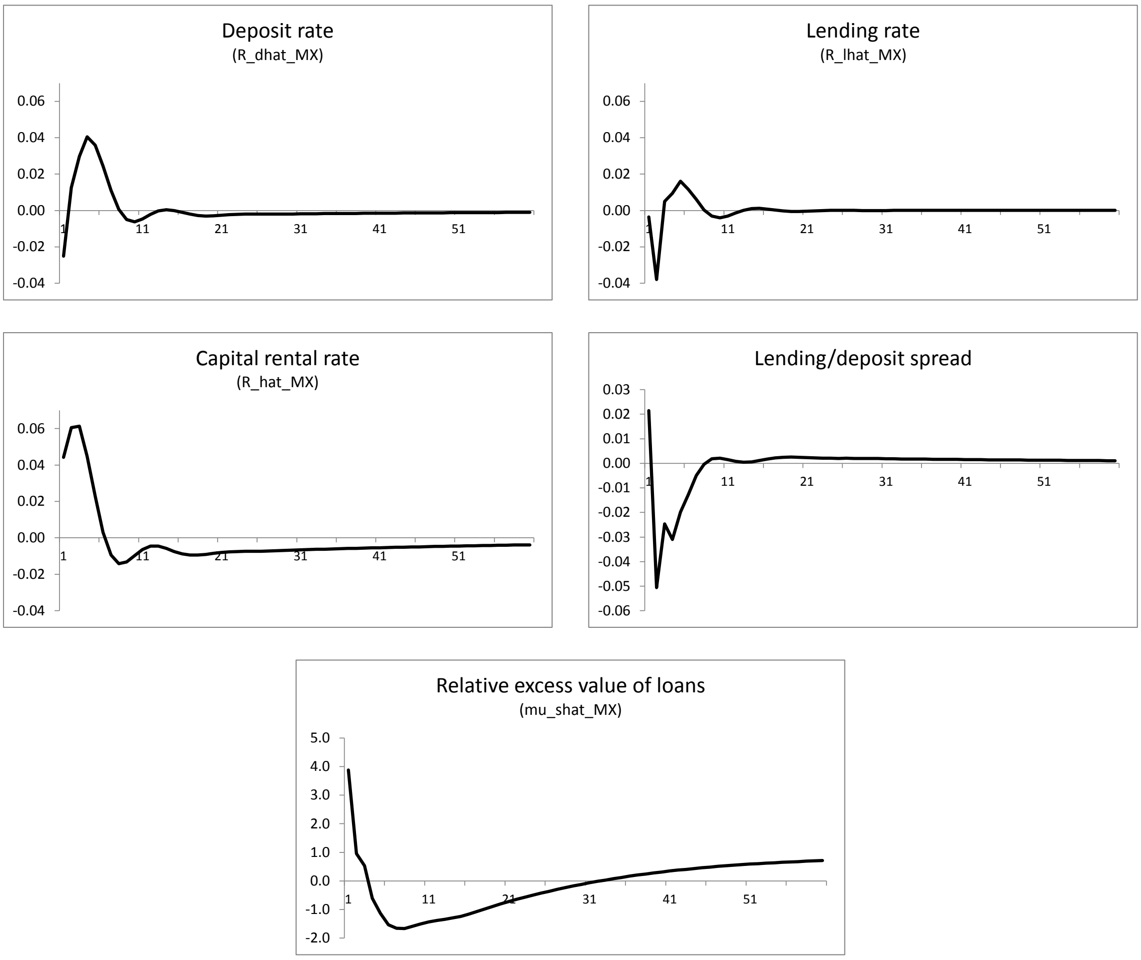


In Canada the most immediate impact can be seen on the lending rates which are subject to a considerable de-stabilising effect during the following three quarters and therefore the deposit/lending rate spread contributes to accentuate the liquidity imbalances between agents in the economy.

Although the effect on lending rates in Mexico is markedly different (lending rates fall in this case), a more responsive deposit rate leads in the end to a similar pattern in the lending/deposit rate spread.

The sluggish recovery of loans to the private sector results in the eventual decline of net worth in the domestic banking system after the shock has mostly lost its main impact.

Figure 3.3.4: International effects of a shock to compulsory reserves in the US, Mexico



The lack of dynamism in loans is a known problem of the Mexican banking sector. In words of Sánchez (2014):

> "In spite of higher loan growth, bank penetration, as measured by the ratio of private-sector credit to GDP, continues to be low, even compared to other nations at an equivalent stage of economic development. Something similar can be said about total domestic financing to the private sector, which amounts to less than one-third of GDP."

Contrastingly, the adjustments in deposits and interbank borrowing are considerably larger and immediate although relatively short-lived. These conditions impose larger variability (and uncertainty) on banking accounts which only harms its prospects for longer-term capitalisation. In terms of the model this also means a comparatively higher proclivity to occurrences of banking default.

In general terms, the shock in the US initially makes loans more expensive in the receiving economies but, as it loses momentum, their spreads eventually become negative and the asynchronous adjustments between rates makes the return to equilibrium to take longer. This benefits depositors in the aggregate as is also shown in Figures 3.3.5 and 3.3.6 while the amount of loans subsequently declines.

The phase with negative spreads impacts the excess value of loans over banking liabilities which, in conjunction with a decrease in interbank borrowing implies that the strengthening in the macro-prudential stance in the US also results in a period of re-capitalization (as represented by the increase in net worth) in the banking systems at the regional level.

This occurs, however, at the cost of harsher conditions for the banks in Canada and Mexico which hinders their potential contributions to the macroeconomy. This way, we find that macro-prudential policies aimed at influencing the liquidity of banks also display international spillovers which may, in effect, start a spiral of credit contraction in the regional financial system.

Figure 3.3.5: International effects of a shock to compulsory reserves in the US, Canada

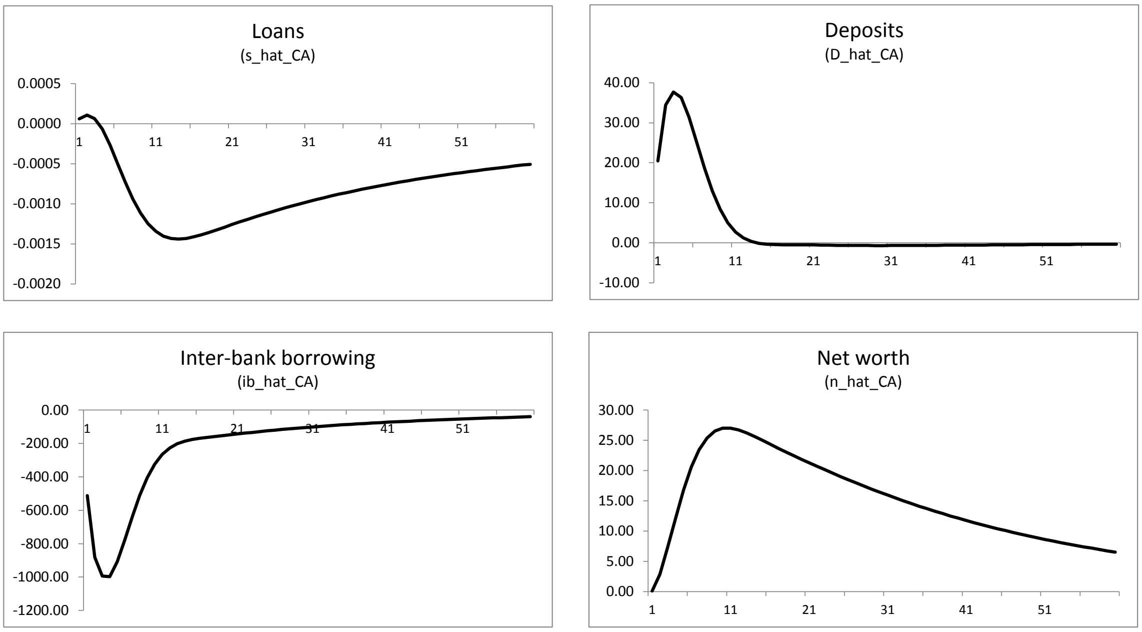
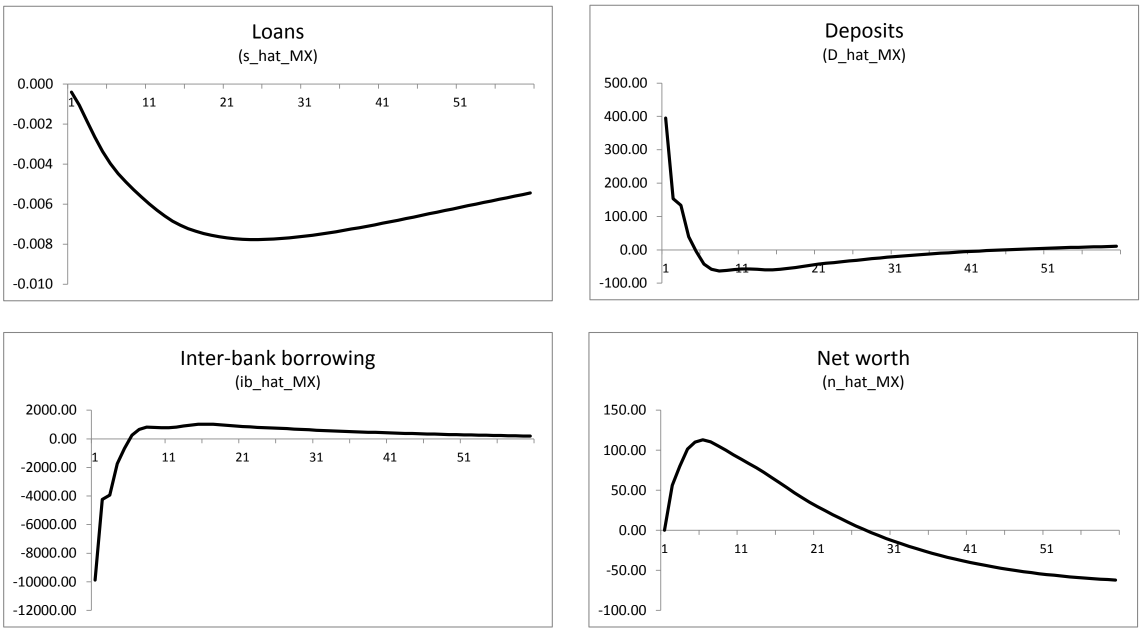


Figure 3.3.6: International effects of a shock to compulsory reserves in the US, Mexico



3.3.3 Shock simulation: Asia-Pacific

Turning our attention to the application of similar exercises on the Asia-Pacific region[17], we start with a monetary policy shock in the regional leading economy: Japan ($\varepsilon^{R}_{JP,t}$).

Spillovers of a monetary policy shock

Simulating a monetary policy shock in Japan, we observe that Australian banks suffer a one-quarter sharp decrease in the lending rate which is the main driver for a similarly short-lived negative spread. The impact, however, has long-lasting implications for the banking operative accounts, particularly for the asset/liability valuation which reflects a much slower recovery mainly explained by the relative persistence in the interbank rate as it punishes the foreign liabilities.

A particularity of the impact on Australia is that the capital rental rate follows a downward path which drags down the deposit rate extending, as a consequence, the time frame for the positive deviations of the spread. This makes credit more expensive to users for longer (twice the number of quarters with positive deviations

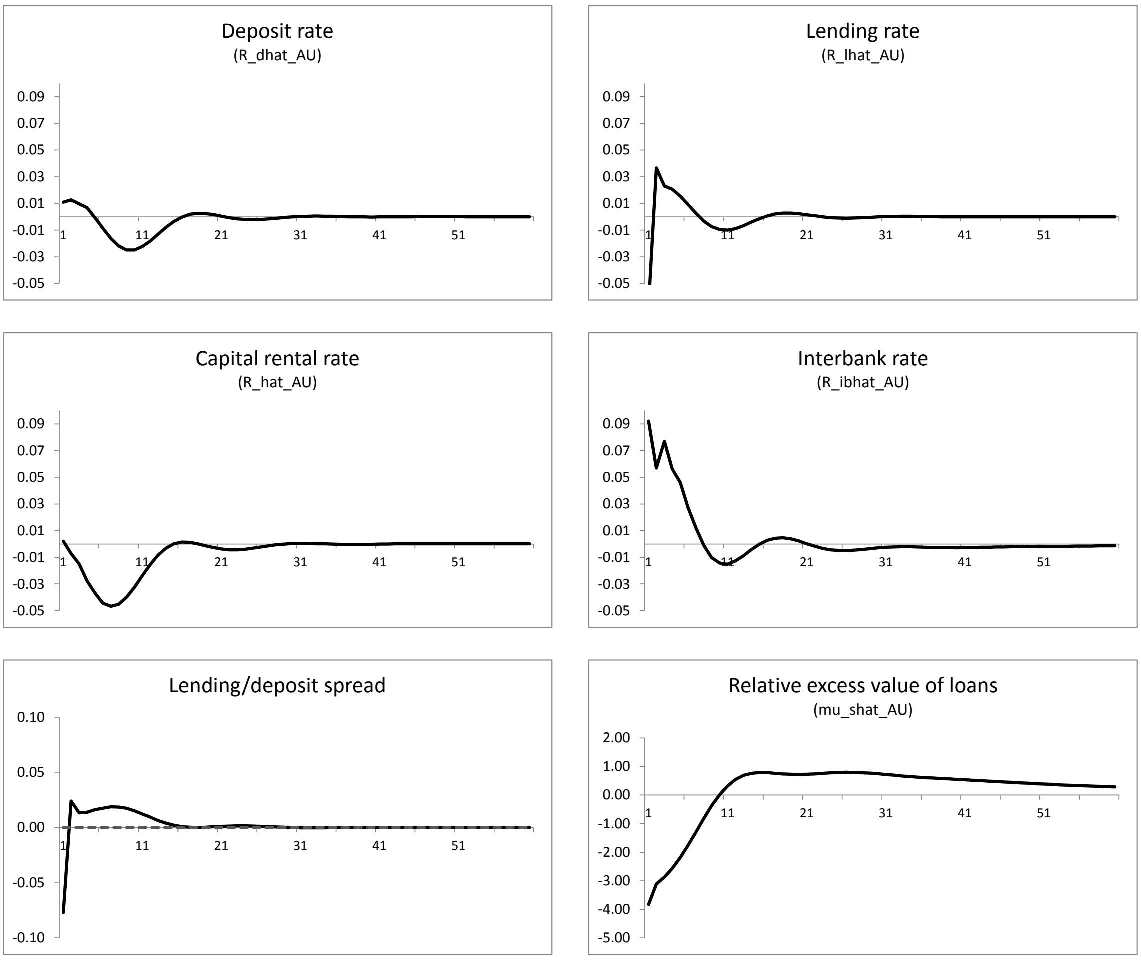
[17]For our empirical purposes, this region is formed by Australia, Japan and Korea (Rep.) but, given its influence on the region (as reflected by international weights) we also included the US economy in the calculation of the solution for this model.

of the lending rate during the main impact of the shock) at the same time depositors suffer the effects of reduced interest earnings.

Contrasting results appear in the case of Korea as the shock generates considerably larger divergences in the rates, especially on the lending rate which reflects in a single quarter jump of the spread equivalent to a deviation from its steady state of 22.5 per cent. This way, the Korean banking system displays the consequences of closer ties with the Japanese economy (the Korean financial weight to Japan is more than twice as large as the Australian equivalent).

The subsequent slump in the lending rate and turning of the spread into negative figures implies an over-compensating fall in the relative value of loans which carries, by implication, lower incentives for the intermediaries to engage in the provision of loans to the domestic private sector.

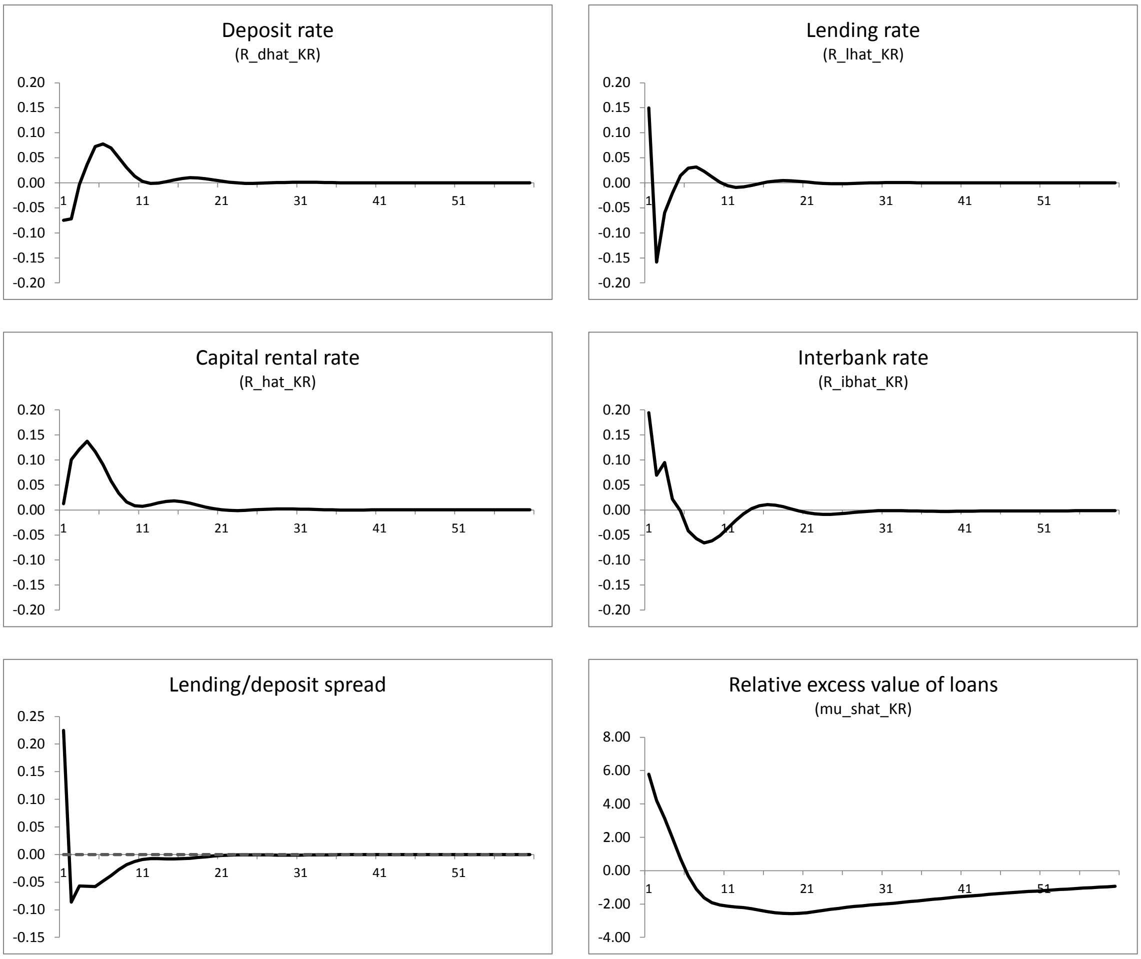
Figure 3.3.7: International effects of a monetary policy shock in Japan, Australia



Under these conditions financial intermediaries assume more passive stances and restrict their activities to those of depository institutions in detriment of the inter-temporal exchanges of liquidity required by the general economy.

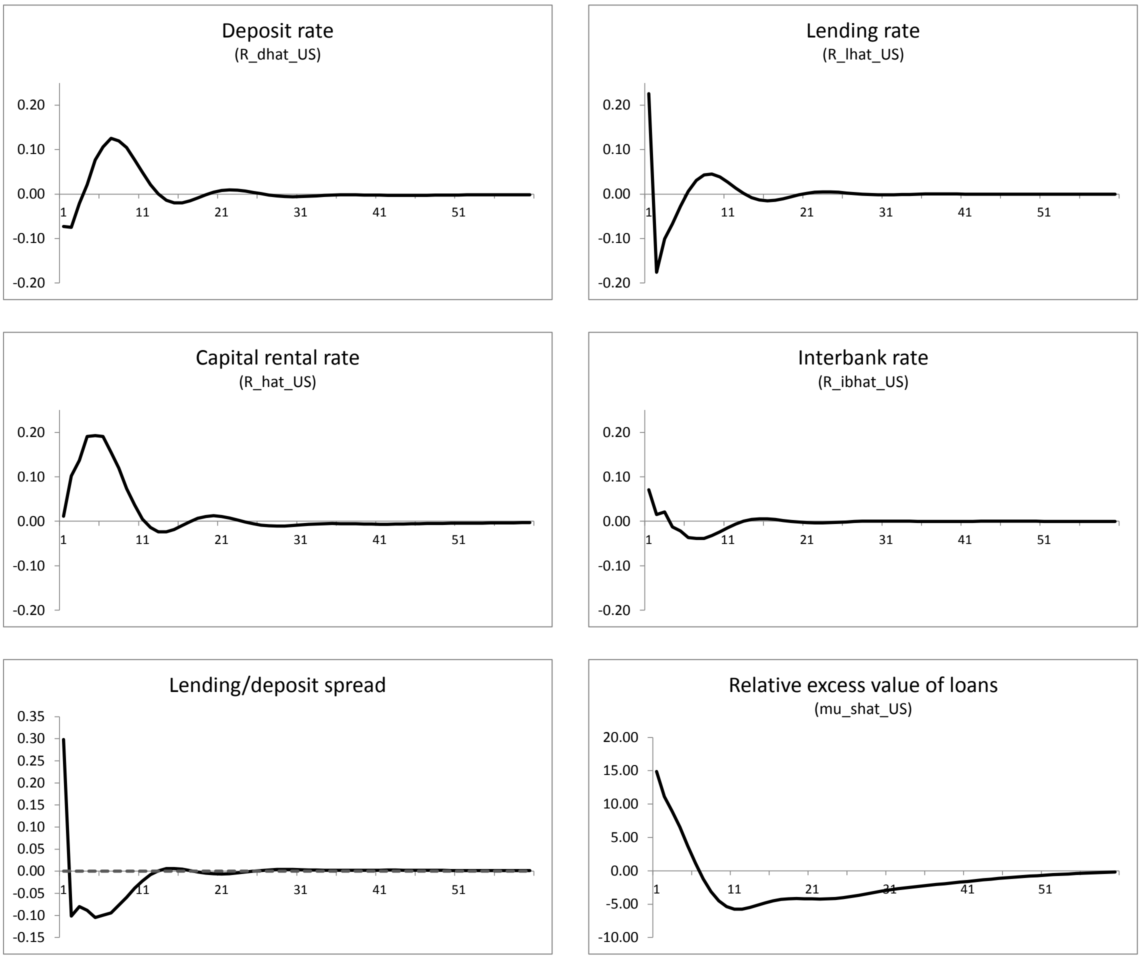
Thus the monetary shock in Japan has far-reaching consequences for the financial sector of a smaller economy as Korea and, although it pushes up main reference rates as the rental rate of capital followed (with delay) by the deposit rate, the imbalances brought by the adjustments in lending rates have long-term effects on the operative decision-making of banks who are likely to be inclined to reduce the amount of loans they provide. Even further, this decline in the relative valuation of loans increases the proclivity of bankers, according to the incentive constraint, to default even in face of a constant parameter θ^{bdef} (i.e. no domestic deteriorations of banking incentives) explicitly demonstrating the relevance of the international markets and policies to the performance of their domestic counterparts.

Figure 3.3.8: International effects of a monetary policy shock in Japan, Korea



As another example of international spillovers, this time at inter-regional level, we also observe reactions of interest rates in the United States from the Japanese shock. This comes as a result of the economic and financial relevance of the Japanese economy to the US given that, for the latter, in the context of the OECD Japan represented the fifth counterpart in relation to foreign investment exchanges between 2009 and 2012 and the third trade partner between 1990 and 2012.

Figure 3.3.9: International effects of a monetary policy shock in Japan, United States



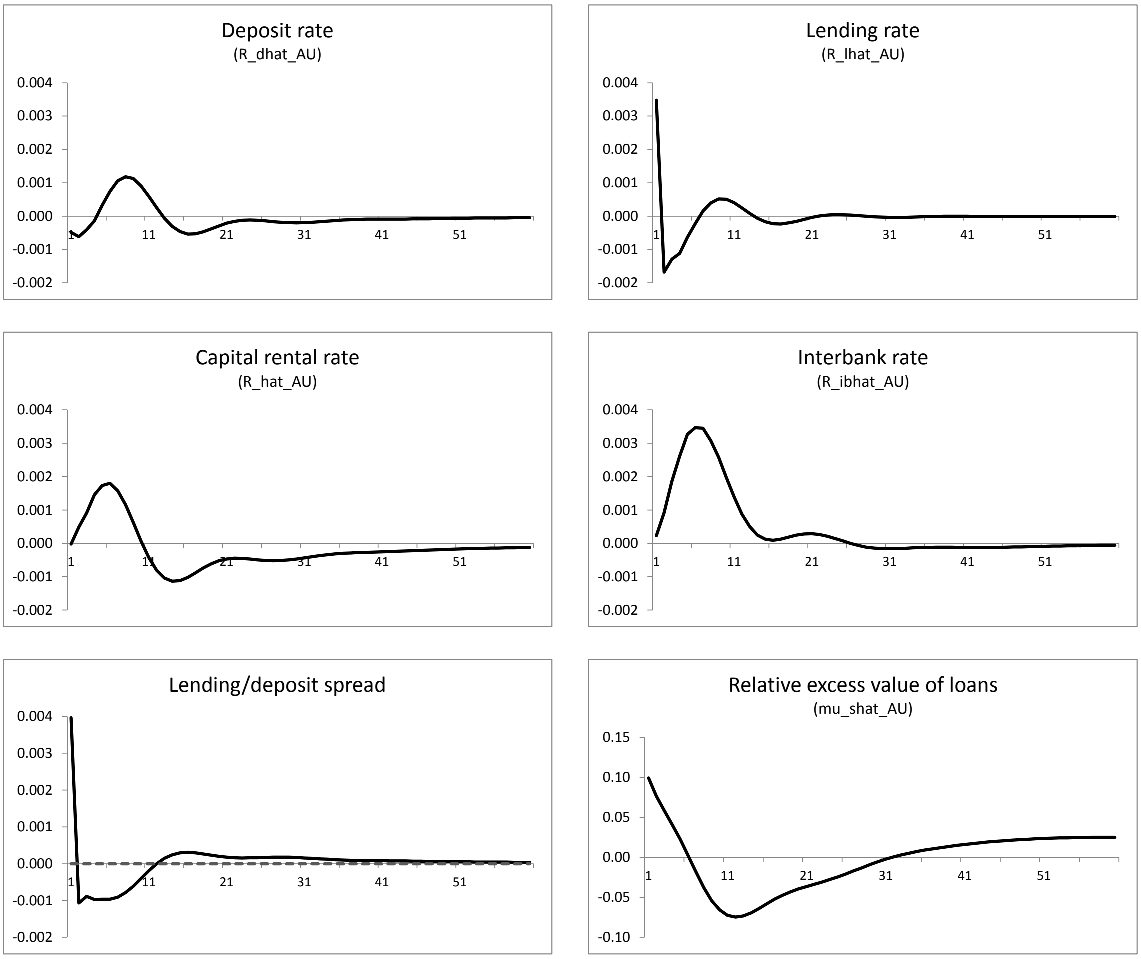
Such economic and financial relationship contributes to explain the disturbances in the interest rates in the US after the shock, most importantly in the case of the lending rate which displayed a significant sensitivity to this policy.

A deflationary spillover to the US drives a negative deviation in the deposit rate and exacerbates the immediate increase of the spread. The subsequent decline in the lending rate, in turn, leads the spread to generate higher incentives to save and, simultaneously, makes spending cheaper (at least its credit-related fraction). The overall outcomes of the inter-regional shock, then, point towards a period of increased activity in the US although it also brings about less favourable conditions for the operation of its banking system given the decline of the relative value of loans.

Fractional reserves shock

An alternative policy shock is simulated in the form of an increase in the reserves requirement set by the Bank of Japan, ($\varepsilon_{JP,t}^{bres}$). Its international effects vary across recipient economies in the simulation[18].

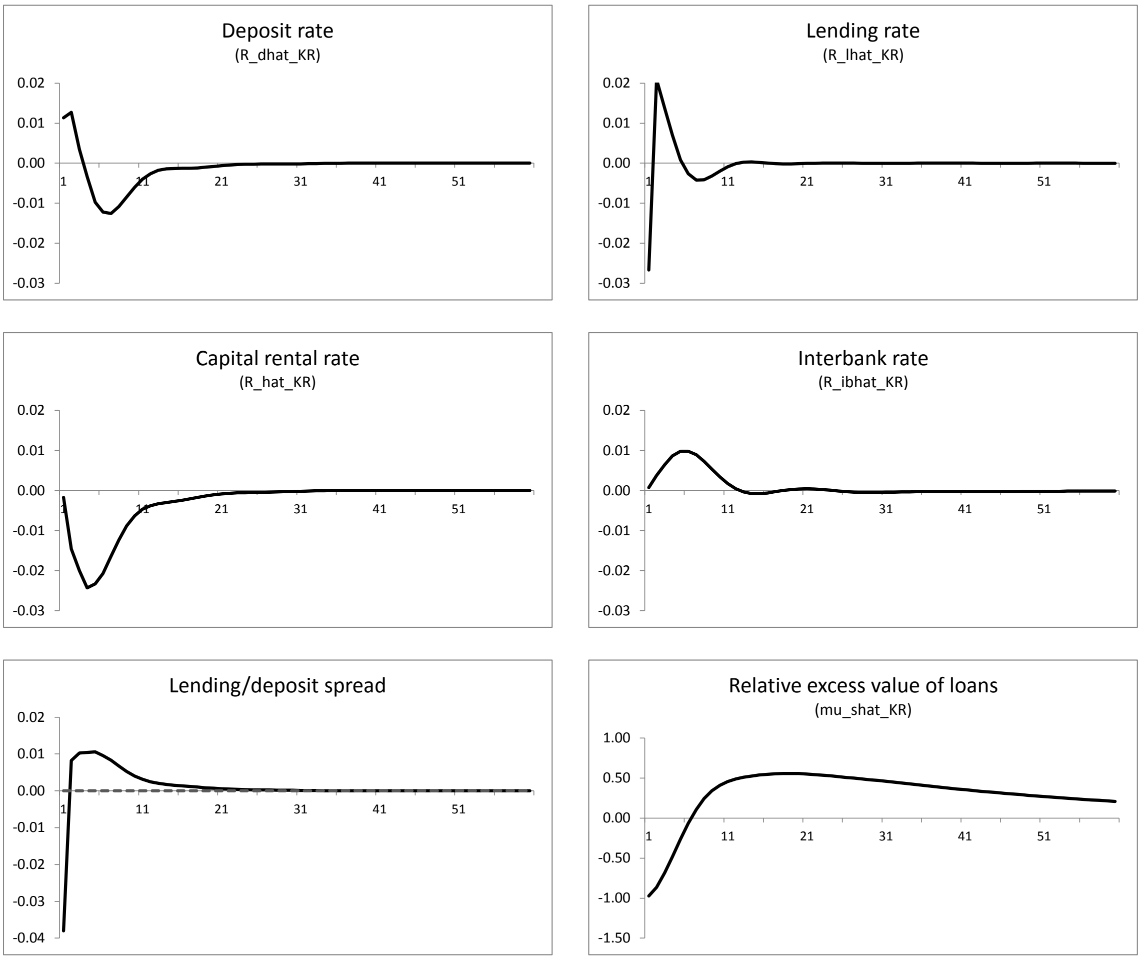
Figure 3.3.10: International effects of a shock to compulsory reserves in Japan, Australia



In the case of Australia, the largest impact occurs on the lending rate, initially increasing the lending/deposit rate spread although, in comparative terms, even at its maximum the impact is the smallest among this set of spillovers.

[18] As in the previous exercise, the model was subject to a simulation of the shock while containing the following countries: Australia, Korea, Japan and the United States.

Figure 3.3.11: International effects of a shock to compulsory reserves in Japan, Korea

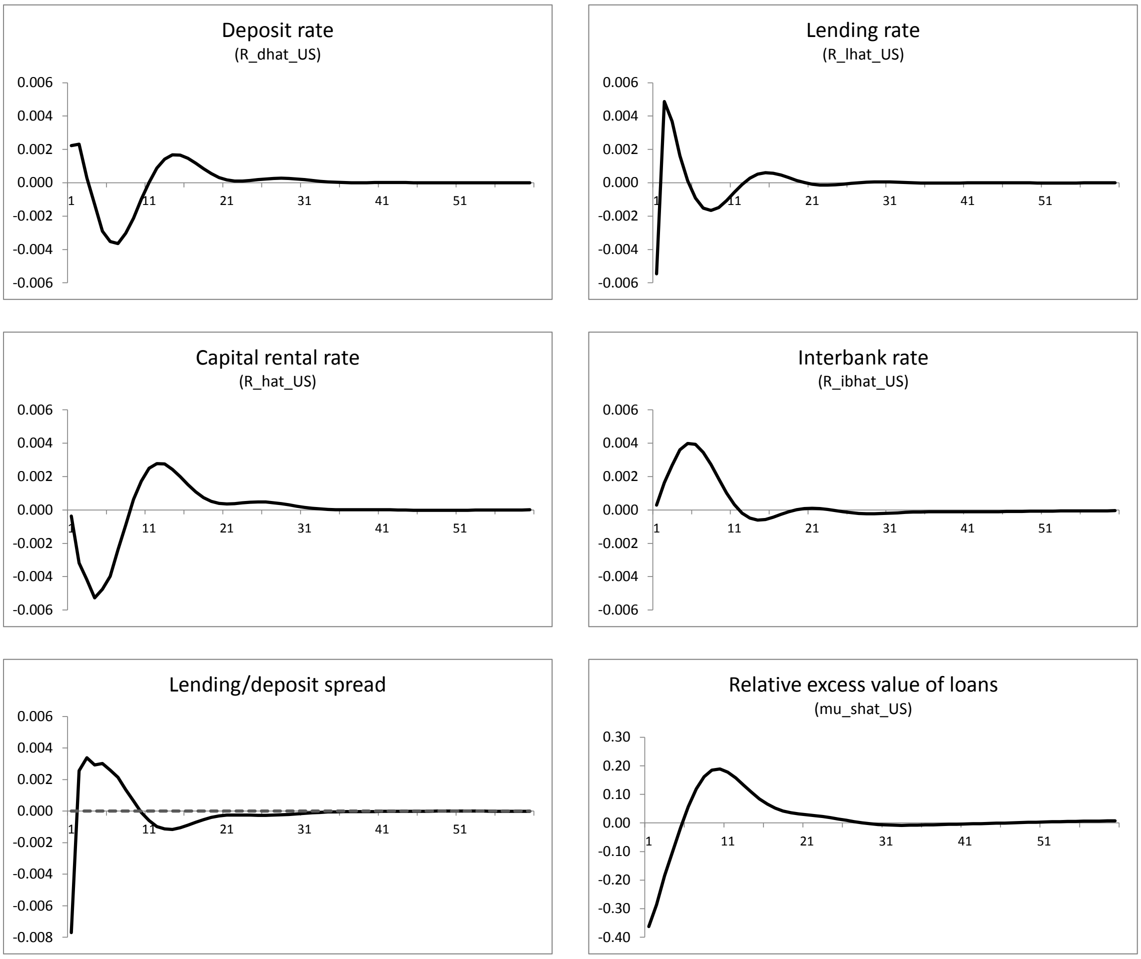


The jump in the lending rate is subsequently overcompensated by a quick fall which, combined with a smoother hump-shaped increase of the deposit rate, holds the spread in negative figures even after the lending rate has returned to the positive range. The increase in returns from loans makes their relative valuation to increase immediately after the shock but this effect is countered by the upward disturbance to the interbank rate until it eventually reaches a minimum in quarter 12.

By contrast, the largest spillover is recorded in Korea with an immediate fall in the lending rate (contrary to the effect of a monetary policy shock described above). It is also noticeable the relatively large increase it means to the interbank rate faced by its financial system. The reaction of the deposit rate, in turn, is evidence of an inflationary effect which reflects in the increase of the deposit rate accentuating the initial disturbance of the spread. These conditions do not last, given the rapid return of the lending rate to positive deviations staying above the deposit rate, even during a secondary downturn, until both of them return to equilibrium levels.

The particularities of the impacts derived from the same shock allow us to evaluate the exposure not only of the economies in the region but also of those out of it which, nevertheless, exhibit significant linkages. As in the previous exercise, we can observe in Figure 3.3.12 the impacts of the shock on the same set of indicators in the United States. It shows that the Japanese shock has enough potential to express into deviations in the relevant US variables.

Figure 3.3.12: International effects of a shock to compulsory reserves in Japan, United Sates



Contrary to the effect of a monetary policy shock, an inflationary spillover pushes the deposit rate up even though, in macroeconomic terms the returns of capital decline in the aftermath of the shock. That increase, at the same time as the lending rate falls, makes the spread to widen largely during the first quarter. The favourable outcomes to borrowers, nevertheless, are quickly reversed by a prompt increase in the lending rates and, as the most significant part of the shock, the disturbances generate a positive spread which also contributes to the recovery of the relative value of banking loans.

These circumstances in the credit market imply, also in sharp contrast to the ones arising from a monetary shock, expensive credit and depositors hit by a decline of their interests earnings. As for US banks, they experience a small decline in their valuation of loans which is almost completely reversed but, in conjunction to an increase in the interbank costs they have to bear, the shock creates a period of higher vulnerability.

3.3.4 Shock simulation: Europe

In the last section of simulation exercises, we look into the international consequences of the two policy variants reflecting the inter-regional interactions between countries in the Euro-zone and the United States. For this set of exercises, we included in the model Germany, France and Spain, which, as a group, represented 61 per cent of the Euro-zone's GDP in 2013. The presence of a monetary union implies that the included European countries share similar patterns in the responses to the described shocks, but beyond those similarities, their remaining macroeconomic and financial particularities contribute to explain a degree of variation between them in terms of their vulnerability to external shocks.

Spillovers of a monetary policy shock

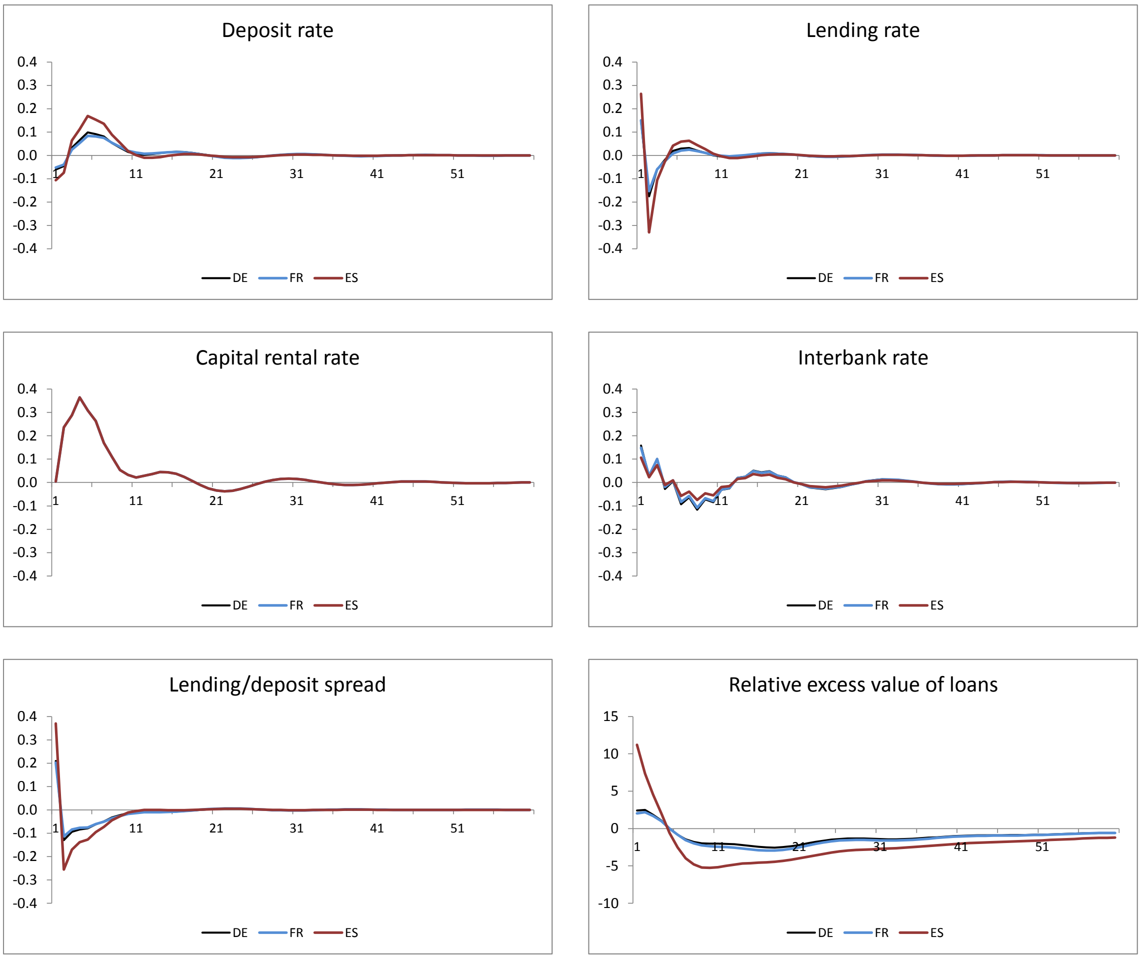
Starting with a one standard error shock to the policy rate in the United States ($\varepsilon^{R}_{US,t}$), we appreciate in Figure 3.3.13 a reduction in the deposit rates driven by a deflation spillover (as evidenced by the upward initial response in the capital rental rate) which, occurring at the same time as an increase in the lending rates, generates a significant increase in the lending/deposit spread during the first quarter.

The responses in Germany and France are generally close to each other, however those in Spain show a considerably larger degree of instability which can be attributed to national macroeconomic and financial features given that the interbank rate to Spanish financial intermediaries is, in fact, the one displaying the lowest deviations from equilibrium levels after the shock.

This *accelerating* phenomenon implies that credit markets in Spain are prone to experience larger impacts from external shocks, particularly with regard to lending rates (up to 78 per cent larger in upward direction and to 88 percent downwards when compared to Germany's maximum and minimum, and with a standard deviation 83 per cent larger for the whole 60-period series).

Different implications for Spanish intermediaries are also shown in relation to their relative asset valuation. A considerably larger (positive) spread makes banking loans to hold a stronger position in their balance sheets and, this way, it provides incentives to extend more credit to the private sector. Nonetheless, the subsequent fall in their value shows that this domestic credit market is subject to a significant deterioration of those incentives and, in comparative terms, more susceptible to occurrences of banking default (the worst period being around quarter 10).

Figure 3.3.13: International effects of a monetary policy shock in the US, selected Euro-countries

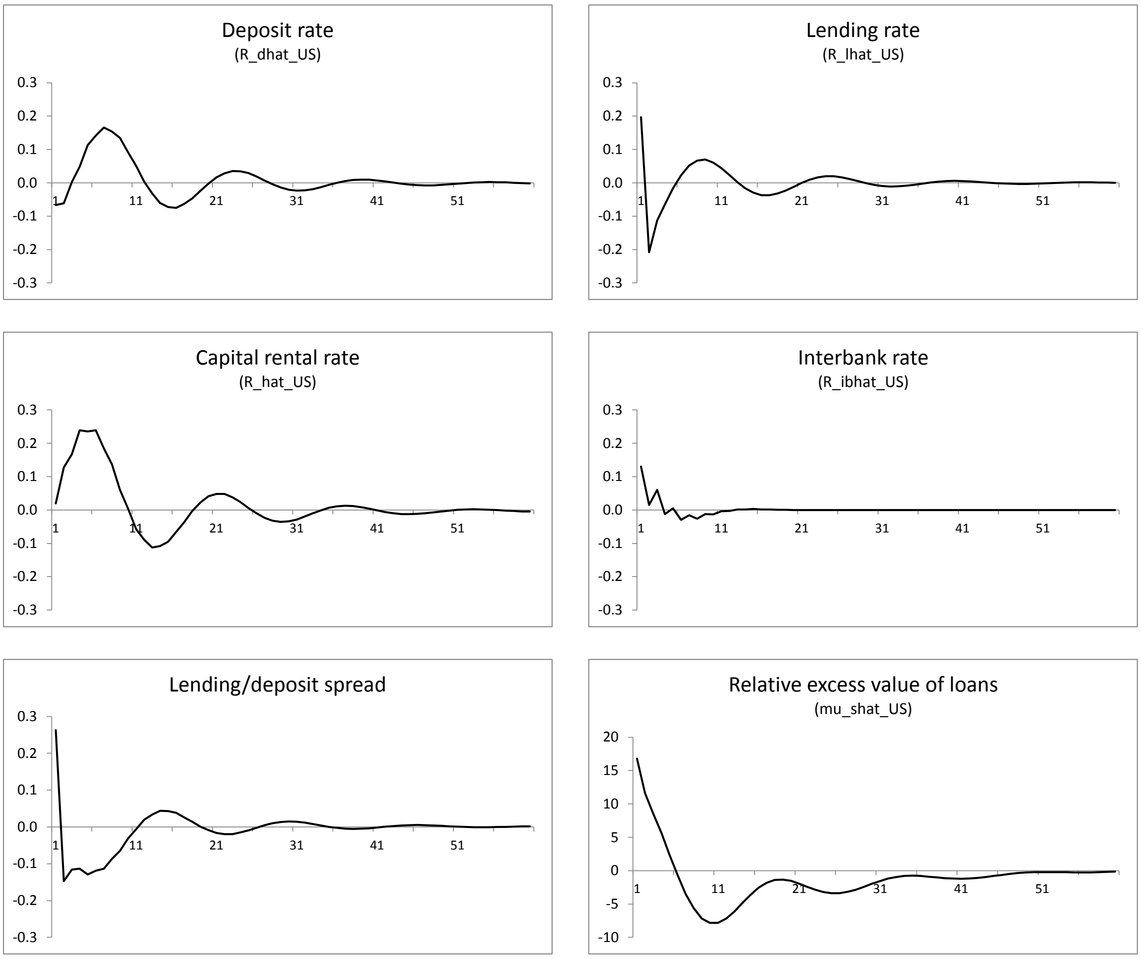


Next, we analyse the spillovers of a monetary policy shock in the Euro-zone (that is, a region-wide shock $\varepsilon^{R}_{EUR,t}$ applied by the European Central Bank) on the US credit markets. As in the previous exercise, there is a deflationary spillover which brings down the deposit rate for two quarters from where it starts to increase led by the domestic capital rental rate.

Again, a *financial acceleration* process is exhibited by the exacerbation of the disturbances in the interbank rate in the US credit markets. As we can see in Figure

3.3.14, the effects of the European shock on interbank rates for the US are relatively limited in terms of size and persistence. Yet, they set in motion cumulative processes within the financial sector which led to significant disruption in the conditions of domestic credit.

Figure 3.3.14: International effects of a monetary policy shock in the Euro-zone, United States



This argument is further supported by the fact that the largest variations occur in the lending rates (which are calculated in direct reference to marginal products in the banking sector). As a consequence, the spread between banking rates in the US also experiences significant fluctuations (although slightly lower than those originated by a shock in Japan). The fall from the initial upward deviation makes the spread negative and it stays so during the periods covering the most active time-span of the shock.

This makes savings relatively more profitable and loans cheaper to repay. However, from the supply-side point of view in credit markets, these conditions impose a strain on the financial intermediaries as indicated by the marked decline in the excess value of loans which reveals a period of pronounced financial vulnerability especially around quarter 11. The recovery from this precarious situation in asset valuation is relatively fast in the US, particularly when compared to examples like the other countries in NAFTA or the Euro-zone (above).

Fractional reserves shock

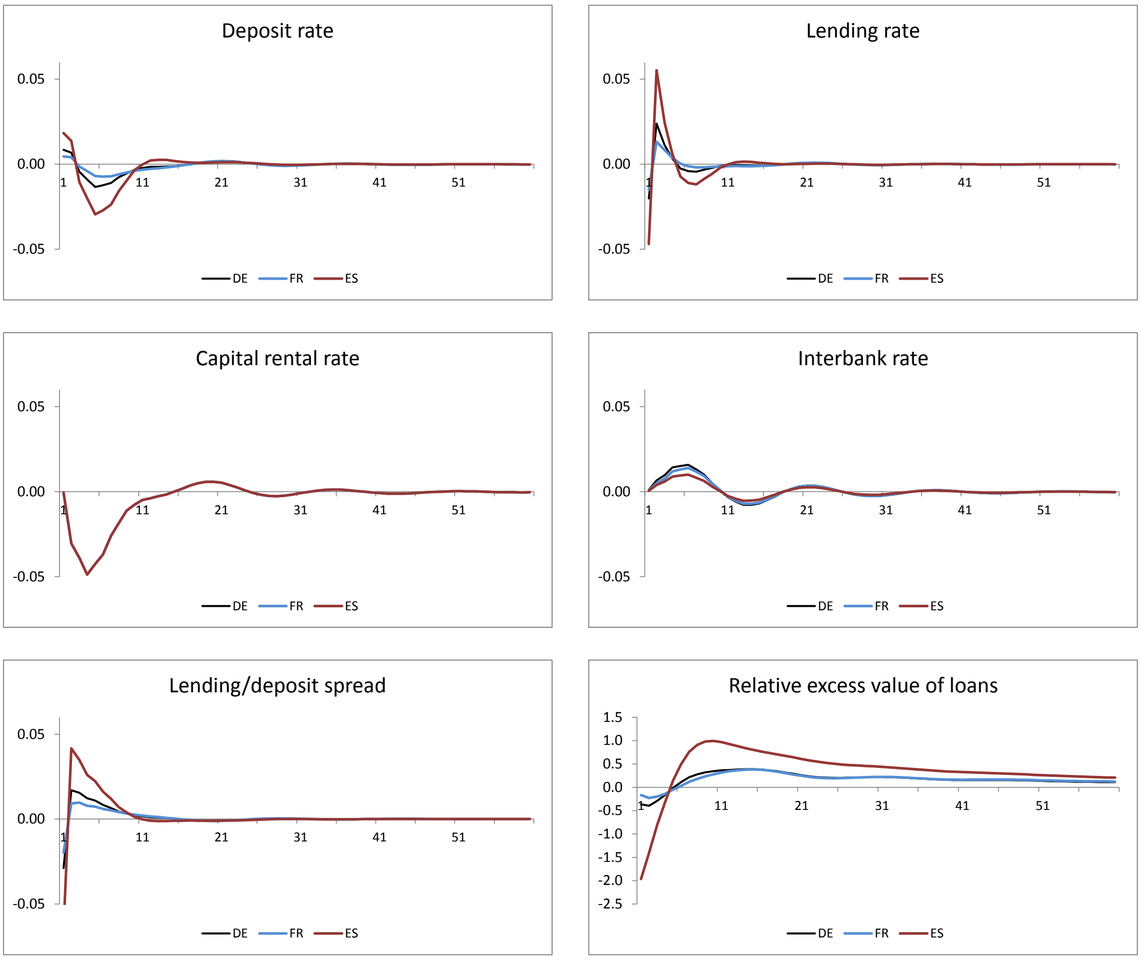
An intervention on the liquidity of the financial intermediaries in the United States is simulated in the form of a shock to the banking reserves requirement by the Federal Reserve, $\varepsilon^{bres}_{US,t}$. The inter-regional spillovers of such a shock on the included Euro-countries are shown in Figure 3.3.15. The displacements of the deposit rates in each one of them, in turn, exhibit the idiosyncratic exposures to inflationary spillovers and, by consequence, the particular impacts of the shock on the returns from savings in each economy. Comparatively, France shows the highest resilience to the spillovers while Spain, on the contrary, is the most diverted from steady state levels. The same pattern of contrasts appear for the lending rates and, consequently, for the spread with deposit rates.

The Spanish banking system is subject to the largest instability despite the fact that it displays the lowest displacements in the interbank rate. These contrasts are explained by the heterogeneous macroeconomic and financial features of each particular economy in the model as well as by the accumulation of *spatial feedback effects*. Spain, for example, receives not only the direct effects of the shock through its commercial and financial association to the US but also indirect effects through the impacts the original shock has on other European economies (see LeSage and Pace (2009, Ch. 1, 2 and 7)).

These characterisations can be derived thanks to the key ability of the model to distinguish, through its international weighting scheme, the particular relevance each country holds within a multi-country network[19]. The difference between the impact of the shock on interbank rates and the extent of the domestic disturbances it causes imply that the external shock is amplified within the Spanish financial market in contrast to the attenuation shown in the case of France.

[19]The feedback effects in this case show greater accumulation for Spain which gives a financial weight to Germany of 0.0527 while the converse is 0.0279 and in commercial terms the asymmetric relationship is even more evident with Spain giving a weight of 0.1728 to Germany while the opposite is just 0.0423 (see Appendix B). A shock affecting Germany, therefore, holds greater relevance to Spain than the other way around.

Figure 3.3.15: International effects of a shock to compulsory reserves in the US, Euro-countries

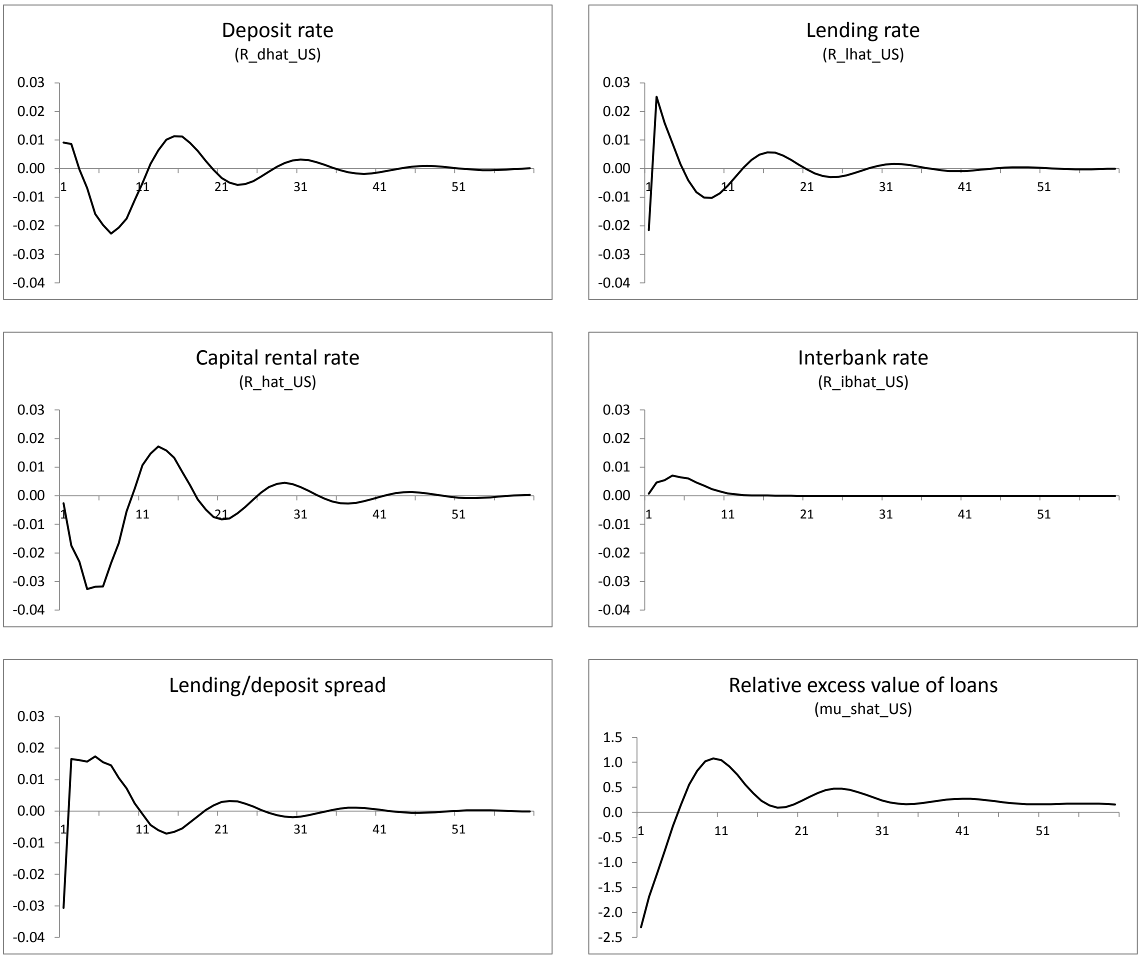


The initial downward displacement of lending rates affects the relative valuation of loans in these banking systems, particularly in Spain, although the recovery of the latter is relatively fast (reaching pre-shock values at or before quarter 5).

For the most part, this shock makes loans more expensive but, from the financial supply-side perspective, interest payments on deposits are depressed and, therefore, the conditions are favourable for a period of re-capitalisation of the banking system in the European countries. The specific implications for banking activity are also distinguishable between countries, with Spain being the most susceptible to a major slowdown. With expensive credit, lower deposits and increased borrowing costs the capitalisation effect is, in fact, associated to a decline in the amount of financial intermediation in these countries.

Lastly, Figure 3.3.16 presents the effects of the spillovers from a reserves shock in the Euro-zone (that is, in the particular definition of it in the simulation), $\varepsilon^{bres}_{EUR,t}$, on the interest rates in the United States. We can appreciate an inflationary short-term effect smaller only than that of Spain above. The largest variations, nevertheless, are recorded in the lending rate which are also deeper than the ones experienced in France and Germany in the previous scenario.

Figure 3.3.16: International effects of a shock to compulsory reserves in the Eurozone, United States



Importantly, these responses describe a financial acceleration of the foreign shock in the US economy given that the impact on its interbank rate is considerably lower than the disruption generated on the domestic credit market. This way, higher vulnerability to the inter-regional shock in conjunction with a significant acceleration effect towards the domestic market bring about substantial variability in the immediate aftermath of the shock and a subsequent period of expensive credit. Lower returns to savings contribute to depict a financial system which is likely to generate negative macroeconomic outcomes given this scenario of disruption on its main function of liquidity balancing.

The shock generates a large downward impact on the relative value of loans but its recovery is relatively fast which, occurring at the same time with a positive spread between the lending and the deposit rate creates propitious conditions for an increase in the net worth of banks. This, however, similarly happens under circumstances leading to depressed activity in banking services.

3.3.5 Effects on real variables

Finally, although our analysis has mainly concentrated on the implications of international shocks for the conditions of the financial markets, there is also evidence that their impacts extend to variations in the real side of the economies involved.

The shocks we have studied in the context of credit markets also have significant effects on the patterns of consumption (*c_hat*) and investment (*i_hat*) as well as on the volumes of commercial exchange (that is, exports, *xs_hat*, and imports, *ms_hat*) and, therefore, on output (*y_hat*). Additionally, in the same line, our analysis platform allowed us to show the repercussions on the levels of employment (E) and real wages (*w_barhat*) that arise from the selected international disturbances.

A depiction of the indirect effects on real variables of the shocks we have explored in this chapter is included in Appendix J. The main impacts on real variables typically concentrate during the first or the second year in the immediate aftermath of the shocks but in some instances real rigidities seem to intervene in the lengthening in time of their effects. That is the case, for example, of investment and employment levels in Mexico.

We can perceive that the monetary and reserve requirement shocks in the United States, for example, impose deeper disturbances on the real conditions in Mexico's output, consumption, investment and employment when they are compared to the same variables in Canada. Greater flexibility in the Mexican labour conditions, in turn, is a main factor for larger variability and lower persistence in time of the effects on real remunerations.

The Mexican balance of trade also exhibits important deteriorations, mainly during the first three quarters after the shocks. It is worth highlighting the larger sensitivity of Mexico's foreign trade to the shock on compulsory reserves in the United States since it confirms that the impact of a shock affecting the conditions of the financial sector has significant real consequences too.

A key example of crucial real consequences from the disruption in the financial sectors caused, in turn, by the foreign shocks involves the decline in investment in both NAFTA countries[20]. For Canada they mostly represent well-delimited, shorter-term downward fluctuation whereas for Mexico the responses of investment pose a

[20] Recall that for this region the shocks are modelled as originated in the US so the *receivers* are Canada and Mexico.

more serious compromise to the pattern of capital accumulation given their larger scale and persistence. This can also be perceived in the downward displacement of output in Mexico for the whole of the simulated period.

In the Asia-Pacific region, a marked preponderance of the responses in foreign trade (especially in imports) to shocks in Japan denotes the specificity of the channels of transmission between these economies. Not only the dynamics of the regional interactions differentiate this group but also a clearly distinct pattern of responses is present between the monetary policy shock and the reserves shock.

Unlike the NAFTA region, which displays a fair degree of consistency between the responses to the two shocks in each receiving member (differing mostly in terms of size but following similar patterns) in Australia and Korea the responses to the two types of shocks are markedly different.

This means that the final repercussions for these economies vary in size and quality depending on whether the financial sector is mediating between the foreign shocks and the real economy. The responses to the shock on the liquidity of the Japanese banking system, however, are considerable smaller than in the NAFTA region.

Antagonism between the economies in the Asia-Pacific region, meaning markedly opposed variations, is also displayed in the profiles of real responses in Australia and Korea.

By contrast, there is a high degree of similitude between the real responses to the shocks in the Euro-zone. Comparing the profiles of the responses between countries, the differences reside in the size of their impacts on each economy. Nevertheless, again, the main differences appear when our comparison is based on the type of shock affecting each country. For the countries in this region, shocks affecting the regional liquidity of financial intermediaries have relatively smaller real impacts and the responses they generate can even be contradictory to the more general, economy-wide monetary policies. This is mainly the case of variables as output, consumption and investment, displaying opposite deviations to those originated from a monetary policy shock.

This way, policy interventions operating through the financial systems display significant particularities in Asia-Pacific and Europe while in NAFTA they tend to emulate (in smaller scale) the responses to monetary policy shocks.

3.4 Conclusions

The choices between alternative policies in the monetary context display distinctive international spillovers across OECD economies. Those spillovers, in turn, generate significant impacts on the conditions of financial intermediation in economies exposed to them through financial and economic linkages. These international interactive features, however, have not been discussed even by the most recent examples of research on financial intermediation in the DSGE field.

In fact, one of the main contributions of this Chapter is that we have measured and characterised international monetary spillovers within 9 selected OECD economies with consequential implications for their financial intermediaries.

Assisted by a modified version of Gertler and Kiyotaki (2010) which we have incorporated in our multi-country platform with the addition of components we deemed relevant in the depiction of banking systems, as compulsory reserves and partial loan-recovery rates at the national and international level, the simulation of international shocks revealed the extent of the exposure displayed by national financial systems and, by implication, the economies they serve.

Unlike previous applications of this financial modelling, our framework enabled us to explore intra and inter-regional spillovers of the two types of monetary interventions representing main alternatives currently used by central banks to manage the economic and financial recovery in the aftermath of the 2007-2009 financial crisis. The multi-country framework to which our financial modelling was added provided a wider platform for the analysis of complex interactions not assessed by the original examples of financial modelling we built on. This way, our DSGE framework was complemented by an original depiction of interrelated financial systems which provided us with new information on the diversity of nominal responses across the OECD to standardised shocks exhibiting various degrees of international exposure and vulnerability.

The economic ramifications of those exposures are important to distinguish between the heterogeneous set of economies we studied. There is evidence, for example, of different degrees of *financial acceleration* of the selected foreign policy shocks in our study. This phenomenon is better understood as the cumulative process by the means of which a foreign shock brings about more than proportional disruption on domestic indicators, such as interest rates, with consequential outcomes for the general economy in terms of the distribution of liquidity between agents which, eventually, also translate into impacts on real variables.

It is important to highlight that between the two variants we have explored for monetary policy (using either policy rates or compulsory banking reserves) there are considerable cross-country differences in relation to the outcomes of their representative shocks as reflected, for example, in the resulting spread between lending and deposit rates in the banking systems. We found that the comparative international impacts of policy interventions aimed to exert changes in the liquidity of financial intermediation systems generally tend to be significantly smaller and, in some cases, generate opposite variations to those arisen from monetary shocks operating, instead, via the central bank's policy rate.

The relatively restricted size of international spillovers from *liquidity* policies is in part a reflection of the fact that, in practice, they cannot be disproportionally large without compromising other objectives (inflation, for instance) thus limiting their effective scope at the domestic level as well as that of their potential international spillovers.

The rationale behind the smaller and, in some cases, apparently contradictory effects of liquidity policies on the nominal context of economies stems from the focused consequences that sectorial policies have on their own domestic financial systems, in contrast to the wider, direct macroeconomic effect of monetary policy shocks. The degree of insertion of the financial system is, nevertheless, a consequential heterogeneity driving national differences between the responses to common shocks.

The idiosyncratic exposure of the affected banking systems leads them to experience characteristic impacts from policies taken abroad.

As examples of cross-country diversity of the impacts of foreign policies, we found contrasting international effects of liquidity and monetary policies applied in the United States. While the degree of nominal disruption from liquidity externalities on Canada's key interest rates was significantly smaller than those derived from monetary shocks, the combination of conditions in its banking system meant that the loan/deposit spreads and the relative valuation of banking assets suffered larger variations when we simulated the first type of policies. Conversely, liquidity policies in the US generated much smaller externalities on Mexico's financial system than those resulting from US monetary policies. These are examples of how our model, then, has been able to distinguish the particularities and outcomes of the international linkages denoting higher strength through the financial system, as in the case of Canada, or through macroeconomic channels[21], as in Mexico.

Furthermore, the two variants of interventions can even display opposite effects on the economies within the network of the national economy which originates the shocks. This was found in Asia-Pacific where monetary and liquidity shocks in Japan created opposite externalities on both Australia's and Korea's nominal and banking conditions, with the liquidity externalities being of restricted size.

In general, we found that the two policy variants are not perfect substitutes in terms of the international externalities they generate on the nominal conditions in which banks operate. While the features of regional characteristic responses vary,

[21] Our frameworks embraces the international exchange of consumption and investment goods as well as of financial assets

in general the policies operating through restrictions on the liquidity of the banking system reflect into smaller disruptions of the nominal environment of foreign banks.

The contrast in relation to the spillovers from the two policy alternatives become clearer when observing that, despite they both generally express as increases in the international interbank rate, their impacts on deposit and lending rates and, consequently, on the spread between them are notably different. These dissimilarities ultimately reflect into credit conditions which are likely to generate imbalances in the liquidity of agents as well as externalities on operative accounts in the banking system as their relative valuation of assets for example and, consequently, on the dynamic patterns of accumulation of net worth for those financial intermediaries.

We also studied inter-regional shocks (US on Euro-zone, Japan on US and Euro-zone on the US), the analysis of which revealed that the externalities arisen from monetary and liquidity shocks give rise to nominal responses in opposite directions in the receiving economies.

This way, the choices of foreign monetary policies are relevant not only in terms of the macroeconomic performance of their financial and commercial partners in the OECD but also in relation to the conditions they impose on the corresponding foreign credit markets and financial systems. We have identified shocks which generate incentives to increase the net worth of banks and also scenarios in which bankers may be more inclined to default on their obligations given a substantial decline in the relative value of their assets. Similarly, we observed how international policy spillovers generating opportunities for banking re-capitalisation may simultaneously lead to episodes of significant decrease in the activity of banks. This way, with our multi-country platform, we have also explored comparative macro-prudential aspects of monetary policy, absent in the original single-economy financial model.

Macroeconomic (as inflation) and financial (as interest rates) spillovers combine in our model's depiction of the international outcomes of policy shocks on the supply side of financial intermediation providing a detailed account of the interactions between heterogeneous economies in comparison with models with greater focus on either source of disruption. The effects on real variables are also found to be significant and, above all, consequential for the conditions for consumption and investment in the economies exposed to international shocks.

Additionally, our modelling of these international effects has allowed us to divert from the usual emphasis on the interactions between countries focused on the comparative size of their economies to a more detailed description based on the relevance of their economic and financial linkages instead. We adopted an approach based on regional networks which allowed us to study international interactions whilst recognising the heterogeneities between economies and their interconnections.

In the experimental context of international spillovers we have analysed, domestic monetary policies would benefit from taking into account the diverse exposure of their nominal space of action to international shocks by accommodating their own choices to those externalities. Such accommodative stances would also contribute to reduce the risk of international acceleration effects and to achieve greater efficiency in the management of domestic nominal and macroeconomic variables.

3.4.1 Paths for further research

We have not considered the distinction of financial intermediaries between parent and subsidiary institutions as in De Haas and Van Lelyveld (2014). Those differences are likely to have an impact on the outcomes of shocks on more consolidated financial systems while, at the same time, may also contribute to a better localisation of the main financial nodes operating in the propagation of international externalities. That line of research is, therefore, promising as a further development for this investigation.

It would also be enriching the extension of the study towards the inclusion of further elements in banking regulation such as those contained in the Basel III framework although this requires a considerable expansion of the model's financial section towards the inclusion of risk-related indicators in banking.

Chapter 4

Horizontal and vertical interactions of macroeconomic policies through a financial cost channel in OECD countries.

4.1 Introduction

The implications of financial risks and their transmission channels to the broader economy constitute a crucial subject not only in the current study of monetary economics but also for the analysis of the resulting interactions between fiscal and monetary policies in a context of significant international interactions.

As a factor of prime relevance to the variations of financial risk assessments, both researchers and policy makers aim to estimate what is the potential strength of the financial spillovers arising from fiscal policies and, therefore, the dimension of the adjustments in monetary policies that can be made in order to account for them. Providing an answer to this interrogation is an important input for any design and programming of macroeconomic policies intended to exploit the fiscal-monetary symbiosis and minimise the efficiency losses from ignoring their combined outcomes.

In order to tackle that question, we develop a concise framework for the analysis of the effects of fiscal policies, as represented by the developments of public debt, which aims to measure key nominal impacts of cross-policy spillovers. We distinguish these externalities both at the national and the international level by performing suitable estimations on selected OECD countries' quarterly macroeconomic data between 1991 and 2013 by the means of a modified methodological setting based on spatial econometric techniques.

In particular, our analysis focuses on the effects of a *cost channel* arising from fiscal policies and the impacts it displays on nominal variables highly relevant to the performance of credit markets. In doing so, our work provides a fiscal version of the cost channel (originally developed in the context of monetary policies) presented by Barth and Ramey (2001) and complements the analysis of Tillmann (2008) centred on the inflation outcomes of a cost channel operating through productive firms holding working capital and, therefore, their costs being sensitive to changes in interest rates and monetary policies.

Our variant concentrates, instead, on the increased costs in the financial sector that arise as a result of higher risks premia associated, in turn, to larger amounts of public indebtedness and the corresponding deterioration in the perception of default risks. This version of the cost channel, set in motion by fiscal policies, is explained through the impact of public debt on relative measurements of financial risk which are eventually imbued in lending rates across OECD economies.

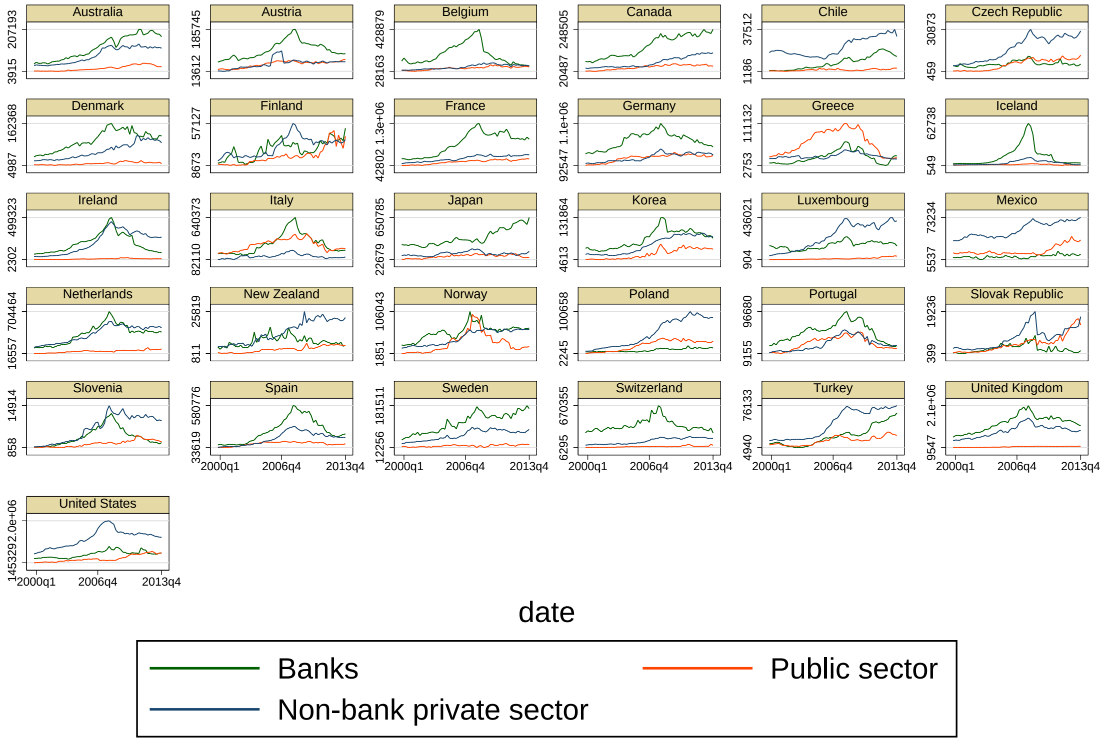
The banking sector holds a central role in both the domestic and the international propagation of these cost-channel effects. This is a direct result of the interaction between the distinctive costs faced by banks operating in each economy (or region) and the impacts on risk assessments from changes in public indebtedness. The degree of international integration between these financial intermediaries paired with their intrinsic exposure to governmental liabilities are key features that provide the operative foundations of this cost channel. Importantly, the resulting impacts on domestic credit markets and macroeconomic performance generate additional pressure on monetary authorities to accommodate to the nominal externalities created this way by fiscal policies.

A substantial international factor also contributes to the spreading of these effects. The banking sector's current asset-exposure (as measured by consolidated foreign claims) to foreign public debt instruments is significant, even high in some instances where it closely approaches or equals the claims on other banks or those on the non-banking private sector as shown in Figure 4.1.1.

This degree of exposure, combined with the significantly increased international risk transfers in the banking sector during the last decade, results in a fast-moving network for the spreading of risks across regions of the world economy. The intensification of these exchanges as well as the contrasts of their inherent heterogeneities are shown in Figure 4.1.2. Some specific cases (as Ireland) have evidently generated larger risks to the global system while others (as Germany) have contributed to their tempering in net terms. Cross-sectional heterogeneities, therefore, have to be considered when analysing international common factors and linkages between these economies.

Figure 4.1.1: Credit-exposure of banking assets by country and sector.

(Consolidated foreign claims by borrowing country, mill. US dollars.)



Source: Author's elaboration with data from BIS, *International Banking Statistics.*

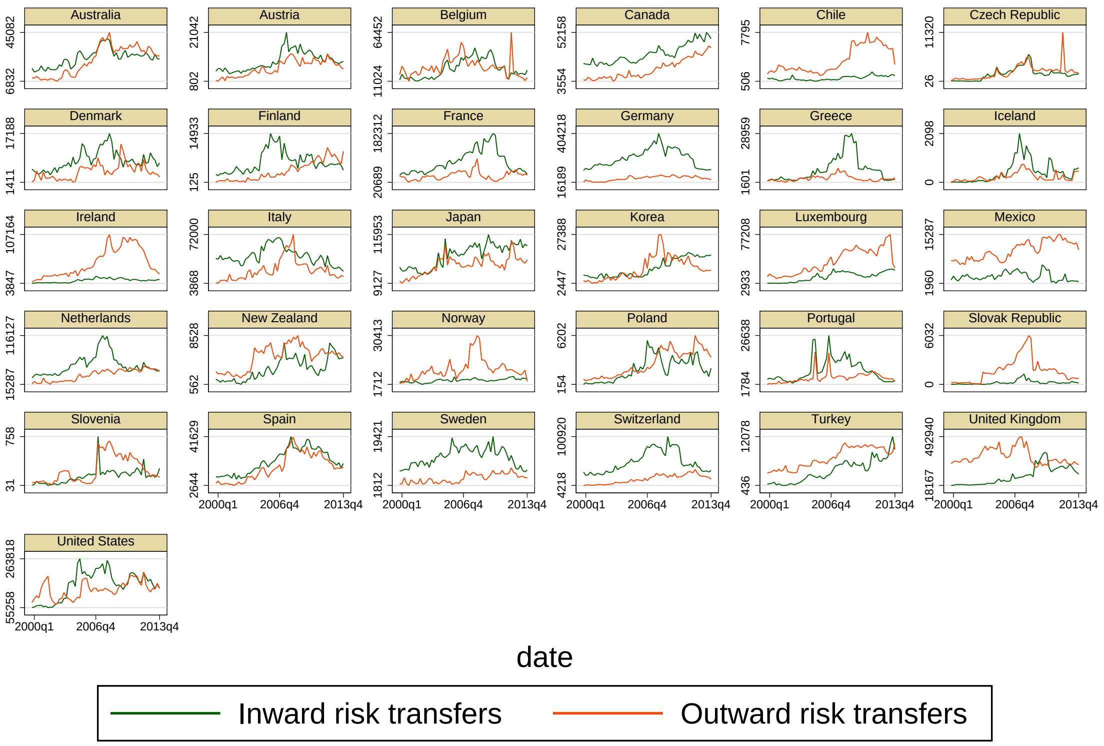
The boost in international risk transfers, taking the form of financial guarantees, credit insurance and more recent innovations like credit derivatives (as credit default swaps, *CDS*, for example), comes as a result of risk-management policies actively pursuing the spreading of the underlying burden between financial markets even before the 2007-2009 financial crisis. Since then, banks have increasingly perceived their credit exposures as tradeable commodities and the market for them has widened.

Nevertheless, those diversification and risk-spreading practices, although they reduce the potential impact of risk deteriorations in individual economies, are still faced with the challenge presented by regional or even global shocks in the growing international risk-sharing networks. Another complication for this risk-mitigating framework is the predominance of low interest rates for extended periods and in wide regions since this incentivises financial institutions to look for the comparatively higher returns of riskier (also called *toxic*) assets offsetting, by doing so, the efforts to improve their risk profiles.

These conditions in the financial markets give a special relevance to the assessments on the soundness of key factors such as governmental accounts and macroeco-

Figure 4.1.2: International risk transfers in the banking system.

(Immediate borrower basis by borrowing country, mill. US dollars.)



Source: Author's elaboration with data from BIS, *International Banking Statistics.*

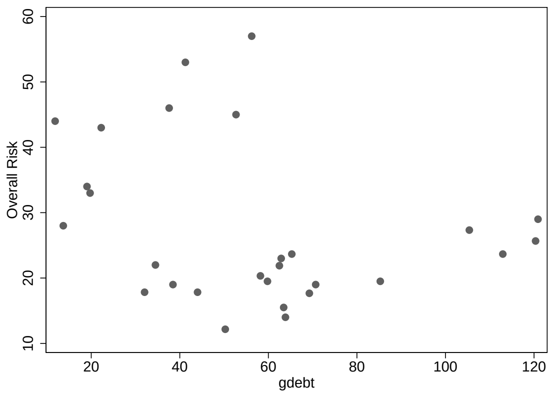
nomic conditions as determinants of the comparative standing each economy holds in the international competition for funding. For these reasons we employ in the analysis a risk index which not only looks into sovereign (i.e. external) debt but also to other critical components as the total government indebtedness (domestic and foreign) and indicators on currency and banking sector risks. All of these components are included in the calculation of the Economist Intelligence Unit's© (EIU) Overall risk index.

In order to understand the pivotal impact of fiscal policies in terms of broader risk evaluations, it is worth highlighting that fiscal issues and their macroeconomic effects occupy an important place in the focus of analysts studying the 2007-2009 financial crisis and its aftermath. Some of them have estimated that a fiscal crises constituted the highest global economic risk in terms of its potential economic impact in 2011 while this source of risk has consistently been listed among the five most dangerous between 2009 and 2013 (Howell (2013, p. 13)). Similarly, in the last edition of the World Economic Forum's Insight Report on Global Risks (WEF, 2014) it was stated that a fiscal crises *in key economies* was the top global risk of highest concern for 2014 (WEF, 2014 p. 9 and 13-14) as well as the one with the highest possible economic impact (WEF, 2014 p. 16-17).

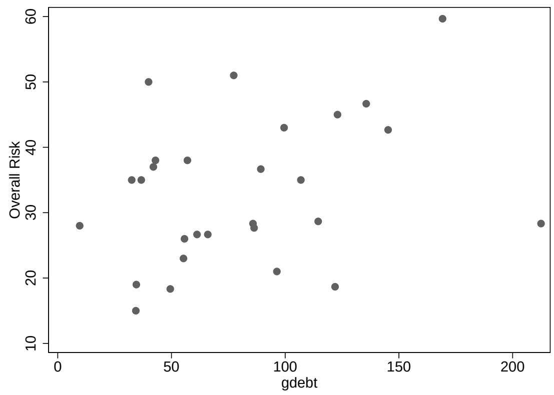
The accentuated relevance of fiscal indicators from an international perspective also finds an expression in comparative risk assessments such as international ratings. We can observe in Figure 4.1.3 how the relationship between public debt and risk ratings[1] in OECD economies became clearer and more responsive in terms of the latter between 2001 and 2013.

Figure 4.1.3: Evolution of the relationship between risk and public debt, 2001 and 2013.

(Public debt as per cent of GDP (x-axis) vs Overall risk index (y-axis).)



(a) 2001Q1



(b) 2013Q3

Source: Author's elaboration with data from OECD and The Economist Intelligence Unit.

In this context, we aim to integrate to our study an international component that is very likely to operate between economies strongly linked by economic and financial exchanges. Its practical expression consists of an original multi-country weighting scheme further explained below. This component, and its varying nature between heterogeneous economies, is addressed by our methodological framework in such a way that it is distinctively represented according to the historical statistic evidence on relevant international linkages.

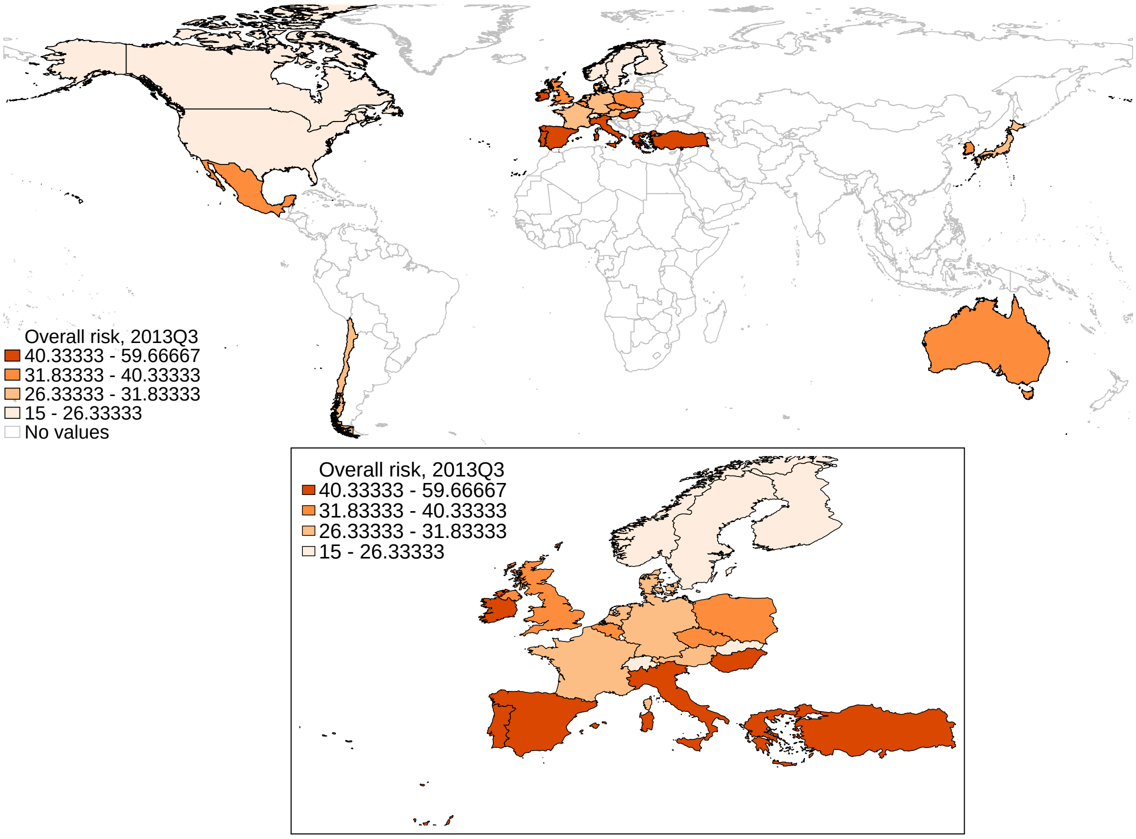
Our modelling strategy reflects the fact that we target the phenomenon of international transmission of risks associated to fiscal variables between a set of economies displaying significant commercial and financial exchanges. Also, within our sample of OECD economies, specific regional groupings can be identified sharing similar risk ratings. In Figures 4.1.4 and 4.1.4a, for example, it is noticeable that there is a spatial element of *clustering* between economies in terms of their similarities in the EIU's Overall risk index.

Those characteristics justify our choice, for empirical purposes, of an innovative quantitative research setting based on spatial econometrics to estimate the fiscally-

[1]Represented by the EIU Overall risk index.

Figure 4.1.4: Overall risk index by country.

(Selected OECD countries, 2013q3.)



(a) OECD Europe (selected countries).

Source: Autor's elaboration with data from EIU.

generated cost channel effects. Exploiting the capabilities of this methodology to explore relationships between units in the presence of cross-sectional dependence, our applied exercises take advantage of an original specification of multi-country weights which departs from purely spatial measurements and additionally incorporates trade and financial weightings. These weights have the objective of achieving an enhanced depiction of key linkages currently operating between the economies under scrutiny.

Our main findings indicate that fiscal policies have a significant effect on relevant nominal variables within the interest of monetary policies. We also conclude that those externalities modify the actual operational space available for monetary authorities both at national and international levels. The implications of this study on the supply-side effects of fiscal policies mainly reside in the requirement for monetary policies to effectively coordinate their actions to the nominal disturbances of the fiscally-generated cost channel. Given the uncertainty around debt accumulation patterns and valuation, this coordination would be better represented by a fiscal regime where fiscal policies lead in terms of their choices on debt and monetary policies accommodate to the nominal outcomes of those choices.

The remainder of the Chapter proceeds as follows: Section 4.2 revisits the theoretical background behind an enhanced role of fiscal policy in macroeconomic modelling and briefly describes relevant features of the interactions between fiscal and monetary policies, Section 4.3 sets our model with financial and fiscal components, Section 4.4 describes our approach and modifications to the spatial econometric methodology, Section 4.5 presents our empirical application and results and Section 4.7 includes our conclusions.

4.2 Vertical interactions: revising the role of fiscal policy

In our view, some simplifications still found in macroeconomic literature on policy analysis are overly restrictive for the representation of important factors of macroeconomic performance. That is the case of the limited role repeatedly given to fiscal policies and the absence of financial frictions in many modelling examples. Open-economy models incorporating monetary policies, consequential fiscal policies and financial frictions (our golden triad) are rarely found.

We believe that the conjunction of those three aspects of the economic and financial operation brings about a number of implications too important to be missed in any policy-oriented analysis. On those basis, our approach consists on developing a suitable framework of analysis to account for the interactions between policies in an open-economy context influenced by developments in the financial markets.

A recent branch of macroeconomic research has been devoted to elaborate on the notion that the assumption involving the so-called *Ricardian* behaviour is not a fundamental tenet or a homogeneously realistic representation in economics[2] (see Akerlof (2007), Bénassy (2007, 2008), Crespo Cuaresma and Reitschuler (2007), Evans, Honkapohja and Mitra (2012) and Reitschuler (2008)). Fundamental weaknesses in the Ricardian argument such as ignoring or minimising the presence of complex tax structures (i.e. which may include distortionary taxes), cash-constrained agents, the distinctive effectiveness of governments as borrowers or imperfect foresight on future taxation, make difficult to fully justify its application in the context of a policy-focused analysis (see Solow (2005) and Linnemann and Schabert (2010)).

Departing from the Ricardian assumption, in turn, brings about considerable consequences for the purposes of macroeconomic modelling. It implies giving a more relevant role to fiscal authorities in the management of cyclical fluctuations

[2] Woodford (2001) argues that even accepting Ricardian equivalence does not imply irrelevance of fiscal policies as a generally valid proposition.

and, therefore, a meaningful duty in the undertakings of macroeconomic policy as a relevant counterpart to monetary authorities. Additionally, the failure of the Ricardian equivalence to hold in some instances gives rise to consequential implications for the relationship between public finance and financial markets. This has been studied, from an empirical point of view, in Laopodis (2012) and in Linnemann and Schabert (2010) and Leith and von Thadden (2008) accentuating on the interaction between monetary and fiscal policies.

On the other hand, in a revised context, the incorporation of fiscal policies also requires some reformulations of the conceptualisation around them. The most relevant appear in relation to its dynamic nature in time given that the government (responsible for the management of fiscal policy) is usually conceived as an infinitely-lived agent although *administrations*, certainly, do end and the differences in preferences they express in relation to fiscal policies and their choices of variables like public debt can be marked[3]. On these issues, some theoretical studies have adopted an approach that allows for the contrast between distinctive policy stances executed by *benevolent* and *non-benevolent* authorities[4] (as in Kirsanova, Stehn and Vines (2005)).

Similarly, other studies, as Davig and Leeper (2006, 2011), point out that fiscal polices display regime-switching between passive and active stances. In the context of our analysis this opens a space to non-automatic and non-simultaneous budgetary adjustments which then, importantly, translate into the presence of governmental debt fluctuations and the associated time-varying probability of default. This varying probability embodies a crucial element in relation to the generation of cross-policy spillovers since financial markets assign a price to it, a price which, we argue, is then transmitted to other agents in the broader economy through financial intermediation.

In this sense, a conceptual framework which better reflects the dynamic nature of governmental debt is necessary in order to escape the limitations of its presentation as a mere accounting rule and connect it, instead, to the nominal aspects of the economy. On this point, an alternative view to the customary depiction of public finances as subject to inter-temporal budget constraints is that government liabilities are, in fact, nominal, as presented by Cochrane (2005). He argues that the government's balance sheet does not represent a budget constraint in a strict sense but a *valuation equation* instead and that this distinction is consistent with

[3]This is far from trivial in terms of its impact on economic policy research. Hallerberg, Strauch and von Hagen (2009) studied important fiscal implications of political competition and succession, particularly on public debt trends and developments while Lane (2003) associated political features of OECD countries to the cyclical responses of fiscal policy.

[4]The former being those whose policy rules perfectly match the preferences of households while the latter might have their own preferences on different levels of the output-inflation mix.

price-determinacy in macroeconomic modelling both in equilibrium (as it was stated earlier by Woodford (2001)) and, importantly, out of it.

In the account of Woodford (2001) particular features that governments hold provide the basis for a distinctive characterisation of their financial behaviour in contrast to households and firms. Their size and ability to exert influence on prices as well as the nature of their debt issuing practices (where liabilities are issued against another, technically safe, future form of their own liabilities which serve as no less than the whole economy's unit of account) constitute key points in the argument for a differentiated treatment of public debt and its valuation in time. Under this perspective, the decision to hold public debt crucially depends, as with other assets, on its expected rate of return.

In Cochrane's formulation (which is compatible with a non-Ricardian approach), nominal debt, D_t, is a "residual claim to government primary surpluses"[5], B_t:

$$\frac{D_{t-1}}{p_t} = \sum_{s=0}^{\infty} E_t \left(m_{t,t+s} B_{t+s} \right) \tag{4.2.1}$$

where p_t is the price level and $m_{t,t+s}$ is a discount factor between periods t and $t+s$.

A forward looking valuation (or expected return) approach has, among other advantages, the ability to follow debt's changes in time while, providing a continuously repeated assessment of its developments which then results in impacts on nominal variables (like prices, as in Cochrane's paper) as well as on explicit and tacit risk evaluations[6]. This approach on public debt is, therefore, valuable for both policy-makers and researchers interested in measuring the nominal effects of fiscal policies.

Also relevant is Cochrane's argument that, in order to obtain price-determinacy, this configuration leads to the requirement of coordination between fiscal and monetary policies in either a monetary or a fiscal regime, the latter consisting of governments leading by setting the conditions of surpluses and debt and, therefore, determining the price level while the monetary authorities accommodate their policies to those conditions.

With interest rates recently reaching record low levels in key economies, new research has increasingly given a more important role to fiscal policy as a true factor of economic performance under restricting conditions for monetary policies. Within those studies special attention is paid to the potentialities of fiscal instruments to act in a complementary manner to a monetary policy hampered by a *liquidity trap* (see

[5] Cochrane (2005, p. 502).

[6] Explicit evaluations are those provided by rating agencies, for example, while tacit evaluations appear embedded in variables like prices or, as in our case, interest rates.

Christiano, Eichenbaum and Rebelo (2011), Cook and Devereux (2011), Dhami and al-Nowaihi (2011), Eggertsson (2011), Eggertsson and Woodford (2006), Woodford (2011)) and others have looked into the implications for policy coordination arising in the case of a monetary union (Canzoneri, Cumby and Diba (2006), Carlberg (2006), von Hagen and Mundschenk (2003), Leith and Wren-Lewis (2011)). For the purposes of this study, however, we have given preference to a wider approach, as in Canzoneri, Cumby, and Diba, (2011) and Niemann and von Hagen (2008), not necessarily limited to the presence of such restricting circumstances.

Keeping these views on fiscal-monetary complementarity in mind, we propose a new, enhanced approach, stressing on the financial implications of elements such as internationally-differentiated risk premia linking interest rate spreads and public debt dynamics into our modelling scheme. These contributions are deemed useful for a better understanding of the operational capabilities and limits for fiscal policies which are, in many senses, analogous to those restricting monetary policies as we explain below.

In contrast to its relatively infrequent expression in New Keynesian models, fiscal policies have been subject to a long-standing review by policy researchers in light of their implications for the monetary management (see Friedman and Heller (1969), McCallum (1984), Kirsanova, Leith and Wren-Lewis (2012) and Sims (2011) as some examples) and a famous line of *unpleasant arithmetic* (with emblematic proponents like Sargent and Wallace (1981), Eusepi and Preston (2008), Adam (2011) and Cochrane (2011)) was developed to make evident the extent of the mutual conditioning between these two policies. Such considerations have also provided the foundations for a strategic approach on the analysis of monetary-fiscal policy formulations. Considering those ideas, some studies have focused on the interactive elements between monetary and fiscal policies (see Laurens and de la Piedra (1998), Traum and Yang (2011) as some examples).

On the other hand, it has become increasingly clear that there are size as well as time-related restrictions to the potential stimuli on the real economy that can be achieved from fiscal policies (as seen by Davig, Leeper and Walker (2011)). A *debt trap*, for example, would imply that fiscal imbalances leading to debt accumulation can effectively reach a level deemed unsustainable which would result in a considerable loss of credibility on budgetary options and, ultimately, in a restriction of the real effects which fiscal policies can achieve in contrast to the potential they have under less stressing conditions. For our purposes, such a restriction on the fiscal capabilities to generate real effects also implies that, beyond certain thresholds, fiscal stances generating further public indebtedness would only reflect in nominal variations and in the deterioration of risk assessments.

4.2.1 Nominal effects of fiscal policies

According to the *consensus assignment*, in contrast to monetary policies, commonly deemed as dominant in achieving nominal targets, the fiscal arm of macroeconomic policy is conceived as fundamentally concerned about the accomplishment of real targets in the economy (see the discussions of Taylor (2000), Kirsanova, Leith and Wren-Lewis (2009) and the models used by Muscatelli, Tirelli and Trecroci (2004), for example). Many of the previous studies recommend, both from operational as well as for optimal institutional design purposes, that fiscal policies should concentrate on their impact on the real side of the economy. Nevertheless, in our view that should not be equivalent to discarding the existence of their nominal effects or even to rule out the possibility of a fiscal complementarity on nominal issues, specially when monetary policies suffer from grave restrictions such as the one implied by the *zero-lower-bound* (see Dhami and al-Nowaihi (2011) for example).

On these issues, a branch of research focused on the implications of the *Fiscal Theory of the Price Level* (henceforth FTPL) explores the nominal impacts of fiscal policies and points towards the optimality (in both economic and modelling/determinacy terms) of particular monetary-fiscal *pairings*[7], reinforcing the notion of interdependence between their economic outcomes.

Our analysis, in common with those perspectives, addresses some of the most consequential nominal effects of fiscal policy as those originated by the developments of public debt in time. In comparison with other fiscal indicators such as fiscal balances, primary surpluses, etc. the trends of public debt embody short-term as well as long-term ramifications, its continuous valuation in time is coherent with the views of the proponents of the FTPL as particularly illustrated by Cochrane (2001) and has richer implications in the context of expectational trends by contributing to the formation of optimistic or pessimistic scenarios, for example, which then translate into corresponding risk assessments.

Under these circumstances, governmental debt management constitutes an important informational element influencing the formation of expectations by private agents. In particular, our own perspective concentrates on a financial channel of transmission between public debt and risk premia (represented by variations of international interest rate spreads) which eventually impacts banking costs and, subsequently, the broader conditions in credit markets. For this, we build on studies like Akitobi and Stratmann (2008) and pursue a description of the impacts on financial markets arising from fiscal policies with the evolution in time of public debt as a key driver.

[7]See for example Leeper (1991), Sims (1994,1997), Woodford (2001), Dixit and Lambertini (2003a), Davig and Leeper (2011) and Cochrane (2001, 2005).

Public debt also holds a crucial and unique role in the depiction of the nominal interactions between fiscal and monetary policies, as argued by Woodford (2001), given the monetary influence on the valuation of outstanding debt through price levels as well as on the service payment costs through interest rates. Our own narrative, however, takes a complementary perspective assessing the fiscal-monetary relationship in the opposite direction as it stresses on the nominal effects of fiscal policies and their consequences for monetary policy. Changes in the present value of government liabilities occurring this way contribute, in fact, to the argument against Ricardian-equivalence theory due to a possible mismatch between the value of future flows of public revenues and expenses giving public debt an intermediary role between fiscal and monetary policies.

4.2.2 Monetary-Fiscal interactions

In a context where fiscal policies hold an active and consequential role in macroeconomic stabilisation, a natural issue arises concerning the resulting cross-policy interactions with monetary authorities (see Solow (2005)). Such an interactive setting casts doubts on the appropriateness of Tinbergen's maxim[8] (one target, one instrument) for describing the operation of macroeconomic policies, at least in the sense that more than one instrument can have non-negligible consequences for the achievement of a single target. This, however, doesn't equate to discarding cases of relative superior effectiveness[9] (meaning higher efficiency in the achievement of targets) or leadership that either fiscal or monetary authorities may display in the accomplishment of a specific target.

Developments in the theory of policy interactions have pointed towards the generation of multi-period models aiming to reflect the dynamic characteristics of joint fiscal and monetary effects. Beetsma and Bovenberg (1997), for example, extended the study of monetary-fiscal interactions to a two-period dynamic setting. Such developments, increasing the space for interactions in time, are important as they also allow for the inclusion of other relevant components which find their principal meaning in their evolution in time, as is the case of public debt. The general setting

[8]We can argue that the *maxim* itself is, in fact, an extreme interpretation of Tinbergen's actual position given that, in his own words: "targets and instruments may very well be different in number.", Tinbergen (1952, p. 37) and "where there are more instruments than targets. This is the most attractive situation, from the practical standpoint,..." (ibid.) "It goes without saying that complicated systems of economic policy will almost invariably be a mixture of instruments belonging to various groups.", Tinbergen (1952, p. 71).

[9]Even if that relative superiority could be time-varying, implying that a conventional arrangement may not always be efficient as might be the case of a scenario where the zero-lower bound has been reached and monetary polices find themselves severely restricted or when, alternatively, a debt threshold imposes a ceiling to fiscal policies' ability to exert a meaningful effect on real variables.

was further expanded to an infinite-time horizon by later studies like Kirsanova, Stehn and Vines (2005) although it was still restricted to a single-economy model.

Among other previous studies on monetary-fiscal interactions it is worth mentioning Lombardo and Sutherland (2004) because of their approach on the comparison over different vertical coordination[10] scenarios. Essentially, they distinguished between the welfare outcomes of coordinated and uncoordinated (also called *Nash*) fiscal and monetary policies.

In turn, Dixit and Lambertini (2003b) compared the welfare outcomes (represented by the output-inflation mix) from diverse combinations of commitment and discretion between monetary and fiscal policies in a static setting with monopolistic competition (which gives rise to sub-optimal levels of output). Their strategic settings included Nash (uncoordinated) equilibria and different leadership profiles. In their analysis, fiscal policies are able to counteract or enhance the welfare outcomes from a range of monetary settings and coincide with Kirsanova, Stehn and Vines (2005) in their positive assessment of fiscal leadership as compared to monetary leadership.

More recently, Canzoneri, Cumby and Diba (2011) provided a clear account on the current state in the theoretical advances towards the description of issues embedded in the relationship between monetary and fiscal policies. In the context of these lines of theoretical progress, we expand the analysis by looking into the consequences of continuous policy interactions in an international setting and by developing an alternative framework for the analysis of their effects across countries which also accounts for key implications for the operation of governments and financial sectors in individual economies.

In fact, the domestic component in our modelling approach resembles that of Davig and Leeper (2011)[11] mainly in relation to the policy rules for monetary and fiscal policies although, as we have pointed out, the fiscal configuration used here concentrates on public debt instead of on the intensity of taxation.

However, a number of modifications were deemed as necessary in the definition of a common space of action (i.e. policy targets) and the instruments applied by policymakers. From our standpoint, for example, the use of public debt as a policy target in itself (as it is included in Kirsanova, Stehn and Vines (2005), Leith and von Thaden (2008), Kirsanova and Wren-Lewis (2012)) fails to reflect the motivations of fiscal authorities for pursuing macroeconomic interventions. The arguments for including indicators on debt or deficit levels as targets usually develop on the grounds of the search for sustainability of fiscal policies. This is, in our view, not a true motivation

[10]That is, coordination between domestic authorities. Horizontal coordination, in turn, consists of international policy schemes.

[11]Which, in turn, is mostly based on Davig and Leeper (2006).

for public policies but a restriction instead over the quality that is expected or desirable from them in the medium and long terms.

Our choice, alternatively, is to consider public debt as a macroeconomic stabilisation policy instrument with real and nominal consequences and, importantly, unlike models using government spending as instrument (as Lombardo and Sutherland (2004) and Leith and Wren-Lewis (2008)), capable of reflecting the constrained scope of action they are able to exploit in actual practice as a result of the monetary implications of the associated probability of default.

The role of public debt as a driver of key nominal variations is a cornerstone of our analysis since it gives rise to a common space of interaction with monetary policies. On these grounds, both fiscal and monetary authorities have access to instruments affecting price levels as well as the interest rates predominating in an economy and therefore engage in a dynamic game where their distinctive efficiency on the accomplishment of targets is revealed.

In our setting, the fiscal effect on interest rates operates through the impact of public debt on the relative risk premium predominating in each economy at a given point in time while its influence on prices is mainly associated to the reactions of aggregate demand resulting from expansionary or contractionary fiscal stances. We concentrate, thus, on the first of these two outcomes.

The financial cost channel we study operates in the following way. Fiscal policies, through the combination of automatic and discretionary adjustments, reflect into developments in terms of debt accumulation. Domestic and foreign financial institutions are exposed to public debt's default risk through their asset sheets and are also subject to the risk benchmark imposed by the ratings on the national government's debt in the country they operate. The conditions of indebtedness in each country are subject to continuous evaluations related to its associated probability of default, those assessments find expression not only in risk ratings but also in market pricing (i.e. interest rates in this case) which generates a differentiated structure of costs for financial institutions in the international interbank credit markets. The disturbances in funding costs for national financial systems, reflecting variations in the idiosyncratic (although not internationally-independent) risk premia, are eventually transmitted to the wider economy through adjustments in lending rates. Finally, the impact on national credit markets also generates pressure on the monetary authorities to adjust their own policies in relation to the modified conditions of financial costs in the economy.

4.3 Model

For the formulation of a setting where both fiscal and monetary policies have nominal and real effects, we generated a modified version of the models in Lambertini (2006) and Dixit and Lambertini (2000, 2001, 2003a and 2003b) allowing both policies to display direct and indirect (i.e. spillover) effects. Real GDP is given by:

$$y_{i,t} = \bar{y}_i + \beta^{f,d} B^g_{i,t} + \sum_{j=1}^{N-1} \beta^{f,i}_{j,i} B^g_{j,t} + \beta^{m,d} \pi_{i,t} + \sum_{j=1}^{N-1} \beta^{m,i}_{j,i} \pi_{j,t} \tag{4.3.1}$$

with $i \neq j$, for $i, j = 1, ..., N$ countries. More compactly:

$$\boldsymbol{y}_t = \bar{\boldsymbol{y}} + \boldsymbol{B}_t \boldsymbol{\beta}^f + \boldsymbol{\pi}_t \boldsymbol{\beta}^m \tag{4.3.2}$$

where $\bar{y}_i$ is the steady state level of output, $\pi_{i,t}$ is the inflation level and we assume that all fiscal surpluses or deficits, $B^g_{i,t}$, are entirely transformed into corresponding changes in public debt[12], $D^g_{i,t}$, which accumulates interest charges at the national rate[13], $R_{i,t}$, such that:

$$D^g_{i,t} = R_{i,t} D^g_{i,t-1} - B^g_{i,t} \tag{4.3.3}$$

Fiscal policies exert effects on aggregate demand and are able to affect output but, at the same time, are subject to a trade-off in terms of the nominal disturbances they also create. Our focus on the financial sector leads us to concentrate on the repercussions of public debt on interest rates.

In this setting, public debt synthesises the fiscal policy stance in the sense that a larger amount, resulting from either lower taxes or greater expenditure, implies an expansionary policy and vice versa for a contractionary stance. There are two policy rules in our model, one for fiscal and one for monetary policies. They are based on the grounds provided by studies like Lambertini (2006) and reflect the fact that both policies are ultimately concerned about the developments of output and inflation. We consolidate the approach of Muscatelli, Tirelli and Trecroci (2004) into a single policy rule for fiscal policies and, in agreement with our definition of welfare, we replaced their fiscal stabilisation term with an inflation component:

$$D^g_{i,t} = \rho_D D^g_{i,t-1} + (1 - \rho_D) \left[d_\pi (\pi_{i,t-1} - \bar{\pi}^f_{i,t}) + d_y \hat{y}_{i,t-1} \right] + \xi^{gdebt}_{i,t} \tag{4.3.4}$$

Attending to the considerations of Dixit and Lambertini (2003a) in terms of the

[12]In actual practice, this may not necessarily be the case because of other debt-accumulating activities or lower debt payments. However, the main phenomena we expect to characterise are preserved with this assumption.

[13]A gross rate so that: $R_{i,t} = 1 + r_{i,t}$.

objectives governing fiscal policies, we formulated this rule to express the motivation behind fiscal decisions. The coefficient for the lagged value of debt[14], ρ_D, refers to the strength of a persistence component and reflects the fact that abrupt changes from previous stances are difficult to perform in the short term leaving a reduced available space for automatic adjustments[15]. This policy rule also refers to an inflation target, $\bar{\pi}^f_{i,t}$, which may differ from that of the central bank.

This way, variations of the fiscal instrument are attributed to two main sources: first, to an automatic response to developments in output and inflation (measured by d_y and d_π, respectively) and, second, to discretionary changes, $\xi^{gdebt}_{i,t}$, which need not be correlated with any of the former terms in Equation (4.3.4).

Public debt is subject to a continuous valuation scheme which results in the calculation of a nation-wide risk premium, $\tilde{\phi}_{i,t}$:

$$\tilde{\phi}_{i,t} = f(\delta_{i,t}, \tilde{X}_{i,t}) \tag{4.3.5}$$

where $\delta_{i,t}$ is the probability of default displaying convex features[16]. Additionally, $\tilde{X}_{i,t}$ is a set of variables representing macroeconomic trends, banking risk, currency risk and others like political risk.

In turn, in line with our valuation approach to public debt, an implicit risk assessment on this variable is eventually exhibited by the adjustments of the interest rate spread given by $\tilde{\phi}_{i,t}$, which explains the difference between the domestic interest rate, $R_{i,t}$, and an international common time-varying reference $\bar{R}^*_t$.

$$\begin{aligned}\tilde{\phi}_{i,t} = R_{i,t} - \bar{R}^*_t = \rho_\phi \tilde{\phi}_{i,t-1} + \beta^D D^g_{i,t-1} + \beta^\pi \pi_{i,t-1} + \beta^{\hat{y}} \hat{y}_{i,t-1} \\ + \sum_{j=1}^{N-1} \theta^D_{i,j} D^g_{j,t-1} + \sum_{j=1}^{N-1} \theta^\pi_{i,j} \pi_{j,t-1} + \sum_{j=1}^{N-1} \theta^{\hat{y}}_{i,j} \hat{y}_{j,t-1}\end{aligned} \tag{4.3.6}$$

or:

$$\boldsymbol{\phi}_t = \rho_\phi \boldsymbol{\phi}_{t-1} + \boldsymbol{D}_{t-1}\boldsymbol{\beta}^D + \boldsymbol{\pi}_{t-1}\boldsymbol{\beta}^\pi + \hat{\boldsymbol{y}}_{t-1}\boldsymbol{\beta}^{\hat{y}} \tag{4.3.7}$$

This spread effectively embodies a risk premium influenced by the developments of public debt, inflation and the output gap (defined as $\hat{y}_{i,t} = y_{i,t} - \bar{y}_i$) in country i and the corresponding spillovers it receives from the rest of j-th economies (i.e. the rest of the world). It accounts for the effect which fiscal policies impinge on the manoeuvring space of monetary policies by the means of their direct and indirect

[14] A term also included in Hallerberg, Strauch and von Hagen (2009) reflecting, in their view, an indicator of long-term sustainability.

[15] As indicated by the factor $(1 - \rho_D)$.

[16] That is: $\delta(0) = 0$, $\delta(D^g)$ is continuously differentiable, strictly increasing in D^g $\left(\frac{\partial \delta}{\partial D^g} > 0\right)$, convex $\left(\frac{\partial^2 \delta}{\partial (D^g)^2} > 0\right)$, $\lim_{D^g \to 0} \frac{\partial \delta}{\partial D^g} = 0$ and $\lim_{D^g \to +\infty} \frac{\partial \delta}{\partial D^g} = +\infty$.

(i.e. international) effects on interest rates (β^D and θ^D, respectively).

In addition, the comparative risk premium explains the differential in the costs each national banking system faces given that they have access to international financing subject to inter-bank lending rates which incorporate the relative differences in risk as compared with reference to the international risk-free rate[17].

Inflation persistence is associated to a Calvo (1983) scheme of incomplete price adjustment with an indexation effect measured by ρ_π:

$$\pi_{i,t} = \rho_\pi \pi_{i,t-1} + \lambda^{m,d} \widehat{R}_{i,t} + \sum_{j=1}^{N-1} \lambda_{i,j}^{m,i} \widehat{R}_{j,t} + \lambda^{f,d} B_{i,t}^g + \sum_{j=1}^{N-1} \lambda_{i,j}^{f,i} B_{j,t}^g \tag{4.3.8}$$

$$\boldsymbol{\pi}_t = \rho_\pi \boldsymbol{\pi}_{t-1} + \hat{\boldsymbol{R}}_t \boldsymbol{\lambda}^R + \boldsymbol{B}_t \boldsymbol{\lambda}^B \tag{4.3.9}$$

Monetary policies operate through an interest rate instrument, $\widehat{R}_{i,t}$. The instrument rate is set following a modified Taylor rule which incorporates the effects of the interest rate spread as well as levels and variations in output and inflation:

$$\begin{aligned} \widehat{R}_{i,t} = \rho_R \widehat{R}_{i,t-1} + (1-\rho_R) \left(\bar{\pi}_{i,t}^m + r_\pi \left(\pi_{i,t-1} - \bar{\pi}_{i,t}^m \right) + r_y \hat{y}_{i,t-1} \right) \\ + r_{\Delta\pi} \Delta\pi_{i,t} + r_{\Delta y} \Delta\hat{y}_{i,t} + r_\phi \tilde{\phi}_{i,t} + \varepsilon_{i,t}^R \end{aligned} \tag{4.3.10}$$

where $\bar{\pi}_{i,t}^m$ is the central bank's inflation target and $\varepsilon_{i,t}^R$ is a policy shock.

This modified rule, based on Adolfson et al. (2005) and (2007), takes into account the considerations of Taylor (2008)[18] and Cúrdia and Woodford (2010) on the central bank's concern for setting up a barrier between financial disturbances and the rest of the economy. In this version, an international component operates through our measurement of interest rate spreads. It is worth highlighting that the central bank is not only concerned about the levels but also about the size of the changes in macro variables from the previous period, reflecting also an interest on stability.

Our two-rule policy setting is a modification of Taylor (2001) where we stress on the nominal effects of fiscal policies and our focus on debt as a policy instrument lead us to consolidate the fiscal rules in Muscatelli, Tirelli and Trecroci (2004) into a single expression as in Equation 4.3.4.

[17] This reference, although changing in time, effectively represents the interest rate in absence of a risk premium.

[18] Based, in turn, on the results from Taylor and Williams (2009).

4.4 Spatial modelling approach

Our modelling methodology adopts the configuration of Spatial Durbin Models (SDM[19]). This is in line with a multi-country approach and useful for the purposes of accounting for relevant international transmission channels of the effects derived from fiscal and monetary policies. By applying these methods, we expand on similar previous examples like Romero and Burkey (2011) who applied spatial econometrics to investigate the links between government debt and economic growth taking into account the presence of international spillovers.

Spatial econometrics provides a useful methodological platform for the analysis of interdependencies between the units of study (here, fiscal and monetary authorities). Our interest in exploring the features of policy spillovers between OECD economies and the significant economic and financial links between them give a spatial dimension to this study. In particular, the SDM framework is of special value for our depiction of international spillovers because it allows for spatial interdependencies not only in the dependent variable but also in the explanatory variables in an heterogeneous fashion[20] (see LeSage and Pace (2009, Ch. 2) and Elhorst (2010)) which, as we have mentioned, is the appropriate case to address in this Chapter given the nature of the economic phenomena of interest.

A generic representation of a dynamic SDM model with fixed effects for N cross-sections can be written as:

$$y_{i,t} = \tau y_{i,t-1} + \rho \sum_{j=1}^{N} w_{i,j} y_{j,t} + \sum_{k=1}^{K} x_{i,t,k}\beta_k + \sum_{k=1}^{K}\sum_{j=1}^{N} d_{i,j} x_{j,t,k}\theta_k + a_i + \gamma_t + \epsilon_{it} \quad (4.4.1)$$

or, in vector notation:

$$\boldsymbol{y}_t = \tau \boldsymbol{y}_{t-1} + \rho \boldsymbol{W} \boldsymbol{y}_t + \boldsymbol{X}_t \boldsymbol{\beta} + \boldsymbol{D}\boldsymbol{X}_t \boldsymbol{\theta} + \boldsymbol{\iota}_N \boldsymbol{\alpha} + \gamma_t + \boldsymbol{\epsilon}_t \quad (4.4.2)$$

where $\boldsymbol{y}$ and $\boldsymbol{X}$ stand for a dependent variable vector and a matrix of K explanatory variables, respectively, ρ represents a coefficient of the strength of spatial dependence in the dependent variable, $\boldsymbol{W}$ and $\boldsymbol{D}$ are spatially-formulated weight matrices[21], $\boldsymbol{W}\boldsymbol{y}$ is termed a spatially auto-regressive component[22], $\boldsymbol{\theta}$ includes all the

[19] See Anselin (1988) and LeSage and Pace (2009, Ch. 3).

[20] This is an advantage in comparison to alternative spatial specifications as Spatial Autoregressive (SAR) models, for example, which operate with common global multipliers for each variable.

[21] There are many variants of these matrices although all of them share the main purpose of attempting to describe the degree of closeness or relevance the units of analysis have between each other. For a review of different approaches on the construction of these matrices see Getis and Aldstadt (2004).

[22] The spatial dimension in econometrics resembles some of the features of time-series economet-

coefficients for spatially-lagged regressors ($\boldsymbol{DX}$) which complements the impact of non-spatially-lagged regressors (as reflected by $\boldsymbol{\beta}$). The cross-sectional and time-related fixed effects are represented by a_i and γ_t, respectively, and $\epsilon_{i,t}$ is a stochastic error term.

One of the main arguments put forward by LeSage and Pace (2009) for the empirical application of spatial models is that the interpretation of spatial coefficients should adhere to a *partial-derivative* format which most of the times will differ from the usual interpretation of estimates in econometrics as these will also incorporate (and distinguish) spillovers across units. For this purpose the model in Equation (4.4.2) can be re-written as:

$$\boldsymbol{y}_t = (\boldsymbol{I} - \rho \boldsymbol{W})^{-1} \left[\tau \boldsymbol{y}_{t-1} + \boldsymbol{X}_t \boldsymbol{\beta} + \boldsymbol{D}\boldsymbol{X}_t \boldsymbol{\theta} + \boldsymbol{\iota}_N \boldsymbol{\alpha} + \gamma_t + \boldsymbol{\epsilon}_t \right] \tag{4.4.3}$$

And, therefore, the overall impact of the k-th regressor can be calculated from:

$$\left[\frac{\partial y}{\partial x_{1k}} \cdot \frac{\partial y}{\partial x_{Nk}} \right] = \begin{bmatrix} \frac{\partial y_1}{\partial x_{1k}} & \cdot & \frac{\partial y_1}{\partial x_{Nk}} \\ \cdot & \cdot & \cdot \\ \frac{\partial y_N}{\partial x_{1k}} & \cdot & \frac{\partial y_N}{\partial x_{Nk}} \end{bmatrix} \tag{4.4.4}$$

and, equally as:

$$\left[\frac{\partial y}{\partial x_{1k}} \cdot \frac{\partial y}{\partial x_{Nk}} \right] = \left((1-\tau) \boldsymbol{I} - \rho \boldsymbol{W} \right)^{-1} \begin{bmatrix} \beta_k & w_{12}\theta_k & \cdot & w_{1N}\theta_k \\ w_{21}\theta_k & \beta_k & \cdot & w_{2N}\theta_k \\ \cdot & \cdot & \cdot & \cdot \\ w_{N1}\theta_k & w_{N2}\theta_k & \cdot & \beta_k \end{bmatrix} \tag{4.4.5}$$

or, more compactly:

$$\left[\frac{\partial y}{\partial x_{1k}} \cdot \frac{\partial y}{\partial x_{Nk}} \right] = \left[(1-\tau) \boldsymbol{I} - \rho \boldsymbol{W} \right]^{-1} \left[\beta_k \boldsymbol{I}_N + \theta_k \boldsymbol{W} \right] \tag{4.4.6}$$

where $w_{i,j}$ are pairwise cross-sectional weights in $\boldsymbol{W}$ or in $\boldsymbol{D}$ if these matrices are not equal, and $(\boldsymbol{I} - \rho \boldsymbol{W})^{-1}$ is a spatial multiplier matrix embracing the feedback effects from first, second and higher orders of neighbourhood between units as can be shown by decomposing it in the following way:

$$(\boldsymbol{I} - \rho \boldsymbol{W})^{-1} = \left(\sum_{q=0}^{\infty} \rho^q \boldsymbol{W}^q \right) = \boldsymbol{I} + \rho \boldsymbol{W} + \rho^2 \boldsymbol{W}^2 + ... \tag{4.4.7}$$

rics (except for important distinctions such as the possibility of two-way simultaneous dependence between units for example) and, in this case, spatial lags mean the inclusion of values of the same variable, at the same point in time but from different units of study (e.g. countries). For a comprehensive introduction to spatial econometrics see LeSage and Pace (2009).

According to Elhorst (2010) this interpretative approach accounts for three main features contained in the matrix of partial derivatives:

- The distinction between *direct* and *indirect effects*, the former (in the main diagonal of Equation (4.4.5)) being those arising from changes in the same unit's explanatory variable while the latter (all non-diagonal elements in the right hand side of Equation (4.4.5)) are the impacts from changes in the same k-th variable but in different cross-sectional units.

- The heterogeneity between the direct and indirect effects according to specific pairings of units whenever $\rho \neq 0$ and $\theta_k \neq 0$.

- The possibility to distinguish between *indirect local effects*, when $\theta_k \neq 0$ reflecting the impacts from neighbouring units[23] and *indirect global effects*, occurring when $\rho \neq 0$ even between units out of each other's neighbourhood.

We gave preference to the spatial approach over alternative methodologies (as VAR or panel data models) due to its ability to represent the specific theoretical basis of an economic formulation under scrutiny while accounting for multiple units, time-periods and, crucially, for the heterogeneous effects of interdependencies between units (i.e. national/regional monetary and fiscal authorities) within certain clustering networks not only from a geographic point of view but also referring to those formed in relation to trade and financial exchanges.

However, given that the cross-unit heterogeneity expresses as a fairly large number of estimated coefficients, summary indicators are required for the purposes of a concise reporting and global analysis. In response to this requirement, LeSage and Pace (2009) propose the use of averages as more succinct indicators including, in first instance, all the diagonal elements on the right-hand side of Equation (4.4.5) for representing the direct effects and, secondly, the row (or column) averages of its non-diagonal elements for the representation of indirect effects.

This, in turn, brings about another requirement because the significance of these indicators of direct and indirect effects needs to be tested. Given their nature (as numbers depending on the values of a combination of other coefficients and their associated distributions) it has also been proposed by LeSage and Pace (2009) that the distribution of the direct and indirect effects could be simulated using the variance-covariance matrix of the parameters derived from a maximum likelihood estimation, which, according to Elhorst and Fréret (2009, p. 940, cited in Elhorst

[23] As defined in $\boldsymbol{W}$ and $\boldsymbol{D}$.

(2010, p. 23)) for the SDM model is:

$$Var(\hat{\rho}, \widehat{\boldsymbol{\alpha}}, \widehat{\boldsymbol{\beta}}, \widehat{\boldsymbol{\theta}}, \hat{\sigma}^2) =$$
$$\begin{bmatrix} \left[tr\left(\widetilde{\boldsymbol{W}}\widetilde{\boldsymbol{W}} + \widetilde{\boldsymbol{W}}'\widetilde{\boldsymbol{W}}\right) + \frac{1}{\hat{\sigma}^2}\widehat{\boldsymbol{\gamma}}\widetilde{\boldsymbol{X}}'\widetilde{\boldsymbol{W}}'\widetilde{\boldsymbol{W}}\widetilde{\boldsymbol{X}}\widehat{\boldsymbol{\gamma}} \right] & \widetilde{\boldsymbol{X}}'\widetilde{\boldsymbol{W}}\widetilde{\boldsymbol{X}}\widehat{\boldsymbol{\gamma}} & \frac{1}{\hat{\sigma}^2} tr\left(\widetilde{\boldsymbol{W}}\right) \\ \widetilde{\boldsymbol{X}}'\widetilde{\boldsymbol{W}}\widetilde{\boldsymbol{X}}\widehat{\boldsymbol{\gamma}} & \frac{1}{\hat{\sigma}^2}\widetilde{\boldsymbol{X}}'\widetilde{\boldsymbol{X}} & 0 \\ \frac{1}{\hat{\sigma}^2} tr\left(\widetilde{\boldsymbol{W}}\right) & 0 & \frac{N}{2\hat{\sigma}^4} \end{bmatrix}^{-1} \tag{4.4.8}$$

with $\widetilde{\boldsymbol{W}} = \boldsymbol{W}(\boldsymbol{I} - \hat{\rho}\boldsymbol{W})^{-1}$, $\widetilde{\boldsymbol{X}} = [\boldsymbol{\iota}_N \;\; \boldsymbol{X} \;\; \boldsymbol{W}\boldsymbol{X}]$, $\widehat{\boldsymbol{\gamma}} = [\widehat{\boldsymbol{\alpha}} \;\; \widehat{\boldsymbol{\beta}}' \;\; \widehat{\boldsymbol{\theta}}']'$ and $tr(\cdot)$ meaning the trace of a matrix.

As described by Elhorst (2010, p. 23), a collection of simulated parameter combinations is achievable by repeated draws[24] of:

$$\begin{bmatrix} \rho_d & \boldsymbol{\alpha}_d & \boldsymbol{\beta}'_d & \boldsymbol{\theta}'_d & \sigma^2_d \end{bmatrix}' = P'\vartheta + \begin{bmatrix} \hat{\rho} & \widehat{\boldsymbol{\alpha}} & \widehat{\boldsymbol{\beta}}' & \widehat{\boldsymbol{\theta}}' & \widehat{\sigma}^2 \end{bmatrix}' \tag{4.4.9}$$

where P stands for the upper-triangular Cholesky decomposition of $Var(\hat{\rho}, \widehat{\boldsymbol{\alpha}}, \widehat{\boldsymbol{\beta}}, \widehat{\boldsymbol{\theta}}, \hat{\sigma}^2)$ and ϑ is a $3 + 2K$ vector of random numbers from a normal distribution with mean zero and standard deviation of one.

A N_d number of draws is generated for estimated values of $\hat{\rho}$, $\widehat{\boldsymbol{\alpha}}$, $\widehat{\boldsymbol{\beta}}$, $\widehat{\boldsymbol{\theta}}$ and $\hat{\sigma}^2$, and direct and indirect effects, μ_{kd}, for the k-th explanatory variable are computed for each of these combinations, then the means, $\bar{\mu}_k$, and standard deviations are used to generate t-values of the form:

$$t_k = \frac{\bar{\mu}_k}{\frac{1}{N_d - 1}\sum_{d=1}^{N_d}\left(\mu_{kd} - \bar{\mu}_k\right)^2} \tag{4.4.10}$$

in order to assess the statistical significance of direct and indirect (i.e. spillover) effects.

4.4.1 Multi-country composite weights

Cross-sectional weights play an important role in this methodological framework. Under a purely geographical perspective they aim to measure the degree of pairwise closeness between units[25] which will then be embedded in the results of any application as a geo-spatial factor allowing for the presence of clusterings and externalities between cross-sections.

[24]By applying Bayesian Monte Carlo Markov Chain (MCMC) simulation for example.

[25]Even alternative concepts as neighbourhood, shared borders or bandwidth distances are all based on the physical distance between units.

Our formulation of the weights used for the econometric application, however, departs from the canonical literature on spatial analysis and aligns, instead, to recently seen variations embracing additional components. The setting we are proposing stems from relative simple principles: since we want, and need, these weights to express meaningful measurements of the relative importance each economy has towards each other within the OECD group, limiting ourselves to purely geographic measurements does not seem appropriate for taking account of more complex interrelationships where other important factors such as trade and financial exchanges are likely to have a consequential role.

For that reason, our stance is that an improved depiction of the overall economic relevance of an economy for each of its counterparts is achieved by including indicators of the commercial and financial exchanges between them in the weighting of their series. Subsequently, in order to prevent edogeneity issues and, following suggestions made by Baltagi (2004) on weighting multi-country series, we have calculated broad measurements[26] which are not associated to the impact of policy changes or even short-to-medium term developments of the variables in the models but reflect more structural relationships instead.

The main question to be answered when formulating these weights in the context of our study is not only how close but *how relevant* is economy i to economy j and vice versa. The answer we propose is based on the observation of historic interconnections in terms of two economic dimensions as trade and financial exchanges, in addition to the spatial factor, which is kept given that geographic closeness is feasible to have implications in terms of other consequential fields such as institutions, migration and remittances, technology transfers, etc.[27].

In a compatible way with SDM's structure, right-hand-side variables are weighted here in a way that reflects the relevance of each counterpart economy in the panel using factual and historically-based indicators, summarised by a composite matrix, $\boldsymbol{Z}$, as:

$$\boldsymbol{Z} = (0.2\boldsymbol{W} + 0.4\boldsymbol{T} + 0.4\boldsymbol{I}) \tag{4.4.11}$$

with $\boldsymbol{W}$ being a purely spatial (inverse distance) matrix, $\boldsymbol{T}$ is a normalised[28] matrix of an index of trade exchanges[29] and $\boldsymbol{I}$ is a matrix reflecting the relative positions in

[26]That is, averages of data spanning across long periods of time so that they are not influenced by quarterly policy changes.

[27]And also after the observation that, within our panel, geographic closeness is not necessarily associated to higher volumes of trade or larger financial exchanges. This is particularly true for the European economies we are considering and to some extent also for those in the Asia-Pacific region.

[28]Where each country's total foreign trade with the countries in the panel equals one in each period.

[29]Defined as the sum of exports and imports for a specific time-horizon (1995-2012, unless

terms of foreign direct investment. The specific details on the calculations of these weights are described in Appendix L.

Similar variants of weightings have appeared in recent empirical research exercises as Chudik and Fratzscher (2011) and Sun, Heinz and Ho (2013) (both without the geographic dimension), Triki and Maktouf (2012) (with trade-based weights) and Dees et al. (2007) with trade-based weights under a GVAR[30] framework for the analysis of cross-country linkages between European economies. Other studies as Sutherland (2004), Beetsma, Giuliodori and Klaassen (2006), Beetsma and Giuliodori (2011), Corsetti, Meier and Müller (2010), Corsetti and Müller (2011), Corsett et al. (2011), Faini (2006) and Lipińska, Spange and Tanaka (2009) have also looked into the relevance of commercial and financial channels of transmission for macroeconomic effects.

Nevertheless, a clear conclusion still cannot be reached from this debate on the comparative strength that each channel should be assigned in our weighting scheme. Our own data also reflects that, while both channels are highly relevant within our chosen regions, none can be clearly named as dominant. For this reason T and I in Equation 4.4.11 are given the same weight. From the same discussion, however, these two components are indeed considered dominant in relation to those which are assumed to be included in W and, therefore the latter is given a lower weight. These are, however, arbitrary choices which are expected to be improved by the means of further research on the relative weights for the components of Z.

As a result of the modifications on the weights for cross-sectional series, our econometric application is able to integrate relevant economic and financial linkages functioning as transmission channels between economies and, in contrast to purely spatial exercises, the estimates for international effects refer to spillovers not just between neighbouring economies but, more comprehensively, within economic and financial networks as expressed by the exchanges we have included in this weighting scheme.

4.4.2 Issues on identification

A recurrent discussion in the area of spatial econometrics relates to the potential problems of identification in its modelling. This is particularly accentuated in the case of dynamic models including temporarily-lagged as well as spatially lagged variables (see Anselin et al. (2008)). On this issue, our modelling adopts one of the restrictions proposed by Elhorst (2012, p. 23) for the use of a dynamic spatial Durbin model consisting of eliminating a spatially and temporarily lagged dependent

otherwise indicated).

[30] Global VAR modelling, developed by Pesaran et al. (2004).

variable term in the model. As shown in Elhorst (2012) feasible options to avoid identification problems in a dynamic spatial Durbin model of the form:

$$Y_t = \tau Y_{t-1} + \rho W Y_t + \eta W Y_{t-1} + X_t \beta + W X_t \theta + \varepsilon \tag{4.4.12}$$

include setting: 1) $\theta = 0$, 2) $\rho = 0$, 3) $\eta = -\tau\rho$ or 4) $\eta = 0$. As Elhorst (2012) argues, among the feasible alternatives to achieve identification, the last one is the less restrictive and has been supported by studies like Franzese and Hays (2007).

More recently, Lee and Yu (2016) put forward sufficient conditions for identification of spatial Durbin models representing network interactions based on the features of the weighting matrices. They argue that identification can be achieved by the structure of the weighting matrix W as long as the diagonal elements of W^2 are not identical. This way, the features of the described networks provide identification to these models.

In more detailed terms, they propose that, with an estimation method relying on Maximum Likelihood, Durbin models with fixed effects are identified if the matrices containing weighted and non-weighted dependent and independent variables (in first differences) have full-rank and I (a conformable identity matrix), $(W + W')$ and $W'W$ are linearly independent (Lee and Yu (2016, p. 146, Proposition 4)). In our application we use the same variables as Lee and Yu (geographical distance, exports+imports) for the construction of weight matrices plus FDI outward and inward positions which, in this regard, display similar network features (hollow matrices with pair-wise idiosyncratic values). This way, our model complies with their identification conditions too. An example of $(W + W')$ and $W'W$ (in our case, $(Z + Z')$ and $Z'Z$ with the composite weights) for 19 OECD economies is included in Appendix L.5. It is easy to observe, by their diagonal and non-diagonal elements that Lee and Yu's condition on the weighting matrix is met (distinctive diagonal values in $W'W$ and non-linearity between the three relevant matrices).

4.5 Data and empirical application

With the objective of unveiling the impact of a financial cost channel from fiscal policies and its domestic and international implications for monetary policies we follow an empirical strategy based on the theoretical and methodological grounds described above. We proceed in two stages: 1) demonstrating the nominal impacts of public debt and 2) illustrating their relevance for the management of monetary policies in an international context.

For these purposes, we gathered a quarterly panel of data on lending rates from

IMF's International Financial Statistics, Oxford Economics©[31] and national statistical sources, to be compared against the United States' 3-month Treasury Bill rate series taken from the Federal Reserve Economic Data database (FRED). Output data was obtained from OECD's Quarterly National Accounts database and de-trended by the means of the Hodrick-Prescott (HP) filter, governmental debt statistics come from Oxford Economics©, price indexes are taken from OECD's Main Economic Indicators and inflation was calculated on a quarter-on-quarter basis. Official (i.e. policy) interest rates were obtained from the corresponding central banks.

Risk ratings were obtained from The Economist Intelligence Unit's Overall risk index to which we applied linear interpolation in order to complete the gaps in the original series[32]. Although our main panel goes from 1991Q1 to 2013Q3, in the exercises including risk ratings the sample had to be resticted to 2001Q1-2013Q3 due to the coverage of these historical series.

4.5.1 Fiscal impacts on risk scores

Public debt is a central factor with multiplicative effects on the financial markets where it is issued and exchanged, particularly in relation to the associated expectations it contributes to generate. In Gates et al. (2012), for example, we have a first-hand explanation of the domestic impacts that sovereign ratings can have on economy-wide risk assessments including, in their words, other agents and financial instruments like "non-financial corporates, financial institutions, sub-sovereign entities and structured finance transactions"[33] which are subject to a significant degree of exposure and contagion risk to sovereign debt issues.

Its centrality in the domestic economic and financial systems and the multiplicative effects it can generate place the government as a natural benchmark in terms of risk assessments, commonly holding the best credit risk ratings in an economy. In turn, risk ratings on sovereign debt respond to a historical association between the occurrence of default and episodes of grave disruption in economic and financial activity, as recessions or banking and currency crises. Therefore events or trends with effects on the probability of default, as sustained debt accumulations, would typically lead to a decline in sovereign credit quality and in that of other exposed

[31]Both available via Datastream©.

[32]This index is not available for every period (we used quarterly data) but only for those periods when a change in the rating was published. By applying linear interpolation, instead of simply repeating the previous value, we aim to depict the displacements between periods and their graduality or steepness to achieve a better reflection of the trajectories between improvements or deteriorations in the index.

[33]Gates et al. (2012, p. 1).

agents among which financial institutions display truly potentiating consequences expanding those deteriorations to a country-wide scale.

A symbiotic relationship exists between the government's debt policies and the financial sector's risk conditions not only in terms of asset sheets, which is nevertheless a significant transmission channel, but also including broader operational circumstances and prospects. Expectational factors linked to the developments of public debt such as the resulting macroeconomic trends, the prevailing conditions of international confidence/liquidity constraints, the threat of remedial austerity programmes and even political uncertainty also participate in the integration of an economy's risk profile. All those factors translate into variations in the risk premia applied to the involved financial institutions in their competition for funding in the international markets and, therefore, in adjustments of credit costs throughout the economy.

But the relationship also operates in the opposite direction. For example, when the sovereign credit quality deterioration impacting financial institutions subsequently generates a negative feedback effect on the credibility of fiscal policy. This can happen given the resulting increased probability of scenarios where public intervention is required in support of the financial system or, alternatively, through the impacts of a restricted credit availability in domestic markets which would lead to macroeconomic contraction, further complicating the financial prospects and economic pressures on the government's policies (see OECD (2012) for an illustration of these phenomena in the case of the Euro area debt crisis).

Furthermore, the nominal outcomes of changes in risk assessments on public debt have even broader repercussions for the economy as they exert pressure on the trends followed by interest rates and, then, over the aggregate patterns of consumption and investment while, at the same time, modifying the action space for the operation of monetary policies. Our modelling, in addition, reflects the interest on the hypothesis that the effects of these assessments are not independent between countries and, particularly, that regional associations can be revealed in the context of commercial and financial networks.

For the purpose of obtaining a measurement of the domestic and international impact of public indebtedness on the overall risk assessment of an economy we use an empirical structure that allows for international connectedness of risk scores,

$Risk_{i,t}$[34] this model is expressed as:

$$\begin{aligned} Risk_{i,t} = \rho^{RS}\boldsymbol{Z}Risk_{i,t} + \beta^{RS,D}D^{g}_{i,t-1} + \beta^{RS,\pi}\pi_{i,t-1} + \beta^{RS,\hat{y}}\hat{y}_{i,t-1} \\ +\boldsymbol{Z}\left(\theta^{RS,D}D^{g}_{i,t-1} + \theta^{RS,\pi}\pi_{i,t-1} + \theta^{RS,\hat{y}}\hat{y}_{i,t-1}\right) \\ +\alpha^{RS}_{i} + \varepsilon^{RS}_{i,t} \end{aligned} \tag{4.5.1}$$

where D^g is public debt as proportion of GDP, $\boldsymbol{Z}$ is a composite weight matrix which includes purely spatial weights $\boldsymbol{W}$ as well as other relevant components such as trade $\boldsymbol{T}$ and financial weights $\boldsymbol{I}$ classifying each country's relative position towards the included counterparts within our OECD sample[35], $\pi_{i,t}$ is quarterly inflation and $\hat{y}_{i,t}$ an estimated output gap, α^{RS}_{i} are country-specific fixed effects and $\varepsilon^{RS}_{i,t}$ is a stochastic error term.

The results of this estimation for 19 OECD economies[36] are presented in Table 4.5.1. From them, we can observe that there is a significant international component (as measured by ρ^{RS}) operating between economies in terms of this risk evaluation and that governmental debt and inflation display both direct and indirect (spillover) impacts on the score while the relationship with the output gap is significant only in domestic terms.

We can, therefore, verify and measure the statistical impact that the developments of public debt have on this assessment of risk. By these means, debt management can intervene in the determination of a country's risk premium which will, as we elaborate later, eventually constitute a factor of adjustments in interest rates and, crucially, in the differential of the costs faced by financial institutions across the OECD.

Moreover, an important contribution of these results is the measurement of the indirect effects of public debt. In this sense, it is noticeable that risk scores are more sensitive to regional increases in debt (those occurring within the neighbourhood/network of a country) with the indirect effects coefficient amounting to 62.6 per cent of the total calculated impact of this variable.

In other words, the responsiveness of this risk rating indicates that increases in public indebtedness are more worrying when they are shared by a region or cluster of economies, to the extent that the external accumulation of debt inflicts a stronger impact to the rating than the one resulting from domestic fiscal policies. These results are in line with our previous review of Howell (2013) and WEF (2014) on

[34] As measured by The Economist Intelligence Unit© (under the concept of Overall risk rating score, obtained via Datastream©).

[35] See Appendix A for details on the calculation of the weight matrices used in this study.

[36] Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Slovak Republic, Sweden, Switzerland, United Kingdom and United States.

Table 4.5.1: Effect of fiscal policies on risk scores.

			$Risk_{i,t}$		
VARIABLES	Main	ZX	Direct	Indirect	Total
$D^g_{i,t-1}$	0.0656***	0.0198	0.0704***	0.118***	0.188***
	(0.0112)	(0.0177)	(0.0094)	(0.027)	(0.0284)
$\hat{y}_{i,t-1}$	-0.702***	0.426***	-0.688***	0.117	-0.571***
	(0.1226)	(0.1493)	(0.1304)	(0.2016)	(0.1768)
$\pi_{i,t-1}$	1.224***	-1.2098***	1.1902***	-1.0802*	0.1099
	(0.2248)	(0.351)	(0.2383)	(0.6414)	(0.6729)
ρ		0.545***			
		(0.0388)			
σ^2_ε (variance)	11.909***				
	(0.5472)				
Observations	969				
R-squared	0.3278				
Countries	19				
Sample	2001Q1 to 2013Q3				

Fixed effects are not reported (only individual effects were significant).
Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

the critical role of fiscal policies in shaping the international map of risks.

We also observe in the nature of the direct and indirect effects of public debt, revealed by their positive signs, that connectedness between economies makes them share factors of concern in this area. As we have described above, the international financial system provides a channel for the spreading of risks related to public debt and, this way, deteriorations or improvements in one economy are shared with others in the network with the same quality. This is in contrast, for example, with the indirect effects of inflation where external deteriorations (i.e. increases in inflation in the network) are associated to a reduction of the risk index of a country reflecting, therefore, emphasis on the relative soundness of the domestic economy. Unlike the case of public debt, the risk-externalities related to inflation open the doors to *beggar-thy-neighbour* policies (characterised by conflicting interests between parties).

4.5.2 Fiscal impacts on international interest rates spreads

As a variant of the empirical application by Hodrick and Vassalou (2002, p. 1280), we have fixed a single international reference interest rate against which each series on banking lending rates is compared in order to calculate a spread representing the corresponding cross-sectional relative risk premium. Using the resulting series as a dependent variable, a spatial econometrics version of Equation (4.3.6)[37] can be formulated as:

$$\begin{aligned}\tilde{\phi}_{i,t} = \tau\tilde{\phi}_{i,t-1} + \rho\boldsymbol{Z}\tilde{\phi}_{i,t} + D^g_{i,t-1}\beta^D + \pi_{i,t-1}\beta^\pi + \hat{y}_{i,t-1}\beta^{\hat{y}} \\ +\boldsymbol{Z}\left(D^g_{i,t-1}\theta^D + \pi_{i,t-1}\theta^\pi + \hat{y}_{i,t-1}\theta^{\hat{y}}\right) \\ +\alpha_i + \lambda_t + \varepsilon_{i,t}\end{aligned} \tag{4.5.2}$$

where $\tilde{\phi}_{i,t}$ is i-th country's interest rate spread between its lending rate and the United States' 3-month Treasury Bill rate[38]. This equation also includes country, α_i, and time-fixed effects, λ_t, as well as a stochastic error term, $\varepsilon_{i,t}$.

However, learning from Akitobi and Stratmann (2008) on ways of addressing the issue of endogeneity between fiscal stances and interest rate spreads, we approximate an indicator of discretionary fiscal policy, $\xi^{gdebt}_{i,t}$, by the means of a second-level estimation. The equation mainly develops on the grounds of two macroeconomic variables which are most commonly included in the objective function of macroeconomic policy-makers[39] such as the output gap and inflation (the *fundamentals*). These two variables are considered to be the main triggers for the response of automatic stabilisers (an effect we want to disentangle from the series on public debt.). For this purpose, an AR(1) model with fixed effects was used to derive the discretionary component of government's debt as represented by the residuals of:

$$\begin{aligned}\Delta D^g_{i,t} = \gamma^{gdebt}_1\hat{y}_{i,t-1} + \gamma^{gdebt}_2\pi_{i,t-1} + \gamma^{gdebt}_3\pi^2_{i,t-1} \\ +\lambda^{gdebt}_t + u^{gdebt}_i + \xi^{gdebt}_{i,t}\end{aligned} \tag{4.5.3}$$

There, a squared inflation term is added in order to account for possible non-linearities in the nominal relationships in this equation, λ^{gdebt}_t represents time-fixed effects while u^{gdebt}_i stands for idiosyncratic fixed effects.

Equation (4.5.3) implies that fiscal policies are the final result of a composite structure of impulses where the first part ($\gamma^{gdebt}_1\hat{y}_{i,t-1} + \gamma^{gdebt}_2\pi_{i,t-1} + \gamma^{gdebt}_3\pi^2_{i,t-1}$) assumes the role of a modified Taylor rule for fiscal policies (see Equation (4.3.4) above), the second is a fixed effects adjustment component ($\lambda^{gdebt}_t + u^{gdebt}_i$) and the third ($\xi^{gdebt}_{i,t}$) includes the remaining variations in the instrument deemed, therefore, as discretionary in the sense of unanticipated (given the described information set).

[37]For the sake of clarity, we omit the summation operators.

[38]Which is taken, therefore, as an international risk-free rate. This brings about the assumption of perfect access for all the included economies to the primary market of debt instruments valued at this rate.

[39]Even more so in the context of fiscal-monetary interaction models.

This estimation is valuable in its own right since, from it, we can appreciate some features of the responsiveness of our selected fiscal indicator to key macroeconomic developments. The results are included in Table 4.5.2 reflecting the partition of the sample into *low variation* and *high variation* series[40].

Table 4.5.2: Measuring the *automatic* component of government debt.

	$\Delta D^g_{i,t}$	
VARIABLES	Low var.	High var.
$\hat{y}_{i,t-1}$	-0.160***	0.0856**
	(0.0355)	(0.0357)
$\pi_{i,t-1}$	-0.256*	0.115*
	(0.141)	(0.0578)
$\pi^2_{i,t-1}$	0.0941*	-0.0007*
	(0.0539)	(0.00037)
Observations	1,615	760
Countries	17	8
R-squared	0.282	0.188

Fixed effects are not reported.
Robust standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

We can derive key distinctions from the dimensions and direction of these coefficients, especially when comparing the two partitions of our sample. In fist instance, it is evident that the *automatic stabilising* component of fiscal policy displays a considerably larger sensitivity to inflation and the output gap in low-variation countries (around twice that of high-variation countries in the case of the linear coefficients).

It is also noticeable that the direction of the adjustments follows a completely opposite pattern for each group:

- In relation to economic activity, as measured by the output gap, while in low-variation countries governmental debt behaves in a (lagged) counter-cyclical manner, high-variation economies tend to experience pro-cyclical (lagged) variations.
- In terms of the general response to inflation, low-variation economies energetically avoid overheating conditions typically by reducing their indebtedness

[40]This partition was performed on the basis of the dispersion of the interest rate spreads, $\tilde{\phi}_{i,t}$, in such a way that *low variation* countries are those with a standard deviation strictly lower than 9 within the series comprising the period 1980q1 to 2014q1. Both listings are included in Appendix K.

whereas high-variation economies display the opposite behaviour.

- From the non-linear factor of inflation, we observe that the levels reached by inflation matter for low-variation countries. That means that the change in debt will be different according to the gravity of the previous situation in terms of prices. For high variation countries, although the equivalent coefficient is statistically significant, it is too small to attribute any meaningful response in this sense.

The residuals from the estimation of Equation (4.5.3), $\hat{\xi}_{i,t}^{gdebt}$, are shown and evaluated in Appendix M[41]. These were subsequently replaced into Equation (4.5.2) to perform the following regression:

$$\begin{aligned} \tilde{\phi}_{i,t} = \tau\left(\tilde{\phi}_{i,t-1}\right) + \rho\boldsymbol{Z}\left(\tilde{\phi}_{i,t}\right) + \hat{\xi}_{i,t-1}^{gdebt}\beta_{\xi}^{D} + \pi_{i,t-1}\beta^{\pi} + \hat{y}_{i,t-1}\beta^{\hat{y}} \\ +\boldsymbol{Z}\left(\hat{\xi}_{i,t-1}^{gdebt}\theta_{\xi}^{D} + \pi_{i,t-1}\theta^{\pi} + \hat{y}_{i,t-1}\theta^{\hat{y}}\right) \\ +\alpha_i + \lambda_t + \varepsilon_{i,t} \end{aligned} \tag{4.5.4}$$

The results are shown in Table 4.5.3 including the model's regressors (*Main*), the spatially-lagged regressors (ZX) and, most importantly, the direct, indirect and total effects calculated on the basis of LeSage and Pace (2009, Ch. 2 and Ch. 4). These are able to quantify the bi-directional international feedback effects from variations in the regressors while accounting for the commercial and financial networks described in our weighting scheme.

It is noticeable the confirmation of a highly significant international dimension for the dependent variable (as measured by ρ) which backs the approach we have taken on risk-sharing networks. On the policy side we can see that, in addition to its responsiveness to fundamental variables (output and inflation), interest rate spreads also react to the discretionary component not only of domestic fiscal policies (the direct effect) but also to that of foreign counterparts (the indirect effect) within the low-variation sub-sample[42] in such a way that increased levels of public debt lead to increases in the relative interest rate spreads.

Again, the extent to which a network is affected by public indebtedness proves to be important as we observe the size and sign of the coefficient of indirect effects in comparison to the one on the direct outcomes of debt. In this case the foreign or, in our terms, network-related component amounts to 81.7 per cent of the total

[41] Although none of the fixed effects are reported, appropriate tests were conducted to confirm the presence of idiosyncratic and time-fixed effects. Hausman tests for the former and Wald tests for the latter.

[42] We excluded the United States from this exercise since it holds the role of reference country (i.e. the spread against its own rate is not significantly different from zero).

calculated impact of this regressor. On the other hand, a relevant difference from the previous section relates to the impact of foreign inflation. When analysing the association with interest rate spreads, the indirect effect of inflation is positive (as is the direct effect) which points towards the existence of a discrepancy between tacit and implicit evaluations of risks in the markets. In the latter case, it is manifest that inflation in an economy's international network has a pronounced effect on the interest rate spread it experiences.

In a similar line, we also notice that, given the financial nature of the dependent variable, when evaluating the responses to international developments (i.e. indirect effects) it appears to be more sensitive to nominal than to real variables[43]. In comparative terms, the indirect effects from governmental debt and inflation are larger than those arising from foreign output gaps.

The estimate for the indirect effect of (discretionary) governmental debt implies that, in average, if all the countries in a network contained in the low-variation sub-sample increase their public debt by one percentage point (recall we are using measurements as percentage of each country's GDP), a single economy will receive network effects leading to an increase in its own relative spread by more than nine basis points in a quarter. In turn, our estimated discretionary component of governmental debt also displays a non-negligible impact on the spreads as a domestic factor. In average, the direct effect means that for every unit increase in domestic government debt the relative spread will increase by 2 basis points in the following quarter.

Finally, the same exercise was applied to the high-variation sub-sample (9 countries[44]) but a number of factors indicate this configuration is not adequate for their specific study. First, and most importantly, the linkages between this group of economies are more diffuse when they are examined outside the low-variation interaction space[45].

In this sense, the implications are that economic networks play an important part in the determination of spreads (i.e. in the transmission of risks) but also that the dominant participation of key economies renders insignificant other exchanges outside their sphere of influence.

[43] Recall we are analysing quarterly data, more structural (long-term) evaluations may be prone to give higher relevance to real variables.

[44] Chile, Greece, Hungary, Ireland, Mexico, Poland, Portugal Spain and Turkey. It is noticeable that most of these countries display a considerable geographic dispersion. Also, most these economies have experienced periods of very large variations in their series which makes very difficult to perform an accurate assessment of their interrelations.

[45] The largest link, represented by the weight given to Spain by the Portuguese economy, is mostly dominated by their geographic proximity but, still, at very low levels when compared to the commercial relation of the latter with Germany or to its exchange of investments with the Netherlands.

Table 4.5.3: Effect of fiscal policies on spreads (low-variation countries).

VARIABLES	Main	ZX	$\tilde{\phi}_{i,t}$ Direct	Indirect	Total
$\tilde{\phi}_{i,t-1}$	0.941***				
	(0.00605)				
$\xi^{gdebt}_{i,t-1}$	0.0215*	0.182**	0.0209*	0.0923**	0.113***
	(0.0112)	(0.0861)	(0.0122)	(0.0390)	(0.0437)
$\hat{y}_{i,t-1}$	0.121***	0.189***	0.121***	0.0822**	0.203***
	(0.0162)	(0.0708)	(0.0178)	(0.0344)	(0.0353)
$\pi_{i,t-1}$	0.0495*	0.503***	0.0460*	0.230**	0.276***
	(0.0287)	(0.190)	(0.0273)	(0.0974)	(0.106)
ρ		0.248***			
		(0.0438)			
σ^2_ε (variance)	0.243***				
	(0.00888)				
Observations	1,440				
R-squared	0.973				
Countries	16				
Sample	1991Q1 to 2013Q3				

Fixed effects are not reported.
Standard errors in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

4.5.3 Implications for monetary policies

In the map of interactions between monetary and fiscal policies, the financial effect on debt of the management of interest rates by the central bank has an evident expression in Equation (4.3.3) where monetary decisions directly affect the domestic costs of debt repayments. In turn, in this Chapter we choose to stress on the relevance of fiscal policies in relation to their impact on the feasible space available to monetary policies to manage their instruments.

Having established that fiscal policies display significant direct and indirect impacts on lending rates which, in our context, involve an expression of the comparative standing of each economy in terms of its perceived risks, we now turn our attention to elaborate on the relevance of these results for monetary authorities, particularly those relying on the management of interest rates as their main instrument.

The confirmed presence of not only domestic but also international externalities from fiscal policies, which modify the patterns of interest rates, justifies the inclusion of a component representing spreads in the modified Taylor rule in Equation (4.3.10). This alternative, simplifying expression has, therefore, the advantage of embracing the effects from both domestic and international fiscal sources of pressure on the rates and, by doing so, provides a concise and transparent account of vertical and horizontal interactions with monetary policies.

I our view, this variant keeps the spirit of the recommended structure given by Taylor (2008) in relation to the incorporation of monetary adjustments to disturbances in the financial markets as a measure to prevent them from spreading into the economy and, in addition, takes in consideration the impacts of international externalities.

But central banks can only exert their direct influence on policy rates while lending rates are, by every account, established by financial markets in a de-centralised way. The costs faced by financial intermediaries and other financial frictions generate a gap between those rates. On the other hand, it is true that the way financial intermediaries operate implies that commercial rates cannot diverge substantially from the benchmarks given by official rates[46] and, above all, from the trends pursued by the monetary authorities. So, for our narrative on a necessary response from monetary policies to be valid, it is first required to explore the link between the policy instruments and the rates in the domestic credit markets.

For this purpose, we examine the empirical features of the relationship between lending rates and the conduct of monetary policy-controlled rates in OECD countries. Using lending rates and official policy rates series for a panel of 25 countries[47] between 1990Q1 and 2013Q4 we assess the extent of the correspondence in their patterns over time by the means of a fixed effects (FE) model which takes into account heterogeneities among individual series.

In table 4.5.4, a close correlation between official and commercial rates is verified all across the sample. These results are consistent with the estimations of Chowdry, Hoffmann and Schabert (2006) on the imperfect pass-through between policy rates and lending rates.

Subsequently, we test our claim that the fluctuation of interest rates in the private markets constitute a modification of the manoeuvring space for monetary authorities. In other words, that a two-way interaction exists between private developments

[46] Of course a number of particularities intervene in the differences between a policy rate and the various rates in the domestic financial markets. Different maturities, market segmentation and others imply the coexistence of a range of rates. However, our argument takes the notion that if the central bank applies a change in its official rate, the whole yield curve will eventually adjust to it, ruling out fundamental discrepancies.

[47] Australia, Austria, Canada, Chile, Czech Republic, Finland, France, Germany, Iceland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.

Table 4.5.4: Policy rates and commercial lending rates: FE model.

	Var. Dep.: *Policy rate*			
VARIABLES.	Coef.	Std. Err.	t-stat	Prob.
Lending rate	0.962	0.018	52.05	0.000
Constant	-4.668	0.258	-18.10	0.000
Observations	2055			
R-squared	0.726			
Countries	25			
Sample	1990Q1 to 2013Q4			

Fixed effects are not reported.

and policy decisions.

Monetary policy-makers reading data on the conditions in the financial sector and exerting, at least partially on that basis, influence over the markets sets the case for a test on the causality forces behind this cycle. Otherwise, those monetary authorities would be able to completely sterilise any disturbance by assuming policy-stances in an independent way from the prevailing financial scenarios.

For an exploration of the statistical association in that regard, we applied a Pairwise Dumitrescu-Hurlin (DH) Panel Causality Test[48] (see Dumitrescu and Hurlin (2012)) to the series[49]. The results indicate that there exists a bi-directional causal relationship between them. This means, first, that policy rates influence market rates as expected but, importantly, that they also receive a degree of pressure coming in the opposite direction.

The implications of these outcomes are important since they provide a complementary perspective on the monetary management that has not been widely examined. First, on a quarterly basis, policy rates cannot display significant divergences from market rates and, secondly, monetary authorities are not able to completely counteract disturbances to the lending rates which may arise, as we have shown, after the effect of factors such as the externalities imposed by domestic and foreign fiscal policies.

Their inability to fully suppress the effects of fiscal externalities means that

[48] This is, in strict terms, a non-causality test (in the sense of Granger (1969)) which takes into account the heterogeneity between cross-sectional series in a panel.

[49] For this test, we have selected one quarterly lag due to the intrinsic immediacy of the changes in these variables which is supported by the results in Table 4.5.4 and the cross-correlogram for these series shown in Figure 4.5.1 where the largest correlation occurs in a simultaneous manner (during the same quarter).

monetary policies must accommodate their own instrument accordingly once those impacts have realised. This evidence supports the appropriateness of an institutional arrangement where fiscal policies act as Stackelberg leaders in the fiscal-monetary game (in agreement with the conclusions reached in Dhami and al-Nowaihi (2011), Dixit and Lambertini (2003), Kirsanova, Stehn and Vines (2005) and Niemann and von Hagen (2008)).

Figure 4.5.1: Policy rates and commercial lending rates: cross-correlogram.

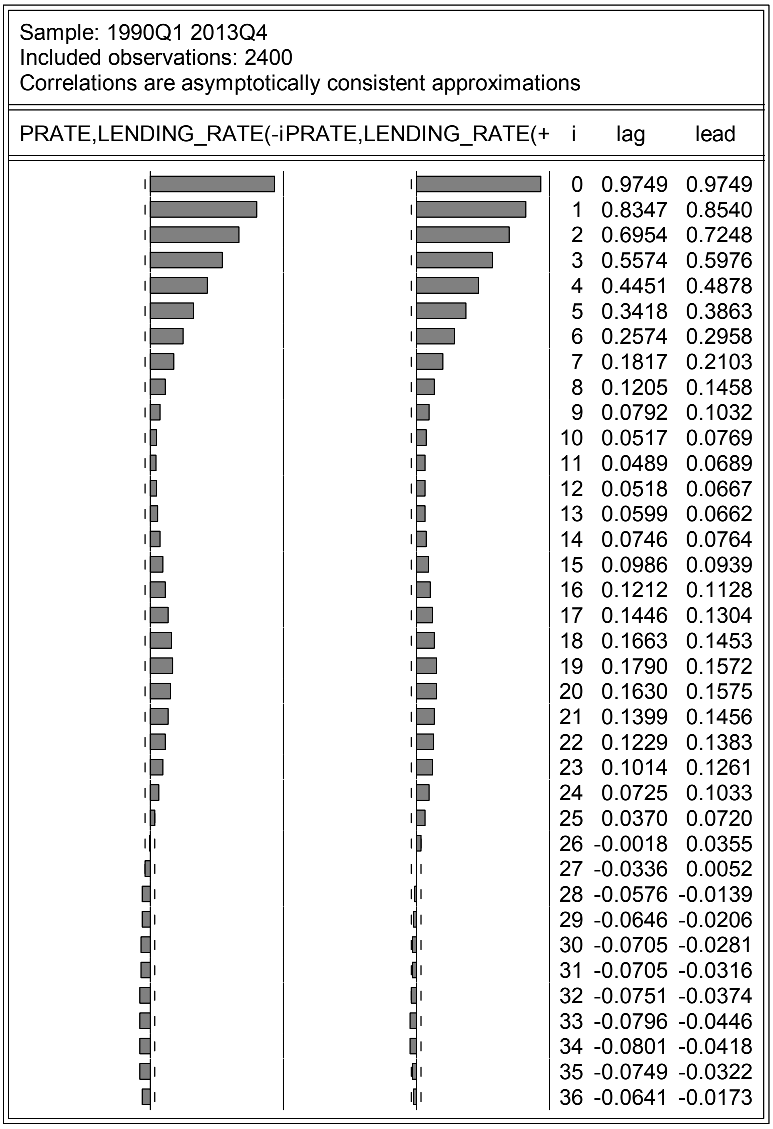


Table 4.5.5: Policy rates and commercial lending rates: DH tests.

Pairwise Dumitrescu Hurlin Panel Causality Tests			
Null hypothesis	W-Stat	$\bar{Z}$-Stat	Prob.
Lending rate does not homogeneously cause Policy rate	0.2206	-2.72638	0.0064
Policy rate does not homogeneously cause Lending rate	0.1083	-3.10821	0.0019
Sample	1990Q1 to 2013Q4		
Countries	25		
Lags	1		

4.6 Omitted variables and the Spatial Durbin Model

The observation of pair-wise correlations between variables in empirical applications of spatial econometric models has been suggested as a way to infer the presence of an omitted variable with spatial dimensions. In our case, the highest of such correlations appears in the case of output series we have used in our empirical exercises.

Table 4.6.1: Pair-wise cross-section correlations of the data.

Variable	PWC		Variable	PWC
$Risk$	0.54		$\tilde{\phi}$ (spread)	0.50
D^g	0.29		ξ^{gdebt}	-0.06
$\hat{y}$	0.73		$\hat{y}$	0.65
π	0.44		π	0.36
Countries	19		Countries	16

This is a reflection of the interconnections between economies across our sample. The suggestion is, however, that these conditions cast doubt on the reliability of the estimates obtained by the means of spatial methodologies.

The literature on spatial econometrics, in turn, has discussed this issue and arguments have been put forward in defence of an evolved configuration with spatially-lagged dependent and independent variables as is the particular case of the Spatial Durbin Model (SDM) we used.

LeSage and Pace (2009, Ch. 3) provide a wide explanation on the advantages of the SDM over other spatial techniques precisely in the context of omitted variables with spatial dependence arguing that it is, in fact, "a strong motivation for use of the SDM model specification in applied work where omitted variable problems seem likely"[50]. They warn, nevertheless, that if the SDM is applied when the underlying data generation process corresponds to alternative settings without spatial lags in the explanatory variables (as in the spatial-autocorrelation model or SAC), the results will still be consistent but inefficient. On this point, our application has shown good significance of the spatially lagged components of the models confirming, by these means, the applicability of the SDM setting.

Elhorst (2010, p.14) supports the use of SDM schemes based on their ability to produce unbiased estimates even in cases where the *true* data generating process belongs to a different spatial model.

As LeSage and Pace (2009, Ch. 3) and Pace and LeSage (2010), Fingleton and Le Gallo (2009) concluded that the biases in the estimates obtained from SDM are lower than the ones resulting from models which ignore the presence of omitted variables. Ertur and Koch (2007) also supported this case in an international application of the Solow model with omitted information and technological interdependence.

Corrado and Fingleton (2012) found that the SDM configuration is of practical use for mitigating possible biases arising from omitted spatially dependent regressors although they condition this result on the correct choice of weighting matrices in the models.

Gibbons and Overman (2012), however, disagree with these findings and consider the SDM as a tool which still cannot be rendered as a *general* solution to the omitted variable problem given its shortcomings in relation to more general (non-spatial) settings when compared with alternative methods as those relying on instrumental variables. Further research is needed in this area.

4.7 Conclusions

Although the fiscal-monetary interactions have long been subject to scrutiny in the context of the *unpleasant arithmetic* of Sargent and Wallace (1981) and other leading theoretical research as Dixit and Lambertini (2001, 2003a), the recent experience of restricting conditions for monetary policies has resulted in an increased interest for the study of the fiscal counterparts as a complementary resource for the matters of macroeconomic stabilisation. In line with these views acknowledging more important roles to fiscal policies, we have targeted the study of a particular channel of transmission associated to their impacts on the domestic and international financial markets. Our assessment has taken into account both explicit (risk ratings) and

[50] LeSage and Pace (2009, p. 75).

implicit (risk premia in interest rates) responses to developments in public debt.

By the means of our empirical application, using an innovative multi-country weighting scheme, we have confirmed and measured the impact of fiscal policies on nominal variables which are central to the performance of financial markets in an internationally competitive context as represented by OECD economies. In turn, these impacts have important consequences for the operation of each of those economies given that they modify their respective patterns of financial costs. It is also important to notice that these outcomes are not limited by national frontiers as significant international spillovers do exist.

We have provided evidence of a relevant international effect of public debt which can be associated in practice to historical periods of generalised deterioration in the public accounts (as in the case of the 2009 Euro area debt crisis). As discussed above, those generalised events are a current source of concern in the analysis of global trends in the aftermath of a financial crisis.

These findings are relevant for monetary authorities since the mentioned outcomes of developments in fiscal policies generate changes in the space of action available for the management of interest rates in an economy. As a result of what we have defined as a fiscal cost channel, deeper impacts can be expected, spread by the financial sector, in relation to the aggregate patterns of consumption and investment in face of the changes in the costs of funding.

Future developments for this study may point towards distinguishing the specific roles of public debt's sub-classifications as domestic and foreign debt and other particularities as its different maturities which will provide a more detailed profile of their corresponding impacts. It also remains in this agenda the opportunity to explore the direct and indirect effects of monetary policies and their significance for fiscal policies in a mirroring framework to the one used in this Chapter.

Chapter 5

Conclusions

5.1 Conclusions

In this thesis we have addressed key issues on international economic and financial interactions and the resulting implications for monetary and fiscal policies in selected OECD countries. We adopted an international perspective in view of contemporaneous events that make its relevance evident in the context of growing networks across the world economy and with the objective of contributing to the understanding of the features and consequences of such interactions by the means of appropriate tools of specialised research.

The New Open Economy Macroeconomics literature has a justified revitalised role in the current practice of research and policy studies. Nevertheless, wider dimensions of analysis are increasingly required. Generalised events as the 2007-2009 financial crisis, the subsequent global recession and the European sovereign debt crisis are but a few recent reminders of the relevance that common shocks have on the performance of national and regional economies. The idiosyncratic exposure and vulnerability to international sources of disruption, on the other hand, have significant implications for the design of national macroeconomic policies.

However, despite the central role they hold in modern macroeconomics and their frequent use for policy analysis purposes, the vast majority of DGSE models are still lacking regional and global perspectives of interactions between heterogeneous economies as well as detailed descriptions of the relationships they display with other members of the relevant commercial and financial networks. Policy makers, as a consequence, face an important restriction in terms of information on the effects that international shocks have on their respective spaces of action. These circumstances may lead to inefficient policies by ignoring disturbances generated on national economies as a result of regional and global shocks.

Unfortunately, previous research has failed to comprehensively explore the implications of international interactions beyond monetary unions or groups of relatively homogeneous economies. This creates a gap in the economic knowledge on interactions occurring at wider regional or global levels and on the potential adjustments that national authorities could perform accordingly.

That is why, as a response to those shortcomings in the previous literature, the macro-econometric platform for policy analysis we developed in Chapter 2 provides an innovative expansion of the open-economy setting described in Adolfson et al. (2005, 2007)[1] to a wider multi-country framework. We incorporated key components on international relationships, as country-specific foreign variables and international weights, for a more particular representation of the macroeconomic links and interactions between economies. With our addition of a broader international perspective to an otherwise single-economy model, the structure of selected variables in the resulting framework allowed for the study of regionally and globally-common disturbances absent in the original model.

The resulting macroeconomic framework is, in comparison to most current DSGE settings, aimed to analyse wider international aspects of macroeconomic relationships between economies while, at the same time, provides a high degree of specificity on the features of the heterogeneous national units which are included. Only highly-developed (and highly-complex) models in the current macroeconomic research (as Kumhof et al. (2010)) have approached such international issues with a comparable international perspective.

By the means of our expansion of Adolfson et al. (2005, 2007) to a multi-country setting, we contribute to close the knowledge gap on international interactions with a coherent and flexible macroeconometric platform for the analysis of international shocks. The coverage of our empirical analyses is also intended to reduce the *local bias* found in previous models in exchange for a wider perspective on international networks in economics and finance. In contrast with its original foundations and with other examples of DSGE modelling in the international field, the resulting extended model is capable of assessing the impacts of regionally and globally-common shocks.

Bi-directional weights embedded in the model, precisely measuring the focus and asymmetries of commercial and financial interconnections, are crucial complements we calculated for each economy's profile in the model which contributed to an equally detailed formulation of country-specific foreign variables. Such a design is instrumental in the model's new ability to distinguish and represent the heterogeneous relationships and exposures to foreign shocks between similarly varied economies which constitute the main focus of this thesis. National units, in the context of our research, assumed distinct roles in the exchange of international externalities as

[1]Based, in turn, on the Christiano, Eichenbaum and Evans (2005) paradigm.

generators and/or *receivers* of disturbances.

Our modelling of macroeconomic policy variables is characterised, this way, by the inclusion of regionally-shared shocks. Unlike previous modelling which evaluated international shocks from the perspective of either a monetary union, large economies or national scopes, our extended framework embracing all those possible profiles proved valuable for the assessment of a richer set of interactions within and between wider international networks as represented in our regional settings.

On the one hand, the depiction of fully-fledged monetary unions, as a special case of regional configuration in the model[2], enabled us to perform well-suited simulations about shocks in the Euro-zone. But, in addition to that, fiscal and monetary policy variables adopted a new configuration which allow the researcher to design experiments where policies shared international shocks without necessarily being involved in a formal agreement. This is a stance rarely found in a research field where a monetary union is a dominant feature in the typology of cases analysed by previous research but, as we have mentioned, historic instances of common shocks beyond monetary unions have not been infrequent and this required a wider approach to international macroeconomics.

For monetary policies in our setting, for example, in addition to the reactions to the real exchange rate of the original ALLV configuration, we included in the modified *Taylor* rules elements of monetary adjustment in the policy rate as responses to variations in the relative risk premium (represented by a spread between interest rates) and to regional shocks. These modifications derived from the bases set by Taylor (2008) on the need to adjust monetary policies to conditions of financial volatility as the one experienced during the 2007-2009 financial crisis.

Fiscal policies, in turn, as an expansion of Fernandez-Villaverde (2010), were depicted on the bases of dynamic stochastic processes also displaying exposure to common shocks recognising possible scenarios of common fiscal deterioration as the one corresponding to the 2009 European debt crisis.

Our international-shock evaluation framework includes macroeconomic information for all 34 economies in the OECD, however, for the achievement of greater precision and specificity, the parameter profiles of 12 OECD economies[3] (9 of them used in the main body of Chapters 2 and 3) were further individualised by the means of historical data and Bayesian estimations. This updating allowed for a well-calibrated execution of stochastic simulations of selected shocks in the model,

[2]Our regional design allows for the members of monetary unions to retain their economic and financial national features, including independent fiscal policies, therefore there is no need to create other aggregations as an *Euro-country*, for example.

[3]Australia, Belgium, Canada, France, Germany, Italy, Japan, Korea Mexico, the Netherlands, Spain and the United States.

and to assess the differentiated responses within and between regions in terms of a *welfare set* defined by output, consumer and general prices, the interest rate and employment in each economy.

As an expression of the advantages of our modelling, the results of its empirical application confirmed the presence of international macroeconomic externalities and showed their particular features across three OECD regions: North America, the Euro-zone and Asia-Pacific. This kind of empirical contrasts have not been addressed in previous studies but are, nevertheless, important to consider from national, regional and global-macroeconomics points of view given their intervention on the space of action available to policy makers.

In a series of exercises that, to the best of our knowledge, are unique in the macroeconomic literature (most certainly in DSGE's), the comparative international implications of standardised shocks to the discretionary elements of monetary policy and to the rules applied by the corresponding authorities were studied, expanding the *rules-versus-discretion* analysis to a multi-national context.

Our study of international externalities found that shocks to the inflation targets pursued by regionally-leading monetary authorities (which, therefore, acted as shock-originators) display larger and more persistent effects on macroeconomic variables of shock-receiving economies in contrast to comparable discretionary monetary shocks. Shocks involving the monetary rules generated larger disruptions in the welfare set for all three regions when compared to shocks to the discretionary component of monetary policies.

These findings provide additional information and support to the literature on international policy coordination in the form of specific measurements of vulnerability to the foreign setting of macroeconomic policies. This is particularly relevant in a context where large and small economies interact given that, in a leadership game (as Stackelberg, for example), the latter would find valuable considering these developments in the leader's rules into their own policy design in order to accommodate to the resulting international real and nominal externalities.

We also compared the international effects of shocks to the risk premium and found contrasting variability between regions in the responses of real and nominal variables according to their composition and economic arrangements but, most importantly, we measured in each case the comparative vulnerability to these financial deteriorations. The Euro-zone displayed particular exposure to this type of shocks both in nominal and real terms. This information is valuable for the adjustment of monetary policies to conditions of financial variability as suggested by Taylor (2008) for the US economy and extended in our modelling to reflect international financial conditions.

Cross-policy externalities, also at the international level, were similarly scrutinised in the form of the nominal responses to foreign fiscal shocks. In this context, spending shocks proved to generate larger disruptions to welfare in the NAFTA and Euro-zone regions but income tax shocks generated the largest deviations in the Asia-Pacific region. These exercises provided relevant information on the inter-regional specificities of the responses to comparable regional shocks and, in doing so, further contributed to show the relevance of our international approach given that, under these circumstances, domestic monetary authorities have to adjust to the externalities produced by foreign fiscal policies.

Similarly, we took the analysis on the implications of differences in preferences between policy-makers to an international stage. Our platform addresses this issue by the means of contrasting the effects of regionally-common shocks to world output and world inflation. The results contribute to discern that, from a global point of view, common output shocks are considerably more disruptive for the welfare set of the member economies in each region. In this sense, the preferences displayed by foreign macroeconomic authorities in terms of the output/inflation dichotomy matter for the success of national policies. Our evidence favours the argument for giving a higher weight to output stabilisation for the benefit of the global economy as depicted in our study.

The contrasts in the impacts on domestic variables between the two sources of disruption can be as wide as 68.5 per cent and, therefore, the implications for domestic macroeconomic policies are significant. In terms of policy coordination, this means that: 1) the stances assumed by foreign authorities in their selection of priorities between output and inflation do matter for the domestic management of macroeconomic policies[4] and 2) that the effects are unevenly distributed among members of the regions we have analysed creating distinctive challenges to the corresponding domestic economic authorities to adjust in view of those effects.

In general terms, the features of the exchanges of externalities we have explored by the means of our new policy evaluation platform, contribute to a better understanding of the implications derived from strategic roles observed in the international economy where countries or regions act as leaders or followers according to the relevance they hold against other participants and the vulnerabilities displayed at the national level, concepts for which we have provided specific measurements in the cases of selected OECD economies.

The results of these exercises, combining national, regional and global aspects of macroeconomic interactions, are evidence of our framework's capabilities for the analysis of international scenarios which would have, otherwise, been out of reach for

[4]To the comparative extent that we have specifically measured for each case.

previous models with a more restricted international outlook. They provide valuable information for the re-assessment of domestic policies in view of the international impacts to which they are susceptible in particular degrees.

Subsequently, in Chapter 3, we responded to a widely shared criticism on previous DSGE modelling by further extending our macro-econometric platform to include financial intermediation. The scheme we selected for this purpose is particularly characterised by embracing the effects of financial frictions, understood as increased costs derived from imperfections, in our case, in the credit markets.

In addition to the necessary transformation to a multi-country setting and linearisation of the model to achieve full compatibility with the DSGE framework developed in Chapter 2, our financial depiction deviated from the emphasis given by its original proponents (Gertler and Kiyotaky (2010)) to extreme cases where frictions are either complete or totally absent and operates, instead, with intermediate, more feasible cases, with incomplete effects of such inefficiencies.

By combining our DSGE platform with their financial modelling we achieved an important synergy by the means of which key financial considerations are integrated to a robust macroeconomic, open-economy scheme, which they lack, while, in turn, their financial depiction decidedly helps to address the weakness of the original DSGE setting we used in relation to its capability for the analysis of relevant financial components and phenomena as international interactions in credit markets subject to the corresponding imperfections (in our case, financial frictions).

We modified the original financial setting with the inclusion of the effects of inter-bank credit markets and fractional compulsory reserves for a better representation of the conditions of operation that financial intermediaries face through their asset sheets. This has the advantages of providing an objective rationale for decisions in the banking sectors related to default and net worth accumulation. An international comparative exploration of the incentives that, in this sense, are generated by distinct monetary policies is also an innovative part of the information outcomes of our extended model.

Keeping the same regional approach of Chapter 2, we explored the international repercussions on the supply-side conditions of credit markets of two alternative scenarios of monetary policies. They were intended to compare the outcomes of interest-rate-based policies and those aiming to affect the liquidity of the financial system. This comparison is relevant to consider in view of possible situations where monetary policies face important restrictions as those implied by the *zero-lower-bound* and find themselves obliged to resort to other alternatives such as liquidity interventions.

One of the main contributions of Chapter 3 is that we measured and characterised international monetary spillovers within 9 selected OECD economies with consequential implications for their financial intermediaries. The outcomes of the simulations contributed to measure the vulnerability of the domestic banking systems in terms of deviations of relevant interest rates as well as of a summary indicator of the assets/liabilities conditions.

In the general context of this study, our results confirmed the presence of international externalities impacting the conditions of the financial intermediaries. In addition to an heterogeneous map of vulnerabilities, where the United States displayed the highest resilience, we were able to distinguish cases of an *accelerationist* effect (even in the US) by the means of which foreign externalities translate into more than proportional deviations in the domestic markets. These outcomes, therefore, constitute an empirical assessment of the cumulative financial mechanisms set out by Bernanke, Gertler and Gilchrist (1999) but, in our case, from an international perspective.

We found that liquidity interventions tend to be of limited potentiality as compared to monetary policy shocks and in some instances even produce contradictory deviations to their interest-rate equivalents. Our model has been able to distinguish the particularities and outcomes of the international linkages denoting differentiated strength through financial systems or through macroeconomic channels.

This way, the choices of foreign monetary policies are relevant not only in terms of the macroeconomic performance of their financial and commercial partners in the OECD but also in relation to the conditions they impose on the corresponding foreign credit markets and financial systems. We have identified shocks which generate incentives to increase the net worth of banks and also scenarios in which bankers may be more inclined to default on their obligations given a substantial decline in the relative value of their assets. Similarly, we observed how international policy spillovers generating opportunities for banking re-capitalisation may simultaneously lead to episodes of significant decrease in the activity of banks. This way, with our multi-country platform, we have also explored comparative macro-prudential aspects of monetary policy, absent in the original single-economy financial model.

Unlike previous applications of this financial modelling, our framework enabled us to explore intra and inter-regional spillovers of the two types of monetary interventions representing main alternatives currently used by central banks to manage the economic and financial recovery in the aftermath of the 2007-2009 financial crisis. The multi-country framework to which our financial modelling was added provided a wider platform for the analysis of complex interactions not assessed by the original examples of financial modelling we built on. This way, our DSGE framework was complemented by an original depiction of interrelated financial systems which provided us with new information on the diversity of nominal responses across the OECD to standardised shocks exhibiting various degrees of international exposure and vulnerability.

We conclude that domestic monetary policies would benefit from taking into account the diverse exposure of their nominal space of action to international shocks by accommodating their own choices to those externalities. Such accommodative stances would also contribute to reduce the risk of international acceleration effects and to achieve greater efficiency in the management of domestic nominal and macroeconomic variables.

Finally, in Chapter 4 we explored a novel depiction of a financial cost channel based on the international impacts of fiscal policies on the risk premia applicable to each national banking system and, by those means, on domestic and foreign credit conditions and monetary policies. In this framework, risk evaluations associated to public indebtedness find a transmission mechanism in the international interrelations of the banking sector which costs are exposed to variations in risk evaluations which include the sustainability of public finances among their components.

With the aid of a spatial econometric setting, we have confirmed and measured the impact of fiscal policies on nominal variables which are central to the performance of financial markets in an internationally competitive context as represented by OECD economies. In turn, these impacts have important consequences for the operation of each of those economies given that they modify their respective patterns of financial costs.

Our spatial econometric methods, adapted to include bi-lateral composite weights based on the weighting matrices of Chapters 1 and 2 plus a geographic-distance component, helped us to find specific evidence of direct and indirect fiscal effects on risk scores and interest rate spreads. The size and statistical significance of the calculated indirect effects confirm the appropriateness of a network-based approach in the analysis of those nominal externalities.

We found that fiscal policies generate changes in the space of action available for the management of interest rates in an economy. As a result of what we have defined as a fiscal cost channel, which impacts are spread by the financial sector, in relation to the aggregate patterns of consumption and investment in face of the changes in the costs of funding.

In presence of such cost channel, a fiscal regime, where fiscal policies precede in their choices and then monetary policies accommodate to the externalities produced that way, is found to be an appropriate alternative for policy design.

All the interrelations we have explored by the means of our extended econometric platforms constitute, therefore, the bases of a truly strategic component of macroeconomic policies between OECD economies which also finds expression in a set of distinctive profiles of vulnerability to international shocks within the interest of both fiscal and monetary authorities.

5.2 Paths for further research

For Chapter 2, the process of further individualisation of parameters represents an opportunity to improve on the model's depiction of national specificities which will be valuable when exploring additional issues in the macroeconomic context. It would also be interesting to use the grounds provided in Chapter 4 to further develop the representation of public debt and its links with the risk premium applicable in each economy.

In the analysis developed in Chapter 3, in turn, we have not considered the distinction of financial intermediaries between parent and subsidiary institutions as in De Haas and Van Lelyveld (2014). Those differences are likely to have an impact on the outcomes of shocks on more consolidated financial systems while, at the same time, may also contribute to a better localisation of the main financial nodes operating in the propagation of international externalities. That line of research is, therefore, promising as a further development for this investigation.

It would also be enriching the extension of the study towards the inclusion of further elements in banking regulation such as those contained in the Basel III framework although this requires a considerable expansion of the model's financial section towards the inclusion of risk-related indicators in banking.

Lastly, for Chapter 4 the exploration of direct and indirect effects in high-variation economies may be carried out by studying them in the context of their respective regions (as in Chapters 1 and 2) as opposed to taking them as an isolated group. Also, a complementary study can be developed looking into the monetary policy consequences on the costs and risk evaluations associated to public debt.

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Appendices

Appendix A

Available shocks

- Government:

	National	Regional
Capital income tax	$\epsilon_{i,t}^{fpk}$	$\epsilon_{r,t}^{\tau,k}$
Pay-roll tax	$\epsilon_{i,t}^{fpw}$	$\epsilon_{r,t}^{\tau,w}$
Consumption tax	$\epsilon_{i,t}^{fpc}$	$\epsilon_{r,t}^{\tau,c}$
Labour income tax	$\epsilon_{i,t}^{fpy}$	$\epsilon_{r,t}^{\tau,y}$
Government spending	$\epsilon_{i,t}^{fpg}$	$\epsilon_{r,t}^{g}$

- Firms:

	National
Domestic markup	$\epsilon_{i,t}^{\lambda_d}$
Consumption import markup	$\epsilon_{i,t}^{\lambda_{m,c}}$
Investment import markup	$\epsilon_{i,t}^{\lambda_{m,i}}$
Export markup	$\epsilon_{i,t}^{\lambda_x}$
Non-stationary technology growth	$\epsilon_{i,t}^{\mu_z}$
Stationary technology	$\varepsilon_{i,t}^{\epsilon}$
Investment specific technology shock	$\varepsilon_{i,t}^{\Upsilon}$
Asymmetric technology shock	$\varepsilon_{j,t}^{\tilde{z}^*}$
Money demand shock	$\widehat{\nu^w}_{i,t}$

- Households:

	National
Consumption preference shock	$\varepsilon_{\zeta^c,i,t}$
Labour supply shock	$\varepsilon_{\zeta^l,i,t}$

- Monetary policy:

	National	Regional
Risk premium shock	$\tilde{\phi}_{i,t}$	$\tilde{\phi}_{r,t}$
Monetary policy shock	$\varepsilon^{R}_{i,t}$	$\varepsilon^{R}_{r,t}$
Inflation target shock	$\varepsilon^{\widehat{\overline{\pi}}^c}_{i,t}$	$\varepsilon^{\widehat{\overline{\pi}}^c}_{r,t}$

- Foreign (country-specific) variables:

	National	Regional
Foreign consumption shock	$\epsilon^{\hat{c}^*}_{j,t}$	$\epsilon^{\hat{c}^*}_{r,t}$
Foreign investment shock	$\epsilon^{\hat{i}^*}_{j,t}$	$\epsilon^{\hat{i}^*}_{r,t}$
Foreign output shock	$\epsilon^{\hat{y}^*}_{j,t}$	$\epsilon^{\hat{y}^*}_{r,t}$
Foreign inflation	$\epsilon^{\hat{\pi}^*}_{j,t}$	$\epsilon^{\hat{\pi}^*}_{r,t}$
Foreign interest rate shock	$\epsilon^{\hat{R}^*}_{j,t}$	$\epsilon^{\hat{R}^*}_{r,t}$

Appendix B

Weight matrices

B.1 Participation in OECD's real output

Country	*ryw*	Country	*ryw*
AU	0.022201	JP	0.100959
AT	0.007864	KR	0.038604
BE	0.009322	LU	0.000904
CA	0.032872	MX	0.039596
CL	0.007157	NL	0.016041
CZ	0.006392	NZ	0.002977
DK	0.004591	NO	0.006068
EE	0.000631	PL	0.017836
FI	0.004335	PT	0.005496
FR	0.050913	SK	0.002932
DE	0.072746	SI	0.001252
EL	0.005581	ES	0.03057
HU	0.004355	SE	0.008624
IS	0.000303	CH	0.008457
IE	0.004289	TR	0.02624
IL	0.00582	UK	0.055259
IT	0.040378	US	0.358433

Source: Own calculation with data for 2013 from OECD *Quarterly National Accounts*, Gross Domestic Product, Constant prices, constant PPP's, OECD base year.

B.2 Bilateral financial and commercial weights

Financial weights

	AU	AT	BE	CA	CL	CZ	DK	EE	FI	FR	DE	EL	HU	IS	IE	IL	IT
AU	0.000000	0.000000	0.010222	0.039383	0.001383	0.000034	0.000000	0.000000	0.000036	0.018217	0.035085	0.000000	0.000031	0.000000	0.000963	0.000001	0.000928
AT	0.009277	0.000000	0.023370	0.006392	0.000887	0.057538	0.010593	0.000954	0.007105	0.022922	0.264775	0.003896	0.035814	0.000000	0.001246	0.000001	0.101025
BE	0.006073	0.001251	0.000000	0.002029	0.001243	0.005847	0.002558	0.000021	0.017720	0.202430	0.016708	0.001126	0.003231	0.000002	0.017022	0.000155	0.021228
CA	0.027033	0.000689	0.005477	0.000000	0.012876	0.000000	0.001050	0.000000	0.001737	0.021556	0.017018	0.000000	0.011806	0.000293	0.020823	0.000582	0.001525
CL	0.011772	0.004361	0.009372	0.136078	0.000000	0.000001	0.001335	0.000000	0.000000	0.021294	0.007362	0.000000	0.000004	0.000000	0.006153	0.000003	0.010092
CZ	0.000220	0.123647	0.034748	0.001810	0.000008	0.000000	0.006503	0.000004	0.001478	0.054295	0.139104	0.000027	0.003995	0.000205	0.001964	0.000022	0.009459
DK	0.014137	0.002514	0.012419	0.012659	0.000735	0.004460	0.000000	0.000883	0.027057	0.046540	0.076838	0.001141	0.002692	0.005830	0.004766	0.000093	0.010741
EE	0.000256	0.014390	0.003576	0.006529	0.000003	0.000396	0.022291	0.000000	0.283024	0.017869	0.023414	0.000374	0.000349	0.002167	0.007798	0.000567	0.013573
FI	0.001328	0.011421	0.119598	0.010841	0.000408	0.000358	0.035451	0.010433	0.000000	0.009205	0.053795	0.000040	0.003848	0.000517	0.022149	0.000000	0.005290
FR	0.006261	0.003673	0.143248	0.010669	0.000724	0.005755	0.004779	0.000024	0.002647	0.000000	0.084825	0.002992	0.002342	0.000174	0.022896	0.001045	0.039877
DE	0.008485	0.038471	0.031738	0.008421	0.000918	0.009928	0.010846	0.000081	0.007955	0.074452	0.000000	0.002272	0.009158	0.000141	0.009147	0.000993	0.046768
EL	0.000060	0.029292	0.010068	0.000739	0.000000	0.000115	0.004607	0.000028	0.001709	0.073448	0.096843	0.000000	0.004446	0.000034	0.006853	0.000979	0.023380
HU	0.000080	0.036421	0.011687	0.073251	0.000003	0.001147	0.004296	0.000002	0.002148	0.013150	0.070470	0.000379	0.000000	0.000006	0.045203	0.001805	0.008288
IS	0.000203	0.000199	0.000025	0.007318	0.000896	0.000222	0.057036	0.000311	0.012063	0.001367	0.007129	0.000073	0.000276	0.000000	0.002367	0.000061	0.002362
IE	0.009161	0.000789	0.018472	0.020109	0.000092	0.000419	0.003388	0.000046	0.000261	0.048732	0.036031	0.000364	0.025772	0.000042	0.000000	0.000038	0.023535
IL	0.003937	0.000104	0.007222	0.090086	0.000002	0.000187	0.000182	0.000000	0.006993	0.008572	0.015388	0.000098	0.019775	0.000058	0.001760	0.000000	0.014398
IT	0.002741	0.049185	0.047653	0.003757	0.001299	0.002312	0.005395	0.000214	0.001959	0.120547	0.098843	0.003329	0.005506	0.000124	0.021993	0.000512	0.000000
JP	0.067173	0.000000	0.021831	0.018415	0.000000	0.000000	0.000000	0.000000	0.000000	0.050899	0.035612	0.000000	0.000000	0.000000	0.000000	0.000000	0.004064
KR	0.028739	0.004556	0.017543	0.031983	0.000819	0.005722	0.001348	0.000000	0.001408	0.035057	0.050038	0.000059	0.019307	0.000051	0.010292	0.000087	0.003017
LU	0.000000	0.002596	0.078606	0.035586	0.000000	0.001731	0.003411	0.000042	0.000955	0.036275	0.061962	0.000878	0.007246	0.000000	0.059208	0.000000	0.031154
MX	0.000618	0.001085	0.003114	0.028557	0.008553	0.000237	0.003744	0.000003	0.000267	0.011753	0.024084	0.000002	0.004396	0.000008	0.001465	0.000198	0.002444
NL	0.009630	0.008133	0.053899	0.023161	0.001035	0.005853	0.003641	0.000145	0.006530	0.053253	0.062818	0.001856	0.003490	0.000615	0.045686	0.004230	0.036530
NZ	0.692678	0.000000	0.001731	0.007926	0.000049	0.000000	0.002160	0.000000	0.000000	0.002011	0.009214	0.000000	0.000000	0.000000	0.001468	0.000000	0.000088
NO	0.003977	0.008134	0.067421	0.016585	0.001710	0.000530	0.079173	0.001916	0.014576	0.070653	0.040433	0.000106	0.002892	0.002297	0.006081	0.000000	0.002244
PL	0.000457	0.031866	0.034388	0.001126	0.000020	0.011533	0.019592	0.000527	0.008644	0.110769	0.139437	0.001568	0.005494	0.003065	0.013894	0.001188	0.050500
PT	0.000364	0.011157	0.009401	0.032802	0.000000	0.000316	0.023873	0.000050	0.000135	0.051590	0.037619	0.000046	0.003188	0.000027	0.023220	0.000000	0.046646
SK	0.000003	0.169810	0.033995	0.000442	0.000092	0.097070	0.009535	0.000129	0.002904	0.039986	0.114193	0.000060	0.054069	0.000128	0.008501	0.000083	0.078760
SI	0.004282	0.363750	0.041022	0.000964	0.000006	0.012184	0.011061	0.000001	0.003437	0.072205	0.090847	0.001701	0.010380	0.000000	0.001306	0.000016	0.089842
ES	0.005710	0.005286	0.025460	0.010392	0.017594	0.005727	0.004374	0.000000	0.000119	0.083411	0.052678	0.001341	0.017817	0.000122	0.017133	0.000236	0.053559
SE	0.004550	0.003853	0.052165	0.011802	0.001499	0.001889	0.079048	0.006418	0.107609	0.024285	0.059246	0.000128	0.000866	0.000100	0.008750	0.001032	0.007075
CH	0.014196	0.058459	0.014599	0.032056	0.001766	0.002062	0.007602	0.000000	0.000970	0.053948	0.070436	0.001418	0.009184	0.000000	0.013226	0.002076	0.020581
TR	0.000932	0.057663	0.045749	0.000311	0.000000	0.002670	0.001782	0.000004	0.046881	0.057989	0.087621	0.044034	0.000390	0.000412	0.008947	0.005062	0.025031
UK	0.029066	0.001351	0.026314	0.027143	0.000532	0.000267	0.006939	0.000050	0.001018	0.085703	0.056521	0.001616	0.000203	0.000540	0.037061	0.000665	0.011097
US	0.032836	0.003479	0.023065	0.101583	0.006498	0.001117	0.004277	0.000006	0.001515	0.052927	0.061178	0.000262	0.008232	0.000138	0.038039	0.003665	0.009471

	JP	KR	LU	MX	NL	NZ	NO	PL	PT	SK	SI	ES	SE	CH	TR	UK	US
AU	0.094684	0.003040	0.005442	0.001975	0.060586	0.083004	0.000000	0.000000	0.000005	0.000000	0.000000	0.000000	0.002872	0.043269	0.000000	0.220679	0.378165
AT	0.002653	0.001632	0.062249	0.001461	0.127213	0.001830	0.000711	0.020609	0.001112	0.027805	0.013019	0.014317	0.007114	0.056998	0.026981	0.045696	0.042809
BE	0.015995	0.001284	0.348614	0.002152	0.236735	0.000101	0.002399	0.003970	0.001406	0.002576	0.000565	0.002112	0.005989	0.016498	0.003242	0.033203	0.024515
CA	0.021254	0.005336	0.037044	0.007528	0.071948	0.000672	0.002843	0.000353	0.000062	0.000000	0.000000	0.004873	0.004039	0.024341	0.001309	0.123408	0.572527
CL	0.044314	0.001297	0.013886	0.021120	0.088759	0.001065	0.010731	0.000000	0.000000	0.000000	0.000000	0.302523	0.007549	0.017737	0.000000	0.059846	0.223346
CZ	0.011237	0.008950	0.062810	0.000077	0.333022	0.000011	0.001014	0.017279	0.000418	0.042988	0.001025	0.032597	0.011611	0.045264	0.001439	0.020280	0.032491
DK	0.017503	0.001431	0.057056	0.002866	0.103822	0.000971	0.072933	0.017895	0.010230	0.001559	0.000417	0.015456	0.253668	0.051077	0.002536	0.084138	0.082937
EE	0.000559	0.000006	0.020778	0.000019	0.117622	0.000113	0.044747	0.004124	0.001244	0.001101	0.000010	0.007154	0.337225	0.016598	0.000358	0.026170	0.025595
FI	0.000654	0.000634	0.034128	0.000546	0.175171	0.000161	0.010160	0.006257	0.000095	0.000785	0.000049	0.006361	0.401671	0.003095	0.001289	0.013603	0.060662
FR	0.019858	0.002109	0.092111	0.002147	0.147269	0.000161	0.005136	0.009800	0.003841	0.000847	0.000336	0.039810	0.007907	0.058583	0.003111	0.125619	0.149426
DE	0.017123	0.006977	0.128320	0.003900	0.175722	0.000256	0.005830	0.013487	0.001911	0.003876	0.000413	0.027975	0.020694	0.060554	0.004854	0.107841	0.160493
EL	0.000995	0.000423	0.165545	0.000150	0.250463	0.000000	0.001447	0.007178	0.000218	0.000077	0.000308	0.031692	0.002891	0.022387	0.116384	0.032124	0.115118
HU	0.003328	0.016392	0.271984	0.005659	0.052312	0.000041	0.003156	0.002606	0.001142	0.006845	0.000305	0.054085	0.001671	0.194602	0.000389	0.023699	0.093448
IS	0.000583	0.000534	0.428038	0.000000	0.156960	0.000100	0.021140	0.002313	0.000093	0.000377	0.000000	0.004699	0.028093	0.007709	0.001904	0.158222	0.097326
IE	0.003450	0.001878	0.242228	0.000247	0.179256	0.000099	0.003257	0.000470	0.002252	0.000087	0.000000	0.021602	0.008860	0.037558	0.000041	0.207394	0.104070
IL	0.000846	0.000047	0.016041	0.001790	0.357222	0.000000	0.000146	0.000789	0.000000	0.000000	0.000000	0.006003	0.004279	0.035272	0.001417	0.028559	0.378829
IT	0.004559	0.001379	0.112671	0.001977	0.226597	0.000082	0.000731	0.019852	0.013721	0.004490	0.002338	0.075778	0.007969	0.037255	0.006493	0.061005	0.057734
JP	0.000000	0.028576	0.016897	0.004200	0.171275	0.003775	0.000000	0.000000	0.000000	0.000000	0.000000	0.002583	0.005128	0.015426	0.000000	0.078726	0.475423
KR	0.206022	0.000000	0.007394	0.005402	0.108444	0.000660	0.012485	0.005633	0.001128	0.009274	0.000053	0.006191	0.014464	0.012457	0.002639	0.095562	0.302165
LU	0.003696	0.000000	0.000000	0.000000	0.160460	0.000000	0.000000	0.004238	0.003633	0.000579	0.000079	0.017872	0.013644	0.072975	0.000000	0.232484	0.170691
MX	0.012265	0.001827	0.010313	0.000000	0.109472	0.000305	0.000165	0.000050	0.000170	0.000029	0.000025	0.139428	0.004722	0.026743	0.000011	0.029436	0.574514
NL	0.018590	0.002326	0.143747	0.007796	0.000000	0.000897	0.005762	0.004746	0.007782	0.002267	0.000123	0.032108	0.019581	0.069337	0.004206	0.168780	0.191451
NZ	0.032743	0.000099	0.000935	0.000000	0.038287	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.005646	0.000000	0.048664	0.156301
NO	0.005418	0.006352	0.022289	0.000164	0.136793	0.000684	0.000000	0.006182	0.000334	0.000389	0.000000	0.044997	0.211582	0.024056	0.005682	0.081269	0.135080
PL	0.006637	0.003524	0.129219	0.000131	0.162193	0.000008	0.009610	0.000000	0.006805	0.002223	0.000629	0.041791	0.044559	0.047457	0.001115	0.055003	0.055030
PT	0.000943	0.000618	0.100057	0.000371	0.323871	0.000148	0.000496	0.011147	0.000000	0.000061	0.000009	0.217620	0.006135	0.008686	0.000976	0.065246	0.023181
SK	0.002387	0.043860	0.040762	0.000067	0.238429	0.000000	0.003144	0.004053	0.000114	0.000000	0.000627	0.008639	0.007407	0.014223	0.000145	0.011936	0.014448
SI	0.003967	0.000869	0.028930	0.000108	0.074934	0.000020	0.000231	0.012117	0.000046	0.005795	0.000000	0.002457	0.008628	0.118490	0.001702	0.028568	0.010137
ES	0.002505	0.000941	0.113243	0.044164	0.190358	0.000588	0.006337	0.005546	0.043143	0.000000	0.000000	0.000000	0.006604	0.031463	0.005448	0.141425	0.107279
SE	0.009205	0.003339	0.104765	0.002140	0.149184	0.000086	0.072901	0.004452	0.000826	0.000454	0.000037	0.009512	0.000000	0.026577	0.001230	0.113828	0.131149
CH	0.008439	0.003110	0.182830	0.004168	0.189922	0.000349	0.002250	0.003674	0.002325	0.000356	0.000000	0.013780	0.007719	0.000000	0.001639	0.070603	0.206261
TR	0.006253	0.004275	0.075639	0.000019	0.288619	0.000015	0.001868	0.000574	0.001346	0.000071	0.000006	0.043335	0.001331	0.024015	0.000000	0.078430	0.088725
UK	0.021767	0.000908	0.112503	0.003274	0.193139	0.000828	0.002957	0.002137	0.001528	0.000108	0.000094	0.039101	0.007709	0.035666	0.001420	0.000000	0.290777
US	0.076392	0.009217	0.094667	0.020194	0.155643	0.001715	0.008719	0.002874	0.000540	0.000001	0.000001	0.017970	0.012698	0.060011	0.001022	0.190051	0.000000

Trade weights

	AU	AT	BE	CA	CL	CZ	DK	EE	FI	FR	DE	EL	HU	IS	IE	IL	IT
AU	0.000000	0.004854	0.012282	0.020695	0.003480	0.001671	0.005704	0.000145	0.007577	0.028228	0.060376	0.001255	0.001363	0.000086	0.009767	0.004237	0.033354
AT	0.003014	0.000000	0.023985	0.005552	0.000841	0.038662	0.006907	0.000630	0.006236	0.043966	0.433643	0.003812	0.037929	0.000155	0.004332	0.001667	0.088618
BE	0.004663	0.009472	0.000000	0.006751	0.001353	0.007882	0.007131	0.000618	0.006952	0.167664	0.207476	0.004188	0.005436	0.000262	0.030902	0.010459	0.049108
CA	0.004805	0.002166	0.006289	0.000000	0.002521	0.000615	0.002126	0.000111	0.001955	0.011743	0.020143	0.000421	0.000538	0.000165	0.002879	0.001611	0.009637
CL	0.011497	0.002856	0.024333	0.031353	0.000000	0.000835	0.004750	0.000199	0.008609	0.046784	0.058803	0.003599	0.000366	0.000268	0.002311	0.002223	0.054146
CZ	0.001495	0.058160	0.035041	0.002242	0.000291	0.000000	0.008440	0.001076	0.005717	0.051818	0.371695	0.002719	0.027934	0.000290	0.005491	0.002543	0.050818
DK	0.005413	0.011063	0.030532	0.007062	0.001581	0.009019	0.000000	0.003164	0.028871	0.054537	0.231994	0.005499	0.005353	0.003836	0.012660	0.002111	0.042880
EE	0.001149	0.010024	0.029465	0.004932	0.000613	0.011867	0.037252	0.000000	0.267143	0.027620	0.133152	0.001405	0.012232	0.001225	0.004828	0.000941	0.029175
FI	0.010770	0.012849	0.040372	0.010240	0.003816	0.008464	0.040240	0.033404	0.000000	0.051404	0.173204	0.005552	0.007273	0.000849	0.008361	0.003155	0.041547
FR	0.005057	0.011567	0.120623	0.007757	0.002583	0.008979	0.009242	0.000492	0.006224	0.000000	0.214175	0.005853	0.006278	0.000259	0.012144	0.003265	0.108447
DE	0.005381	0.059181	0.084568	0.006934	0.001984	0.035432	0.019668	0.001088	0.011391	0.118436	0.000000	0.006608	0.020240	0.000610	0.010967	0.003510	0.080659
EL	0.002754	0.015632	0.048164	0.004720	0.002531	0.007629	0.014455	0.000278	0.011773	0.083410	0.194957	0.000000	0.007010	0.000329	0.009772	0.008653	0.178907
HU	0.001574	0.084260	0.033819	0.002352	0.000159	0.045502	0.008181	0.001390	0.008505	0.056834	0.338355	0.004012	0.000000	0.000113	0.005419	0.002964	0.068892
IS	0.009804	0.004570	0.021541	0.011924	0.002127	0.003988	0.066080	0.005754	0.012366	0.042074	0.139361	0.003807	0.002233	0.000000	0.013382	0.001242	0.027704
IE	0.006079	0.004503	0.114313	0.006745	0.000617	0.003910	0.010037	0.000317	0.005120	0.060563	0.094494	0.002945	0.002841	0.000319	0.000000	0.003151	0.033230
IL	0.008302	0.005208	0.119052	0.012527	0.001711	0.004007	0.004552	0.000228	0.006275	0.039608	0.079941	0.006545	0.004006	0.000199	0.008161	0.000000	0.052028
IT	0.007787	0.032142	0.049445	0.008995	0.004096	0.012464	0.009930	0.000642	0.006927	0.153627	0.215653	0.016535	0.011332	0.000202	0.009598	0.006071	0.000000
JP	0.074138	0.004998	0.017612	0.037159	0.011696	0.002802	0.005944	0.000270	0.005175	0.031731	0.074969	0.002100	0.003188	0.000546	0.009814	0.004580	0.023981
KR	0.060399	0.004840	0.012343	0.025943	0.014664	0.003252	0.004072	0.000321	0.006128	0.023673	0.070205	0.005995	0.004063	0.000221	0.004777	0.005020	0.023219
LU	0.000850	0.012326	0.246244	0.004422	0.000342	0.007670	0.006525	0.000259	0.004797	0.154067	0.257915	0.002970	0.003104	0.000229	0.004693	0.001008	0.046653
MX	0.002460	0.001254	0.003338	0.029034	0.006264	0.000000	0.000937	0.000012	0.001019	0.008531	0.029529	0.000235	0.000983	0.000000	0.002314	0.001236	0.010143
NL	0.004174	0.012422	0.160929	0.005978	0.003132	0.012278	0.014307	0.001055	0.011467	0.090730	0.268519	0.005491	0.006613	0.001769	0.012290	0.004620	0.048411
NZ	0.313478	0.003380	0.019120	0.022559	0.002271	0.000903	0.007111	0.000080	0.004114	0.024606	0.051551	0.001943	0.000844	0.000145	0.004317	0.002276	0.026042
NO	0.002253	0.006628	0.033193	0.030936	0.001100	0.008168	0.056470	0.002752	0.025582	0.074246	0.138269	0.002095	0.002005	0.003441	0.013223	0.001425	0.032484
PL	0.001330	0.026058	0.046682	0.003220	0.000680	0.061719	0.021958	0.003593	0.013271	0.067701	0.337757	0.003755	0.025869	0.000598	0.005335	0.002139	0.077815
PT	0.001965	0.008047	0.039484	0.004577	0.001388	0.004991	0.009411	0.000340	0.006839	0.126709	0.170667	0.003103	0.003183	0.000874	0.007677	0.002272	0.065416
SK	0.000886	0.072998	0.023370	0.001623	0.000203	0.202413	0.007079	0.000628	0.005506	0.053143	0.253734	0.003225	0.071526	0.000079	0.002202	0.000799	0.061475
SI	0.001518	0.117169	0.021245	0.003670	0.000473	0.030642	0.008002	0.000623	0.004113	0.084558	0.256925	0.005496	0.042638	0.000112	0.002341	0.003982	0.189662
ES	0.004503	0.011325	0.050322	0.005400	0.005064	0.008362	0.009169	0.000455	0.006542	0.207248	0.172785	0.007216	0.006308	0.000413	0.012505	0.004612	0.108977
SE	0.008643	0.012671	0.052863	0.008303	0.002508	0.009288	0.087035	0.009417	0.067527	0.058788	0.166741	0.003851	0.005987	0.001636	0.010755	0.002559	0.038648
CH	0.006463	0.042529	0.034975	0.009498	0.000956	0.009181	0.008565	0.000364	0.006474	0.108058	0.305825	0.004612	0.005495	0.000378	0.017095	0.005904	0.107908
TR	0.005895	0.015304	0.041451	0.008925	0.002367	0.010790	0.009344	0.001622	0.008841	0.088726	0.208593	0.018585	0.009753	0.000169	0.008286	0.018643	0.111667
UK	0.014002	0.008763	0.066385	0.021688	0.001879	0.008535	0.015503	0.001010	0.011114	0.102180	0.156565	0.004793	0.005613	0.001374	0.061592	0.005906	0.053416
US	0.015578	0.005040	0.023584	0.283308	0.007811	0.001810	0.004115	0.000324	0.003843	0.035536	0.069065	0.001440	0.001957	0.000397	0.017421	0.015102	0.025893

	JP	KR	LU	MX	NL	NZ	NO	PL	PT	SK	SI	ES	SE	CH	TR	UK	US
AU	0.276910	0.100914	0.000099	0.008184	0.019127	0.077359	0.002499	0.001427	0.001160	0.000520	0.000403	0.011534	0.014402	0.014140	0.004256	0.072936	0.199059
AT	0.014637	0.005663	0.002584	0.001991	0.033965	0.000538	0.003782	0.019412	0.003796	0.023502	0.018617	0.019647	0.013811	0.056034	0.009794	0.032160	0.040119
BE	0.020222	0.005149	0.014933	0.003427	0.175352	0.001103	0.009160	0.012086	0.006640	0.002282	0.001092	0.030947	0.020405	0.013529	0.010390	0.085525	0.067444
CA	0.038968	0.012487	0.000378	0.026705	0.006610	0.001205	0.008659	0.001160	0.000735	0.000288	0.000209	0.003234	0.003645	0.004711	0.001627	0.028663	0.792992
CL	0.152037	0.085886	0.000349	0.055055	0.046952	0.001666	0.002797	0.002405	0.002321	0.000419	0.000181	0.038255	0.013459	0.009922	0.007565	0.034544	0.293257
CZ	0.013291	0.005736	0.002145	0.001696	0.048809	0.000189	0.004343	0.067552	0.003273	0.093126	0.006818	0.022031	0.015115	0.015424	0.006889	0.043788	0.024008
DK	0.023350	0.007843	0.002067	0.002224	0.066720	0.001489	0.066270	0.024318	0.006882	0.003112	0.001944	0.023747	0.148116	0.013767	0.007122	0.090389	0.055066
EE	0.016350	0.006218	0.000926	0.001508	0.044223	0.000341	0.026574	0.045403	0.001602	0.003596	0.001821	0.011023	0.173146	0.008216	0.009941	0.041007	0.035084
FI	0.028761	0.011380	0.001391	0.002760	0.072738	0.001076	0.037885	0.022578	0.006756	0.002892	0.001558	0.024592	0.155888	0.014896	0.008906	0.083297	0.071147
FR	0.021933	0.007891	0.007604	0.003651	0.067145	0.000839	0.010700	0.013175	0.014973	0.003913	0.003599	0.091335	0.016102	0.035582	0.011857	0.091733	0.075024
DE	0.029844	0.011655	0.007105	0.006374	0.103178	0.000955	0.016746	0.035337	0.009851	0.011341	0.005566	0.042307	0.023959	0.050487	0.016293	0.080421	0.081924
EL	0.028947	0.034025	0.003902	0.001836	0.069425	0.001147	0.004501	0.010107	0.005366	0.003209	0.004431	0.046979	0.016663	0.020005	0.041192	0.067214	0.050076
HU	0.020193	0.012640	0.001527	0.003725	0.044751	0.000165	0.001822	0.043645	0.004224	0.052685	0.013930	0.025237	0.015593	0.013769	0.011175	0.043120	0.029470
IS	0.046923	0.006335	0.002865	0.000673	0.132937	0.000739	0.080401	0.011270	0.016726	0.001022	0.000846	0.033729	0.046252	0.020818	0.003551	0.121185	0.105774
IE	0.030081	0.007159	0.001361	0.004611	0.049539	0.000721	0.011836	0.004954	0.003969	0.000577	0.000368	0.026391	0.012511	0.025670	0.004210	0.290918	0.175941
IL	0.039542	0.019997	0.001641	0.004355	0.048999	0.000844	0.002305	0.004037	0.003169	0.000755	0.002334	0.023136	0.009774	0.055530	0.028558	0.071926	0.330750
IT	0.021940	0.010501	0.003629	0.005441	0.055446	0.001238	0.006196	0.021677	0.010732	0.007067	0.010830	0.069377	0.014809	0.050367	0.020692	0.069511	0.075102
JP	0.000000	0.124316	0.000000	0.017574	0.031897	0.008659	0.005329	0.002337	0.002015	0.000666	0.000277	0.010868	0.008374	0.016875	0.004134	0.043759	0.412217
KR	0.280182	0.000000	0.000357	0.021031	0.022571	0.006289	0.008411	0.008203	0.001897	0.006530	0.001696	0.010933	0.006806	0.010677	0.010046	0.033707	0.301529
LU	0.006400	0.001827	0.000000	0.005475	0.053907	0.000196	0.002191	0.010701	0.005613	0.001952	0.001481	0.024748	0.013961	0.020743	0.007008	0.052523	0.037205
MX	0.034750	0.020542	0.000332	0.000000	0.006706	0.000961	0.000499	0.000685	0.001089	0.000088	0.000002	0.014464	0.002544	0.004170	0.000665	0.007731	0.807484
NL	0.024518	0.008395	0.004121	0.003868	0.000000	0.000868	0.019418	0.014779	0.007436	0.003284	0.001498	0.031968	0.022646	0.014146	0.009003	0.098503	0.071365
NZ	0.158322	0.049111	0.000395	0.010883	0.014412	0.000000	0.002209	0.000925	0.001459	0.000152	0.000242	0.008326	0.009479	0.008169	0.003189	0.062868	0.185121
NO	0.022421	0.013164	0.000792	0.001204	0.091176	0.000394	0.000000	0.014914	0.006829	0.001423	0.000706	0.020469	0.110508	0.008613	0.005218	0.199884	0.068018
PL	0.008901	0.011983	0.002999	0.001467	0.058468	0.000196	0.014247	0.000000	0.003682	0.031617	0.005775	0.026681	0.033124	0.010813	0.012024	0.055093	0.023452
PT	0.012886	0.004710	0.002359	0.004195	0.053955	0.000486	0.010454	0.006186	0.000000	0.001436	0.000639	0.303564	0.015534	0.011491	0.005912	0.072415	0.036838
SK	0.007233	0.021174	0.001919	0.000978	0.029908	0.000093	0.001768	0.066924	0.002286	0.000000	0.010121	0.019350	0.012236	0.009942	0.009252	0.030606	0.015319
SI	0.005778	0.014482	0.003152	0.001236	0.028589	0.000185	0.002228	0.029725	0.002388	0.022475	0.000000	0.021967	0.010550	0.014564	0.020587	0.024374	0.024550
ES	0.019243	0.008742	0.002983	0.015829	0.053301	0.000715	0.007321	0.011590	0.071466	0.003277	0.001980	0.000000	0.014073	0.017587	0.015188	0.084841	0.050659
SE	0.024050	0.008058	0.002412	0.003649	0.065830	0.001059	0.098723	0.023925	0.006290	0.003208	0.001559	0.022973	0.000000	0.014485	0.008850	0.091852	0.075859
CH	0.035924	0.007756	0.002373	0.004727	0.043346	0.001013	0.003926	0.007765	0.005458	0.002826	0.001958	0.030399	0.012786	0.000000	0.008497	0.059842	0.097126
TR	0.028834	0.025958	0.001788	0.003139	0.039427	0.000760	0.006112	0.018461	0.005698	0.005863	0.004617	0.048455	0.017979	0.036509	0.000000	0.083130	0.104312
UK	0.035591	0.011208	0.002657	0.003826	0.090260	0.002880	0.034205	0.011704	0.009183	0.002495	0.001075	0.043343	0.026957	0.030269	0.012695	0.000000	0.141336
US	0.133349	0.044859	0.000962	0.169564	0.025946	0.003225	0.005115	0.002233	0.002104	0.000667	0.000435	0.009937	0.009409	0.017029	0.006197	0.056749	0.000000

Appendix C

Parameters

C.1 Fixed parameters

Parameter	Value
Money growth rate	μ=1.01
Discount factor	β=0.999
Depreciation rate	δ=0.01
Constant in labour disutility function	A_L=7.5
Constant in real balances utility function	A_q=0.3776
Labour supply elasticity	σ_L=1.00
Wage markup	λ^w=1.05
Capital tax smoothing	ρ_{τ^k}=0.9
Income tax smoothing	ρ_{τ^y}=0.9
Payroll tax smoothing	ρ_{τ^k}=0.9
Consumption tax smoothing	ρ_{τ^k}=0.9
Government spending smoothing	ρ_g=0.9
Risk aversion (real balances)	σ_q=10.62
Substitution elasticity	η_c=5
Capital utilization cost	σ_a=1000000
Calvo probability, wages	ξ_w=0.69
Calvo probability, domestic prices	ξ_d=0.253
Calvo probability, imported consumption	ξ_{mc}=0.444
Calvo probability, imported investment	ξ_{mi}=0.721
Calvo probability, export prices	ξ_x=0.612
Calvo probability, employment	ξ^E=0.787

Indexation parameter, wages	κ_w=0.497
Indexation parameter, domestic prices	κ_d=0.217
Indexation parameter, imported consumption	κ_{mc}=0.220
Indexation parameter, imported investment	κ_{mi}=0.231
Indexation parameter, exports	κ_x=0.185
Domestic prices markup	λ^d=1.222
Imported consumption prices markup	λ^{mc}=1.633
Imported investment prices markup	λ^{mi}=1.275
Investment adjustment cost	$\tilde{S}$=8.670
Habit formation	b=0.708
Substitution elasticity investment	η_i=1.696
Substitution elasticity foreign	η_f=1.486
Technology growth	μ_z=1.005
Net foreign assets	ϕ_a=0.252
Permanent technology smoothing	ρ_{μ_z}=0.698
Stationary technology shock smoothing	ρ_ϵ=0.886
Investment technology smoothing	ρ_Υ=0.720
Asymmetric Technology shock smoothing	$\rho_{\tilde{z}^*}$=0.992
Consumption preferences smoothing shock	ρ_{ζ^c}=0.892
Labour supply preferences smoothing shock	ρ_{ζ^l}=0.676
Markup smoothing, imported consumption	$\rho_{\lambda_{mc}}$=0.970
Markup smoothing, imported investment	$\rho_{\lambda_{mi}}$=0.963
Markup smoothing, exports	ρ_{λ_x}=0.886
Monetary policy parameter, real exchange rate	ρ_x=-0.009

Individualised parameters

Capital share in production,	α	G/Y ratio,	gr
Imported consumption share,	ω_c	Labour income tax,	τ_y
Imported investment share,	ω_i	Value added tax,	τ_c
Inflation persistence,	$\rho_{\bar{\pi}}$	Labour pay-roll tax,	τ_w
Share of wages in advance,	ν^w	Capital income tax,	τ_k

Country	$\boldsymbol{\alpha}$	$\boldsymbol{\omega_c}$	$\boldsymbol{\omega_i}$	$\boldsymbol{\rho_{\bar{\pi}}}$	ν^w
AU	0.4234	0.15	0.05	0.9039	0.7
AT	0.3698	0.31	0.1	0.9829	0.7
BE	0.4551	0.40 (adj)	0.14	0.9544	0.8
CA	0.548	0.24	0.07	0.9168	0.8
CL	0.8199	0.24	0.07	0.9474	0.6
CZ	0.2775	0.39	0.16	0.9642	0.7
DK	0.4975	0.29	0.08	0.9999 (adj)	0.7
EE	0.4701	0.52	0.21	0.9 (asd)	0.7
FI	0.4112	0.25	0.07	0.9112	0.7
FR	0.4505	0.23 (adj)	0.05	0.9 (adj)	0.65
DE	0.4373	0.23	0.06	0.9 (adj)	0.65
EL	0.4633	0.24	0.06	0.9644	0.65
HU	0.3825	0.5	0.15	0.9826	0.7
IS	0.4483	0.25	0.06	0.9 (asd)	0.7
IE	0.6815	0.4	0.15	0.9999 (adj)	0.65
IL	0.6197	0.31	0.08	0.9 (asd)	0.68
IT	0.4195	0.18	0.05	0.96	0.68
JP	0.29 (adj)	0.11 (adj)	0.03	0.9453	0.85
KR	0.3495	0.23	0.11	0.9665	0.7
LU	0.4995	0.71	0.26	0.9 (asd)	0.4
MX	0.5093	0.19	0.05	0.9888	0.6
NL	0.7148	0.36 (adj)	0.11	0.9959	0.7
NZ	0.4969	0.2	0.06	0.9 (asd)	0.7
NO	0.7952	0.17	0.06	0.9289	0.68
PL	0.4839	0.3	0.08	0.8918	0.63
PT	0.514	0.28	0.07	0.9442	0.65
SK	0.3232	0.51	0.18	0.965	0.7
SI	0.4429	0.44	0.15	0.9 (asd)	0.7
ES	0.474	0.19	0.06	0.9732	0.65
SE	0.4711	0.28	0.08	0.9237	0.8
CH	0.458	0.31	0.11	0.9445	0.68
TR	0.6267	0.18	0.04	0.9999 (adj)	0.5
UK	0.50 (adj)	0.21	0.05	0.935	0.8
US	0.4444	0.11	0.03	0.9356	0.95

adj, Adjusted values

asd, Assigned values

Country	gr	τ_y	τ_c	τ_w	τ_k
AU	0.18	0.2339	0.1	0.2339	0.3
AT	0.2	0.3258	0.2	0.1453	0.25
BE	0.23	0.3105	0.21	0.1705	0.14 (adj)
CA	0.21	0.1634	0.05	0.0868	0.265
CL	0.11	0.07	0.19	0	0.2
CZ	0.2	0.0659	0.21	0	0.19
DK	0.25	0.3437	0.25	0.3159	0.245
EE	0.19	0.1383	0.2	0.1183	0.21
FI	0.23	0.3066	0.24	0.2263	0.2
FR	0.19 (adj)	0.2191	0.2	0.0786	0.3333
DE	0.19	0.2107	0.19	0.009	0.2958
EL	0.2	0.2872	0.23	0.1272	0.26
HU	0.23	0.2653	0.27	0.0803	0.19
IS	0.24	0.1964	0.26	0.1924	0.2
IE	0.17	0.1231	0.23	0.0831	0.125
IL	0.24	0.165	0.18	0.0876	0.265
IT	0.2	0.2467	0.22	0.1518	0.314
JP	0.18	0.2027	0.08	0.0615	0.3564
KR	0.14	0.1068	0.1	0.0234	0.242
LU	0.17	0.184	0.15	0.061	0.2922
MX	0.12	0.1004	0.16	0.0868	0.3
NL	0.24	0.288	0.21	0.157	0.25
NZ	0.18	0.1725	0.15	0.1725	0.28
NO	0.2	0.2768	0.25	0.1948	0.27
PL	0.18	0.1823	0.23	0.004	0.19
PT	0.2	0.1718	0.23	0.0618	0.23
SK	0.18	0.1091	0.2	0	0.22
SI	0.19	0.2486	0.22	0.0276	0.17
ES	0.18	0.1541	0.21	0.0906	0.3
SE	0.27	0.2438	0.25	0.1737	0.22
CH	0.11	0.1082	0.08	0.0457	0.1792
TR	0.13	0.2572	0.18	0.1072	0.2
UK	0.21	0.2371	0.2	0.1439	0.21
US	0.16	0.1284	0.1	0.0519	0.4

adj, Adjusted values

Sources:

- α

  The capital-to-output factor was calculated with annual data from OECD Economic Outlook No. 96 November 2014, Gross domestic product, volume, market prices in national currency and Productive capital stocks, volume, national currency, 1990-2013.

- ω_c

  The propensity for consumption imports was calculated using annual data from *OECD Quarterly National Accounts* on Gross Domestic Product, Private final consumption expenditure, Central government final consumption expenditure and Imports of goods and services, 1990-2014.

- ω_i

  The propensity for investment imports was calculated using annual data from *OECD Quarterly National Accounts* on Gross Domestic Product, Gross fixed capital formation and Imports of goods and services, 1990-2014.

- $\rho_{\bar{\pi}}$

  Data on inflation persistence was calculated using AR(1) models on quarterly data on consumer prices for 28 countries from *OECD Quarterly National Accounts*, 1989Q4-2013Q3. The quarterly inflation series were de-trended using the HP filter. For countries without available data a value of 0.9 was assigned. Persistence was bounded to an upper limit of 0.9999.

- gr

  The Government spending to GDP ratio was calculated using annual data from *OECD Quarterly National Accounts* on General government final consumption expenditure and Gross Domestic Product, 1990-2013.

- τ_y

  Personal income tax rates for 2014 are from *OECD Taxing Wages*, Table I.6, All in rate, One-earner married couple, Two children. OECD, 2015.

- τ_c

  Consumption tax rates for 2014 are from KPMG, *Indirect tax rates table*, published online at http://www.kpmg.com/Global/en/services/Tax/tax-tools-and-resources/Pages/indirect-tax-rates-table.aspx.

- τ_w
  Pay-roll tax rates for 2014 are from *OECD Taxing Wages*, Average income tax, one-earner married. OECD, 2015.

- τ_k
  We approximate to capital tax rates for 2014 using KPMG, Corporate tax rates table, published online at http://www.kpmg.com/global/en/services/tax/tax-tools-and-resources/pages/corporate-tax-rates-table.aspx.

Appendix D

NAFTA region estimation results

D.1 Priors and posteriors

Figure D.1.1: Priors and posteriors, NAFTA region.

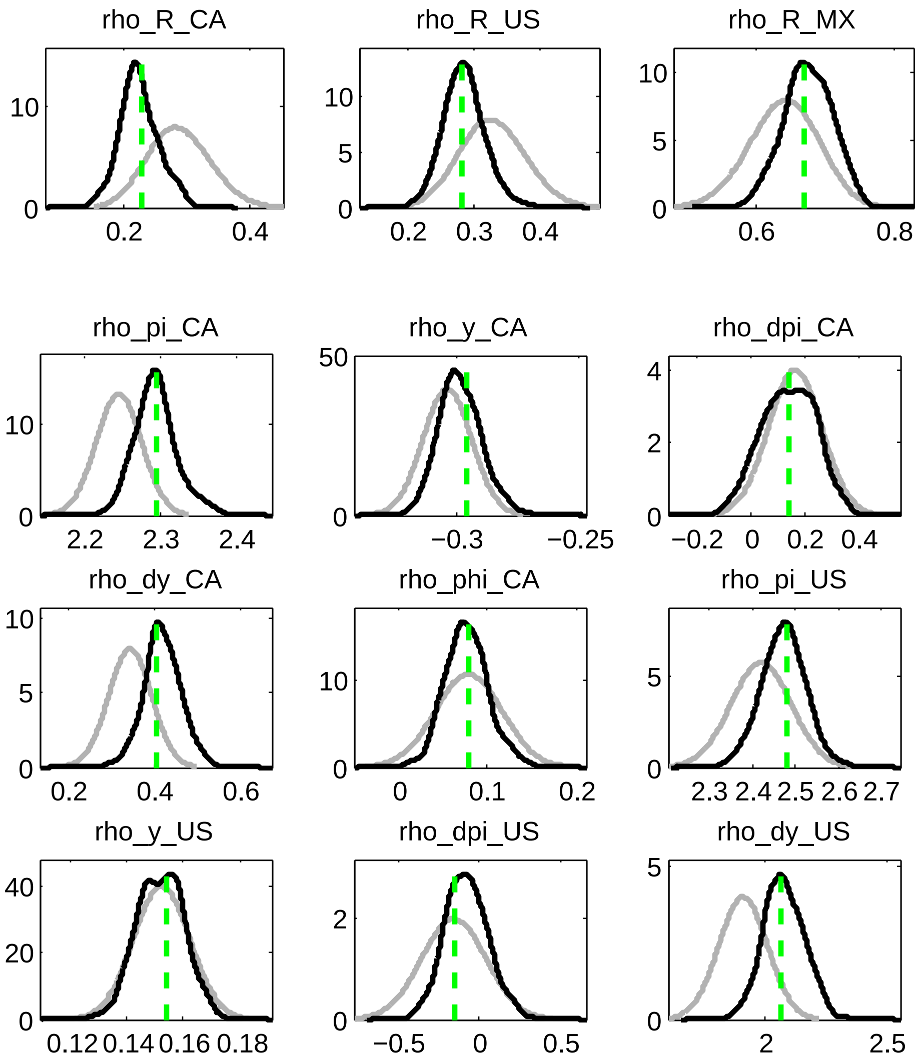


Figure D.1.2: Priors and posteriors, NAFTA region.

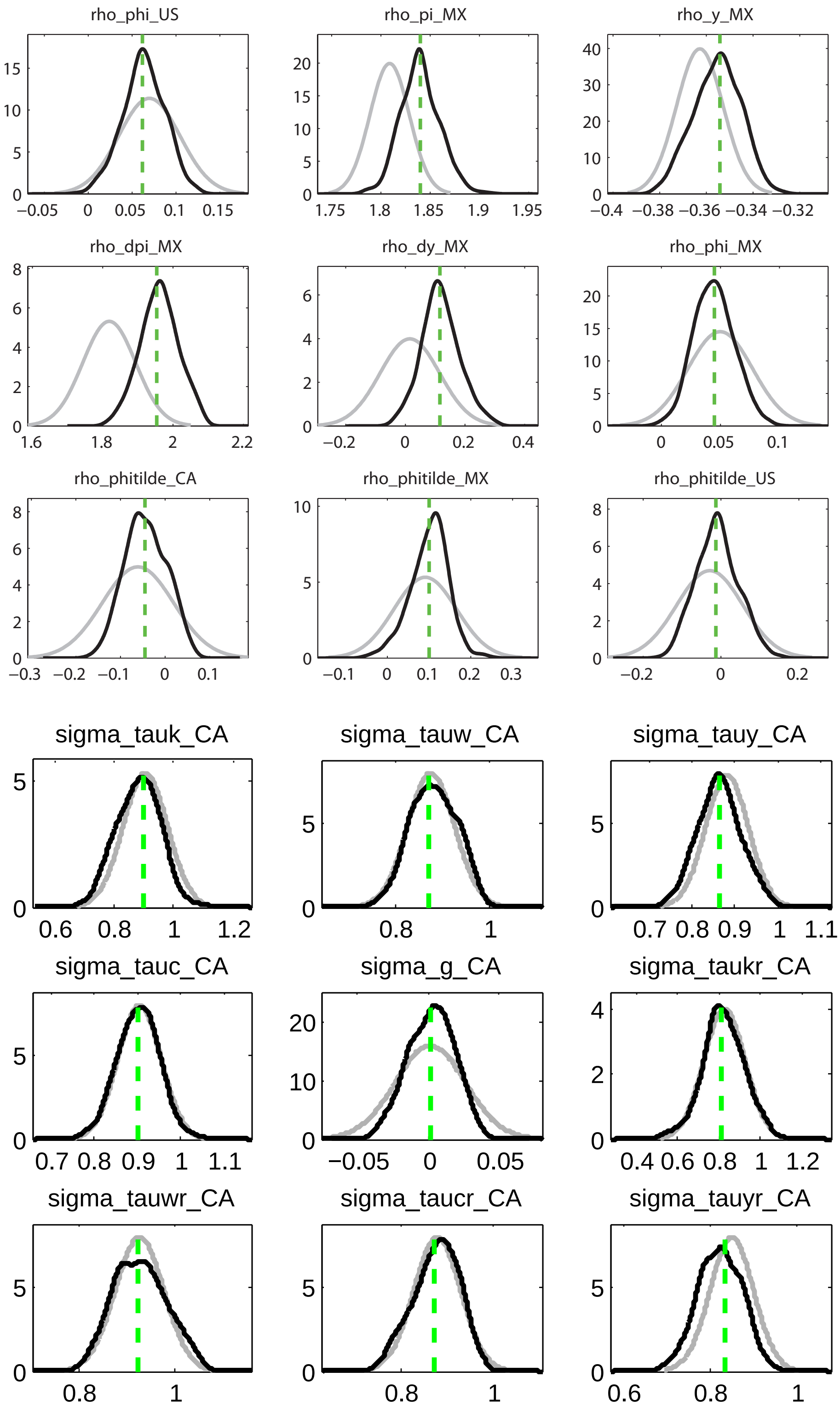


Figure D.1.3: Priors and posteriors, NAFTA region.

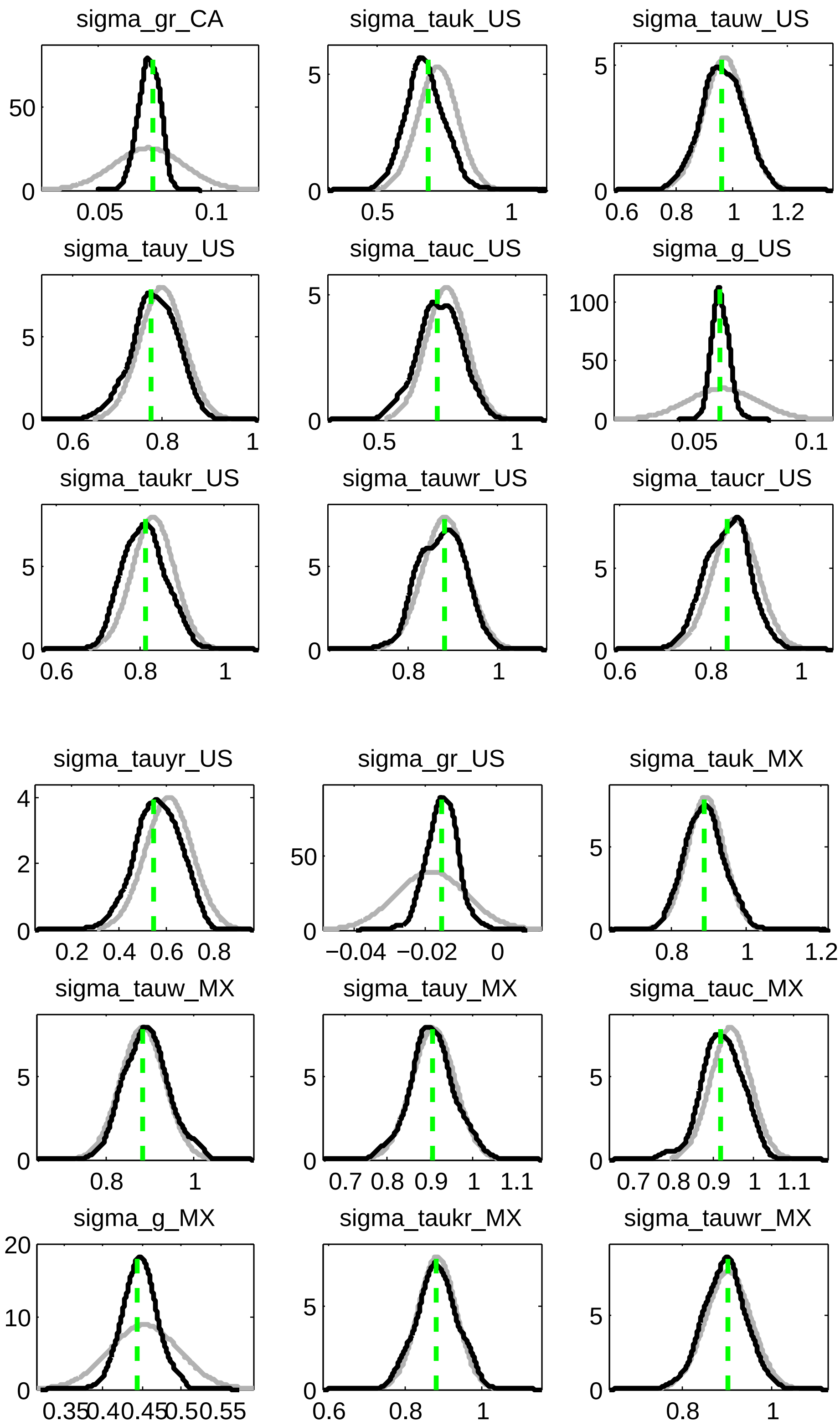
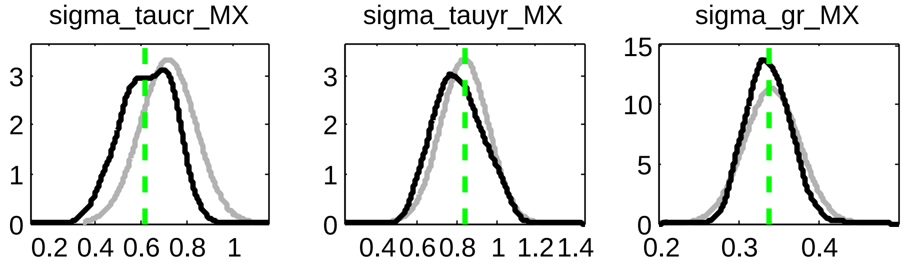


Figure D.1.4: Priors and posteriors, NAFTA region.



D.2 Estimated parameters for the NAFTA region

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
ρ^{R}_{CA}	0.288	0.2239	0.1751	0.2788	beta	0.05
ρ^{R}_{US}	0.329	0.2844	0.2319	0.3322	beta	0.05
ρ^{R}_{MX}	0.641	0.6761	0.6193	0.7344	beta	0.05
ρ^{π}_{CA}	2.245	2.294	2.2442	2.3374	normal	0.03
ρ^{y}_{CA}	-0.304	-0.2988	-0.3134	-0.2849	normal	0.01
$\rho^{\Delta\pi}_{CA}$	0.164	0.1385	-0.031	0.2865	normal	0.1
$\rho^{\Delta y}_{CA}$	0.343	0.4168	0.3434	0.486	normal	0.05
ρ^{ϕ}_{CA}	0.079	0.0765	0.0368	0.1143	normal	0.0375
ρ^{π}_{US}	2.419	2.4716	2.3779	2.5445	normal	0.07
ρ^{y}_{US}	0.152	0.1517	0.1374	0.1639	normal	0.01
$\rho^{\Delta\pi}_{US}$	-0.16	-0.0786	-0.293	0.1419	normal	0.2
$\rho^{\Delta y}_{US}$	1.909	2.0766	1.9352	2.2068	normal	0.1
ρ^{ϕ}_{US}	0.07	0.0631	0.0261	0.1043	normal	0.035
ρ^{π}_{MX}	1.809	1.8397	1.8076	1.8715	normal	0.02
ρ^{y}_{MX}	-0.363	-0.3555	-0.373	-0.3399	normal	0.01
$\rho^{\Delta\pi}_{MX}$	1.819	1.9605	1.875	2.0595	normal	0.075
$\rho^{\Delta y}_{MX}$	0.015	0.1178	0.0075	0.2217	normal	0.1
ρ^{ϕ}_{MX}	0.05	0.0444	0.0179	0.0726	normal	0.0275
$\rho^{\tilde{\phi}}_{CA}$	-0.061	-0.0438	-0.115	0.0356	normal	0.08
$\rho^{\tilde{\phi}}_{MX}$	0.091	0.1	0.0297	0.1782	normal	0.075
$\rho^{\tilde{\phi}}_{US}$	-0.029	-0.0102	-0.0975	0.08	normal	0.085
$\sigma^{\tau^k}_{CA}$	0.904	0.8796	0.7507	0.9852	normal	0.075
$\sigma^{\tau^w}_{CA}$	0.874	0.8798	0.8124	0.9675	normal	0.05
$\sigma^{\tau^y}_{CA}$	0.881	0.8633	0.7823	0.9488	normal	0.05
$\sigma^{\tau^c}_{CA}$	0.904	0.9011	0.8216	0.9755	normal	0.05
σ^{g}_{CA}	0.002	0.0022	-0.0231	0.0296	normal	0.025
$\sigma^{\tau^k}_{NAFTA,CA}$	0.826	0.8212	0.6615	0.9924	normal	0.1
$\sigma^{\tau^w}_{NAFTA,CA}$	0.926	0.9274	0.8363	1.0146	normal	0.05
$\sigma^{\tau^c}_{NAFTA,CA}$	0.879	0.876	0.7914	0.9515	normal	0.05
$\sigma^{\tau^y}_{NAFTA,CA}$	0.848	0.8207	0.7479	0.9096	normal	0.05
$\sigma^{g}_{NAFTA,CA}$	0.073	0.0726	0.0651	0.0797	normal	0.0156

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
$\sigma_{US}^{\tau^k}$	0.727	0.6792	0.5682	0.7987	normal	0.075
$\sigma_{US}^{\tau^w}$	0.972	0.9648	0.8418	1.0867	normal	0.075
$\sigma_{US}^{\tau^y}$	0.801	0.7843	0.6999	0.864	normal	0.05
$\sigma_{US}^{\tau^c}$	0.747	0.7201	0.6049	0.869	normal	0.075
σ_{US}^{g}	0.063	0.0618	0.0557	0.0671	normal	0.015
$\sigma_{NAFTA,US}^{\tau^k}$	0.833	0.8115	0.732	0.8942	normal	0.05
$\sigma_{NAFTA,US}^{\tau^w}$	0.883	0.8755	0.7996	0.9544	normal	0.05
$\sigma_{NAFTA,US}^{\tau^c}$	0.856	0.8385	0.7581	0.9122	normal	0.05
$\sigma_{NAFTA,US}^{\tau^y}$	0.612	0.5635	0.4107	0.7186	normal	0.1
$\sigma_{NAFTA,US}^{g}$	-0.018	-0.0153	-0.0223	-0.0085	normal	0.01
$\sigma_{MX}^{\tau^k}$	0.891	0.888	0.8077	0.9777	normal	0.05
$\sigma_{MX}^{\tau^w}$	0.883	0.8919	0.8101	0.9725	normal	0.05
$\sigma_{MX}^{\tau^y}$	0.907	0.9039	0.8299	0.999	normal	0.05
$\sigma_{MX}^{\tau^c}$	0.943	0.9216	0.8477	1.0066	normal	0.05
σ_{MX}^{g}	0.453	0.4473	0.4102	0.4833	normal	0.045
$\sigma_{NAFTA,MX}^{\tau^k}$	0.884	0.8833	0.7977	0.9748	normal	0.05
$\sigma_{NAFTA,MX}^{\tau^w}$	0.903	0.8944	0.8237	0.9702	normal	0.05
$\sigma_{NAFTA,MX}^{\tau^c}$	0.715	0.6251	0.4388	0.7916	normal	0.12
$\sigma_{NAFTA,MX}^{\tau^y}$	0.841	0.8105	0.6009	1.0046	normal	0.12
$\sigma_{NAFTA,MX}^{g}$	0.341	0.3362	0.2887	0.3757	normal	0.035

Appendix E

Euro region estimation results

E.1 Priors and posteriors

Figure E.1.1: Priors and posteriors, Euro region.

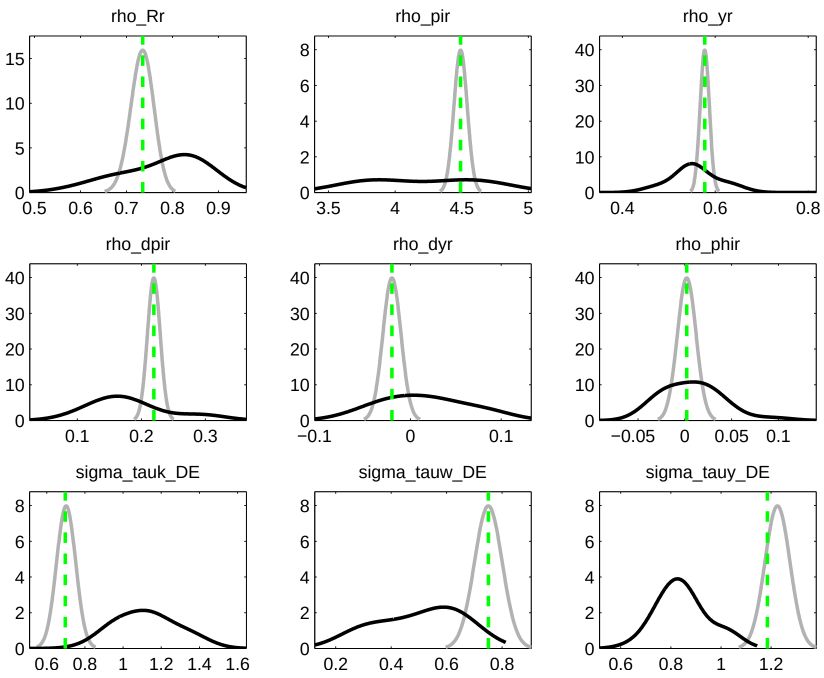


Figure E.1.2: Priors and posteriors, Euro region.

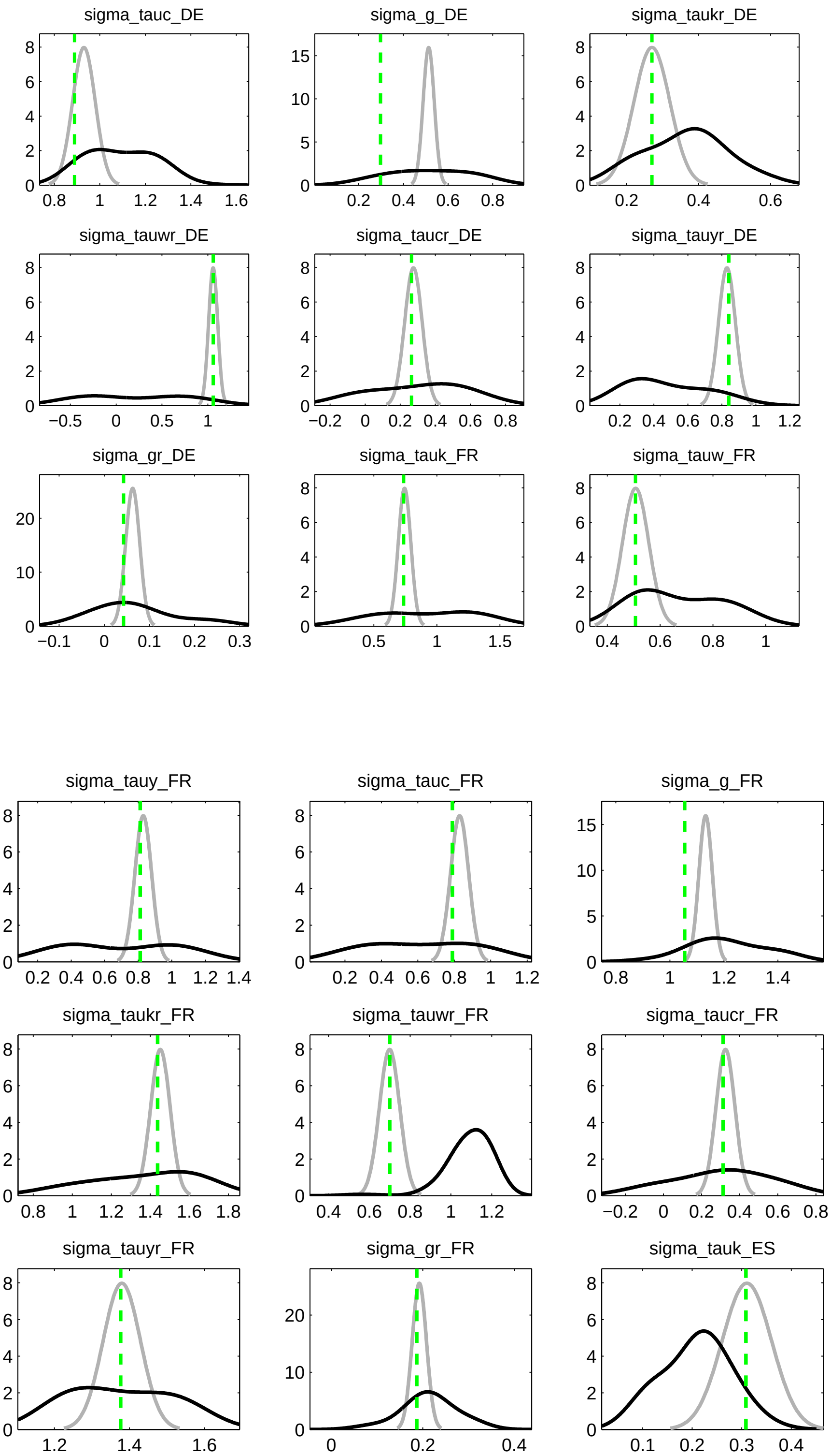
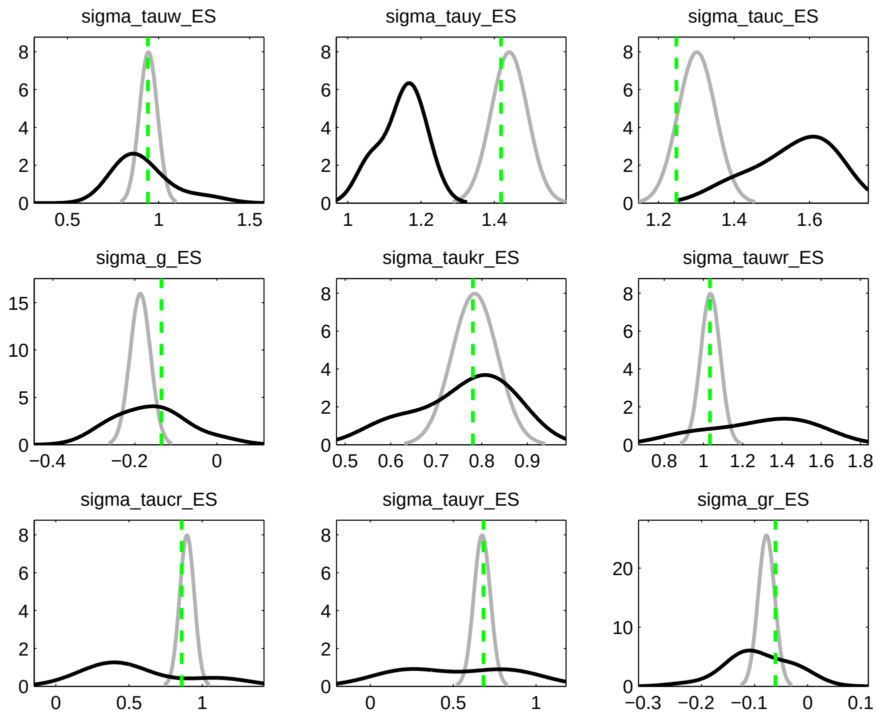
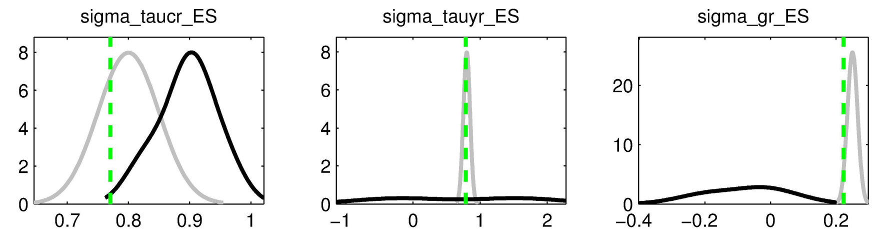


Figure E.1.3: Priors and posteriors, Euro region.





E.2 Estimated parameters for the Euro region

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
ρ^{R}_{EUR}	0.734	0.7772	0.6597	0.8665	beta	0.025
ρ^{π}_{EUR}	4.491	4.2115	3.7257	4.6962	normal	0.05
ρ^{y}_{EUR}	0.577	0.5558	0.4799	0.6251	normal	0.01
$\rho^{\Delta\pi}_{EUR}$	0.22	0.1806	0.1092	0.2963	normal	0.01
$\rho^{\Delta y}_{EUR}$	-0.02	0.0139	-0.0344	0.0854	normal	0.01
ρ^{ϕ}_{EUR}	0.002	0.0077	-0.026	0.0456	normal	0.01
$\sigma^{\tau^k}_{DE}$	0.702	1.1186	0.9615	1.3601	normal	0.05
$\sigma^{\tau^w}_{DE}$	0.751	0.5014	0.3015	0.6756	normal	0.05
$\sigma^{\tau^y}_{DE}$	1.225	0.8466	0.7395	1.0184	normal	0.05
$\sigma^{\tau^c}_{DE}$	0.93	1.0916	0.9187	1.2591	normal	0.05
σ^{g}_{DE}	0.513	0.5143	0.2919	0.752	normal	0.025
$\sigma^{\tau^k}_{EUR,DE}$	0.27	0.3645	0.2136	0.5191	normal	0.05
$\sigma^{\tau^w}_{EUR,DE}$	1.057	0.2115	-0.3792	0.8155	normal	0.05
$\sigma^{\tau^c}_{EUR,DE}$	0.275	0.3013	-0.049	0.6252	normal	0.05
$\sigma^{\tau^y}_{EUR,DE}$	0.83	0.4759	0.2691	0.7459	normal	0.05
$\sigma^{g}_{EUR,DE}$	0.063	0.0666	-0.0334	0.2272	normal	0.0156
$\sigma^{\tau^k}_{FR}$	0.743	0.9203	0.3621	1.3106	normal	0.05
$\sigma^{\tau^w}_{FR}$	0.507	0.6694	0.4923	0.8842	normal	0.05
$\sigma^{\tau^y}_{FR}$	0.83	0.6938	0.3512	1.0576	normal	0.05
$\sigma^{\tau^c}_{FR}$	0.829	0.6153	0.2508	0.981	normal	0.05
σ^{g}_{FR}	1.133	1.2106	1.0898	1.4041	normal	0.025
$\sigma^{\tau^k}_{EUR,FR}$	1.452	1.3685	0.9491	1.613	normal	0.05
$\sigma^{\tau^w}_{EUR,FR}$	0.699	1.0874	0.9996	1.1783	normal	0.05
$\sigma^{\tau^c}_{EUR,FR}$	0.325	0.3019	-0.0768	0.6065	normal	0.05
$\sigma^{\tau^y}_{EUR,FR}$	1.38	1.376	1.2292	1.5382	normal	0.05
$\sigma^{g}_{EUR,FR}$	0.192	0.2124	0.1657	0.3068	normal	0.0156

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
$\sigma_{IT}^{\tau^k}$	1.111	1.2175	1.0255	1.4441	normal	0.187
$\sigma_{IT}^{\tau^w}$	1.123	1.1177	0.9792	1.1813	normal	0.099
$\sigma_{IT}^{\tau^y}$	0.222	0.2061	0.0951	0.3054	normal	0.9
$\sigma_{IT}^{\tau^c}$	0.139	-0.2653	-0.4556	-0.022	normal	0.68
σ_{IT}^{g}	0.004	0.1007	0.0906	0.1125	normal	0.18
$\sigma_{EUR,IT}^{\tau^k}$	0.331	-0.1245	-0.3157	0.0399	normal	0.16
$\sigma_{EUR,IT}^{\tau^w}$	0.567	0.4942	0.4317	0.5599	normal	0.09
$\sigma_{EUR,IT}^{\tau^c}$	0.376	0.1634	0.0362	0.2677	normal	0.21
$\sigma_{EUR,IT}^{\tau^y}$	0.41	0.5519	0.109	1.0958	normal	0.45
$\sigma_{EUR,IT}^{g}$	0.085	0.087	0.0689	0.1025	normal	0.29
$\sigma_{ES}^{\tau^k}$	0.31	0.208	0.1039	0.2786	normal	0.05
$\sigma_{ES}^{\tau^w}$	0.944	0.9157	0.782	1.2144	normal	0.05
$\sigma_{ES}^{\tau^y}$	1.441	1.1468	1.0403	1.1986	normal	0.05
$\sigma_{ES}^{\tau^c}$	1.302	1.5557	1.3838	1.6539	normal	0.05
σ_{ES}^{g}	-0.187	-0.1618	-0.2575	0.0027	normal	0.025
$\sigma_{EUR,ES}^{\tau^k}$	0.784	0.758	0.584	0.8651	normal	0.05
$\sigma_{EUR,ES}^{\tau^w}$	1.036	1.2859	0.9032	1.541	normal	0.05
$\sigma_{EUR,ES}^{\tau^c}$	0.896	0.5631	0.2645	1.1071	normal	0.05
$\sigma_{EUR,ES}^{\tau^y}$	0.674	0.521	0.1826	0.9035	normal	0.05
$\sigma_{EUR,ES}^{g}$	-0.078	-0.0917	-0.1564	-0.0202	normal	0.0156
$\sigma_{NL}^{\tau^k}$	0.89	0.8848	0.8136	0.9317	normal	0.05
$\sigma_{NL}^{\tau^w}$	0.89	0.8916	0.7782	0.9552	normal	0.05
$\sigma_{NL}^{\tau^y}$	0.89	0.8463	0.7936	0.8927	normal	0.05
$\sigma_{NL}^{\tau^c}$	0.89	0.8548	0.7785	0.9534	normal	0.05
σ_{NL}^{g}	0.5	0.3099	0.2628	0.3557	normal	0.025
$\sigma_{EUR,NL}^{\tau^k}$	0.8	0.7907	0.6897	0.9187	normal	0.05
$\sigma_{EUR,NL}^{\tau^w}$	0.8	0.8452	0.7907	0.8983	normal	0.05
$\sigma_{EUR,NL}^{\tau^c}$	0.8	0.7927	0.7422	0.8486	normal	0.05
$\sigma_{EUR,NL}^{\tau^y}$	0.8	0.7771	0.7194	0.857	normal	0.05
$\sigma_{EUR,NL}^{g}$	0.25	0.2193	0.2	0.2426	normal	0.0156

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
$\sigma_{BE}^{\tau^k}$	0.89	0.7821	0.4804	1.1306	normal	0.05
$\sigma_{BE}^{\tau^w}$	0.89	1.0683	0.6296	1.4984	normal	0.05
$\sigma_{BE}^{\tau^y}$	0.89	0.5776	0.3046	0.8322	normal	0.05
$\sigma_{BE}^{\tau^c}$	0.89	0.7099	0.5919	0.8028	normal	0.05
σ_{BE}^{g}	0.5	0.1001	0.0468	0.1997	normal	0.025
$\sigma_{EUR,BE}^{\tau^k}$	0.8	0.979	0.8571	1.1062	normal	0.05
$\sigma_{EUR,BE}^{\tau^w}$	0.8	0.9426	0.5639	1.3357	normal	0.05
$\sigma_{EUR,BE}^{\tau^c}$	0.8	0.8315	0.6703	0.9298	normal	0.05
$\sigma_{EUR,BE}^{\tau^y}$	0.8	0.5083	-0.0603	1.0624	normal	0.05
$\sigma_{EUR,BE}^{g}$	0.25	0.2163	0.1392	0.2669	normal	0.0156

Appendix F

Asia-Pacific region estimation results

F.1 Priors and posteriors

Figure F.1.1: Priors and posteriors, Asia-Pacific region.

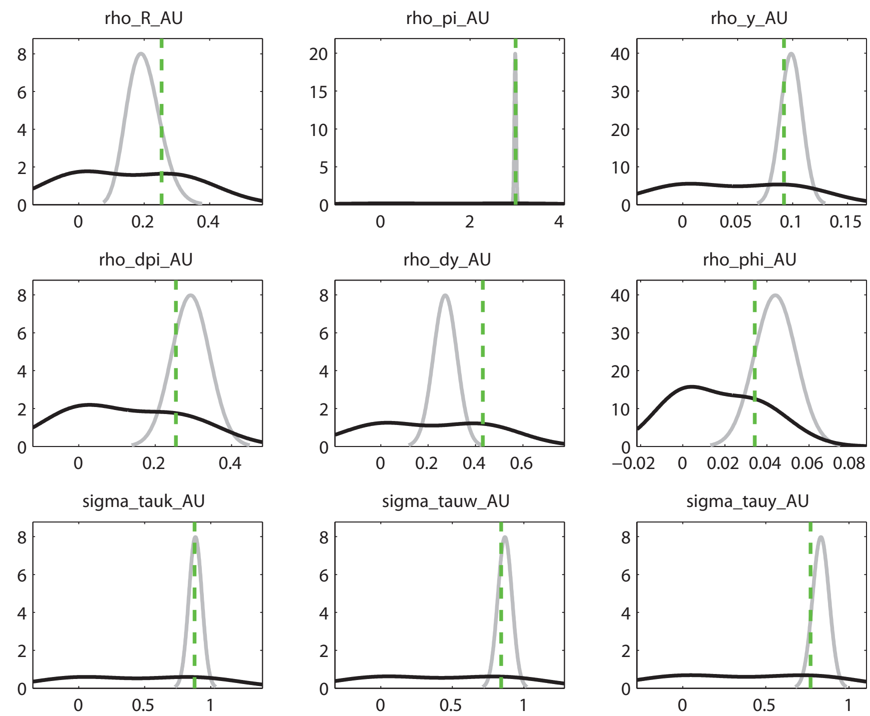


Figure F.1.2: Priors and posteriors, Asia-Pacific region.

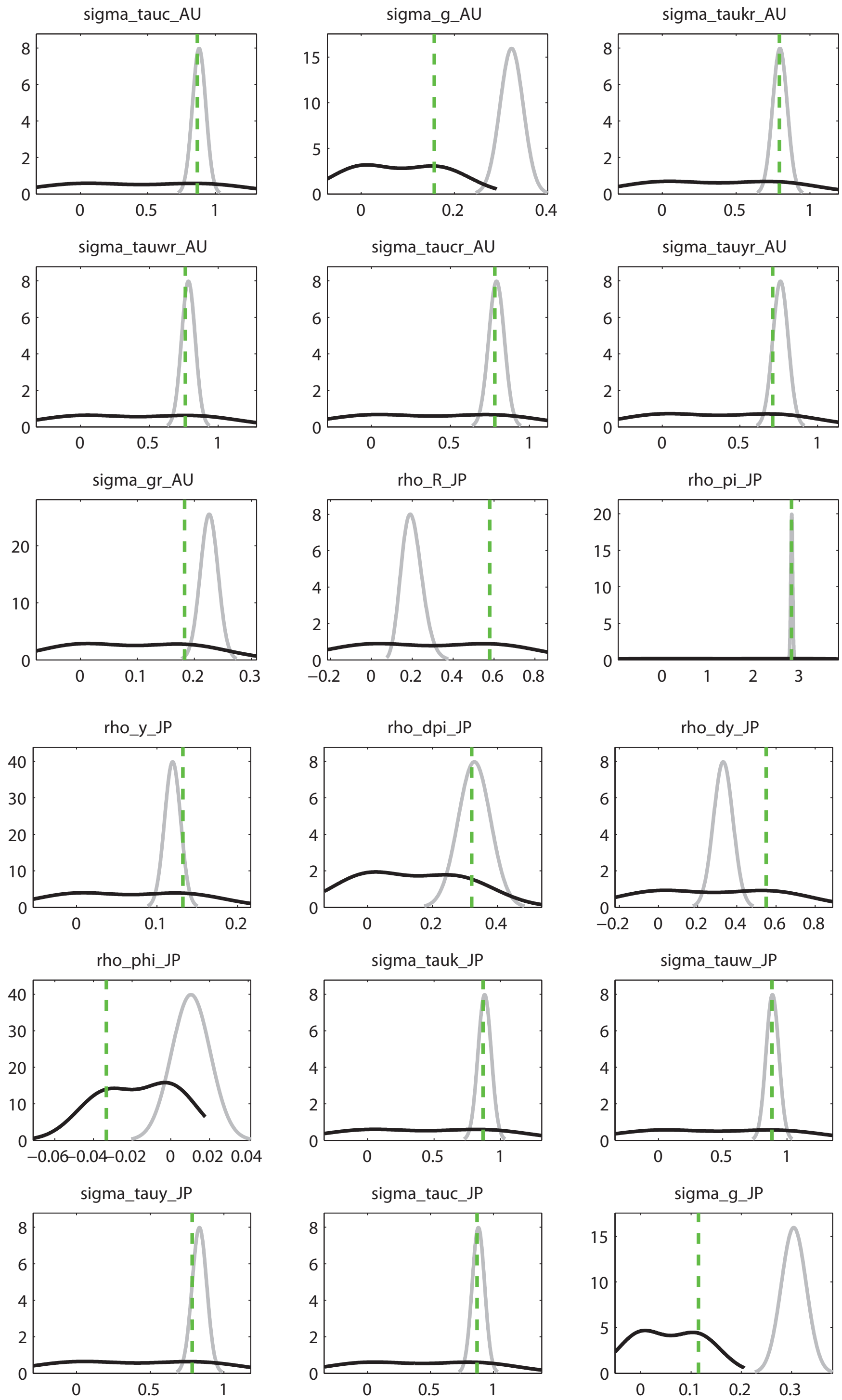


Figure F.1.3: Priors and posteriors, Asia-Pacific region.

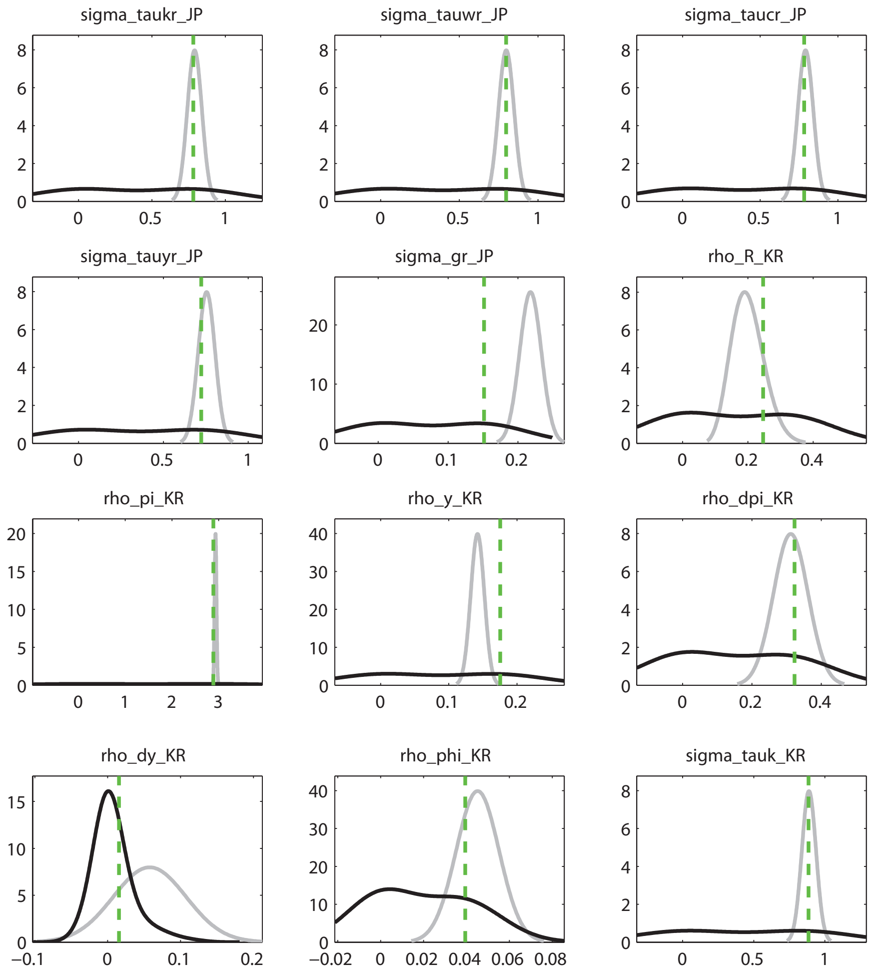
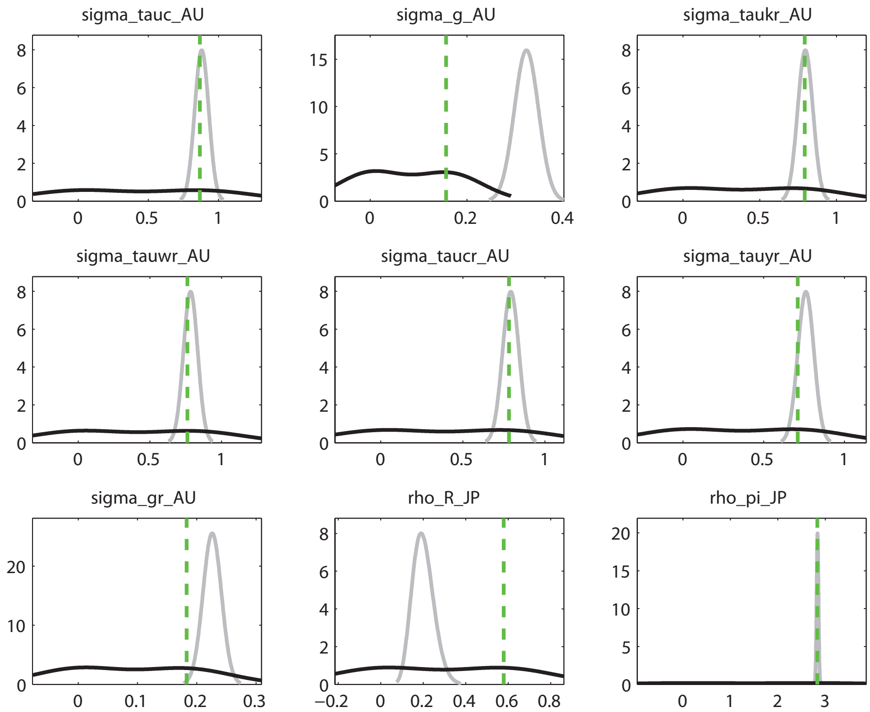


Figure F.1.4: Priors and posteriors, Asia-Pacific region.



F.2 Estimated parameters for the Asia-Pacific region

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
ρ^{R}_{AU}	0.2	0.1486	0	0.3376	beta	0.05
ρ^{π}_{AU}	3.011	1.5092	0	3.033	normal	0.02
ρ^{y}_{AU}	0.099	0.0474	0	0.1027	normal	0.01
$\rho^{\Delta\pi}_{AU}$	0.293	0.1218	0	0.2951	normal	0.05
$\rho^{\Delta y}_{AU}$	0.272	0.2093	0	0.4477	normal	0.05
ρ^{ϕ}_{AU}	0.044	0.0169	0	0.0409	normal	0.01
$\sigma^{\tau^k}_{AU}$	0.884	0.4369	0	0.8929	normal	0.05
$\sigma^{\tau^w}_{AU}$	0.867	0.4171	0	0.8688	normal	0.05
$\sigma^{\tau^y}_{AU}$	0.831	0.3793	0	0.7823	normal	0.05
$\sigma^{\tau^c}_{AU}$	0.88	0.4453	0	0.9369	normal	0.05
σ^{g}_{AU}	0.323	0.0823	0	0.1806	normal	0.025
$\sigma^{\tau^k}_{AsiaPac,AU}$	0.797	0.377	0	0.7905	normal	0.05
$\sigma^{\tau^w}_{AsiaPac,AU}$	0.784	0.4087	0	0.8662	normal	0.05
$\sigma^{\tau^c}_{AsiaPac,AU}$	0.792	0.3853	0	0.7991	normal	0.05
$\sigma^{\tau^y}_{AsiaPac,AU}$	0.761	0.3608	0	0.7584	normal	0.05
$\sigma^{g}_{AsiaPac,AU}$	0.226	0.0913	0	0.1981	normal	0.0156
ρ^{R}_{JP}	0.2	0.2924	0	0.6094	beta	0.05
ρ^{π}_{JP}	2.838	1.4185	0	2.85	normal	0.02
ρ^{y}_{JP}	0.119	0.0656	0	0.139	normal	0.01
$\rho^{\Delta\pi}_{JP}$	0.329	0.1356	0	0.3068	normal	0.05
$\rho^{\Delta y}_{JP}$	0.331	0.2802	0	0.5786	normal	0.05
ρ^{ϕ}_{JP}	0.01	-0.0167	-0.0385	0	normal	0.01
$\sigma^{\tau^k}_{JP}$	0.881	0.4345	0	0.8961	normal	0.05
$\sigma^{\tau^w}_{JP}$	0.887	0.4578	0	0.947	normal	0.05
$\sigma^{\tau^y}_{JP}$	0.834	0.4047	0	0.8421	normal	0.05
$\sigma^{\tau^c}_{JP}$	0.88	0.4259	0	0.8785	normal	0.05
σ^{g}_{JP}	0.304	0.056	0	0.1228	normal	0.025
$\sigma^{\tau^k}_{AsiaPac,JP}$	0.79	0.3946	0	0.8154	normal	0.05
$\sigma^{\tau^w}_{AsiaPac,JP}$	0.799	0.39	0	0.8208	normal	0.05
$\sigma^{\tau^c}_{AsiaPac,JP}$	0.792	0.3799	0	0.794	normal	0.05
$\sigma^{\tau^y}_{AsiaPac,JP}$	0.755	0.3626	0	0.7582	normal	0.05
$\sigma^{g}_{AsiaPac,JP}$	0.218	0.076	0	0.1615	normal	0.0156

Parameter	Prior mean	Post. Mean	90 HPD interval		Distrib.	Post. Std. Dev.
ρ^{R}_{KR}	0.2	0.1619	0	0.3556	beta	0.05
ρ^{π}_{KR}	2.933	1.4462	0	2.908	normal	0.02
ρ^{y}_{KR}	0.142	0.0866	0	0.1804	normal	0.01
$\rho^{\Delta\pi}_{KR}$	0.312	0.1499	0	0.3486	normal	0.05
$\rho^{\Delta y}_{KR}$	0.058	0.0076	-0.0302	0.0427	normal	0.05
ρ^{ϕ}_{KR}	0.045	0.019	0	0.045	normal	0.01
$\sigma^{\tau^k}_{KR}$	0.888	0.4299	0	0.8929	normal	0.05
$\sigma^{\tau^w}_{KR}$	0.89	0.4535	0	0.9507	normal	0.05
$\sigma^{\tau^y}_{KR}$	0.896	0.4584	0	0.95	normal	0.05
$\sigma^{\tau^c}_{KR}$	0.883	0.442	0	0.9108	normal	0.05
σ^{g}_{KR}	0.405	0.1712	0	0.3606	normal	0.025
$\sigma^{\tau^k}_{AsiaPac,KR}$	0.799	0.4046	0	0.8456	normal	0.05
$\sigma^{\tau^w}_{AsiaPac,KR}$	0.8	0.3869	0	0.8236	normal	0.05
$\sigma^{\tau^c}_{AsiaPac,KR}$	0.795	0.4113	0	0.8513	normal	0.05
$\sigma^{\tau^y}_{AsiaPac,KR}$	0.803	0.4096	0	0.8517	normal	0.05
$\sigma^{g}_{AsiaPac,KR}$	0.239	0.117	0	0.2456	normal	0.0156

Appendix G

Full information vs partial information: comparison of selected impulse-responses

Figure G.0.1: International effects of a monetary policy shock in the US, Canada (Full and partial information).

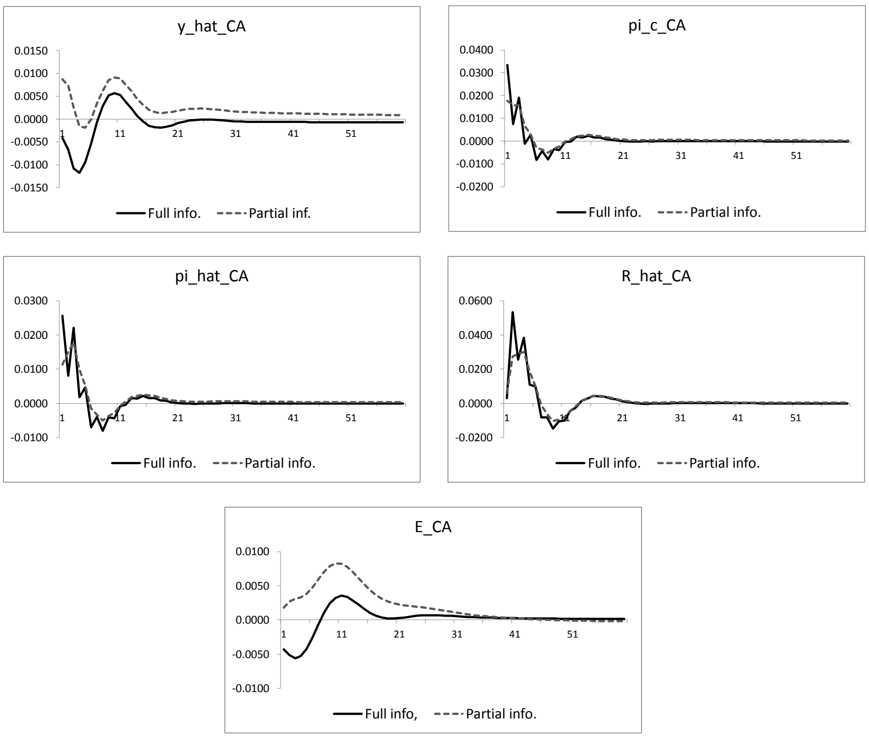


Figure G.0.2: International effects of a monetary policy target shock in the US, Canada (Full and partial information).

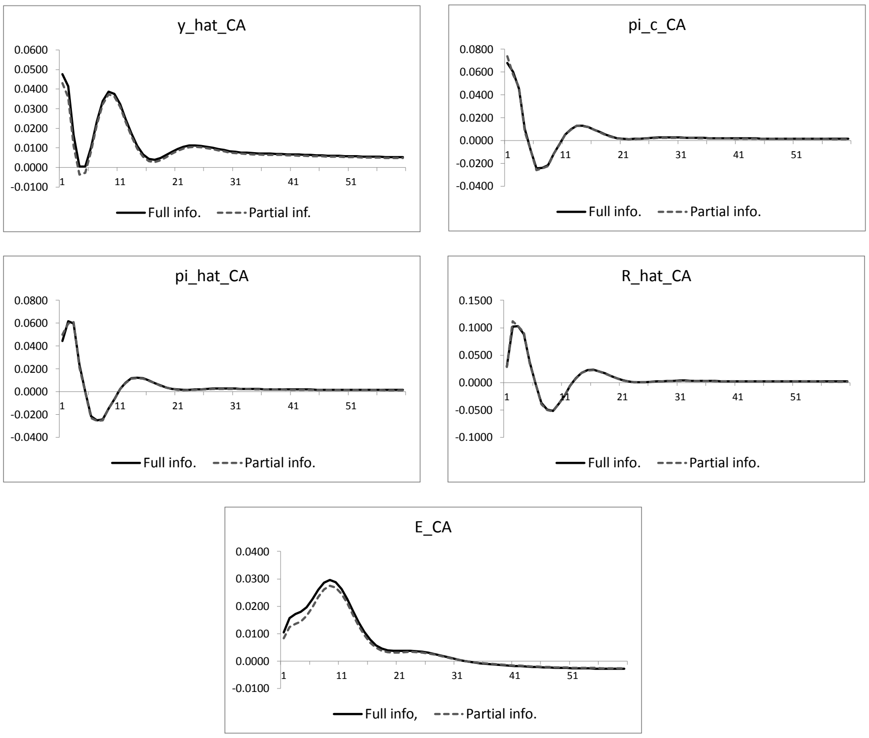


Figure G.0.3: International effects of a monetary policy shock in the US, Mexico (Full and partial information).

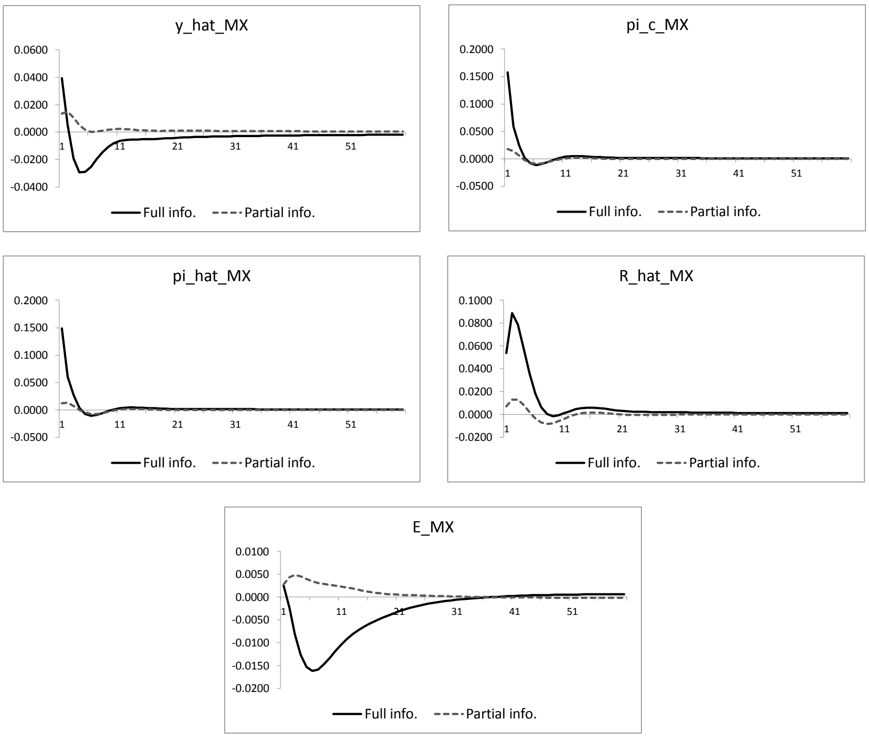
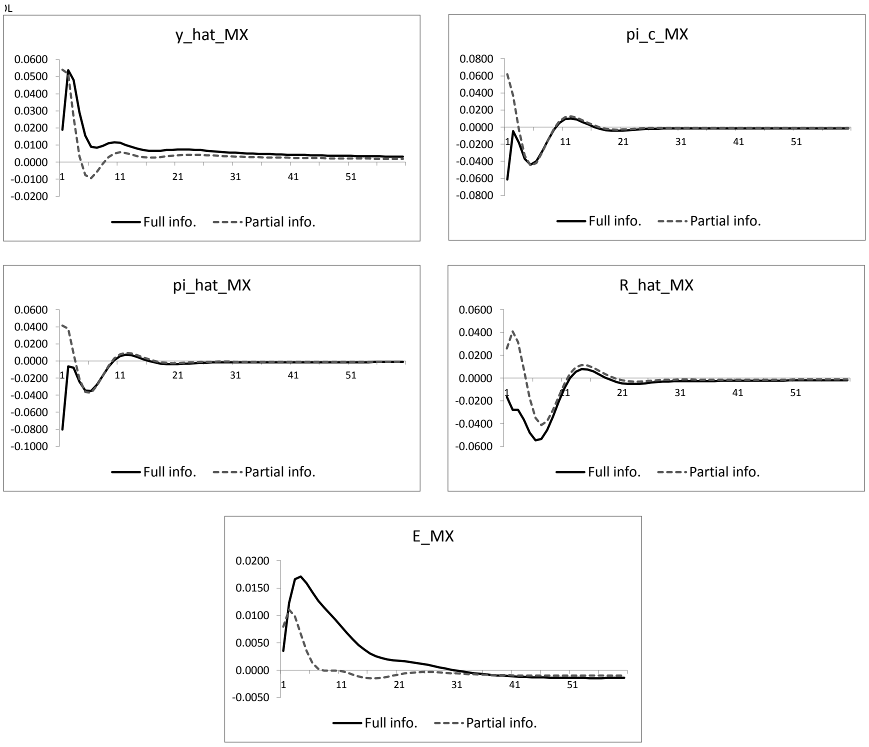


Figure G.0.4: International effects of a monetary policy target shock in the US, Mexico (Full and partial information).



Appendix H

Log-linearised financial sector model

Banking assets:

$$\widehat{S}^b_{i,t} = \widehat{\bar{K}}_{i,t} \tag{H.0.1}$$

Banking leverage:

$$\widehat{\phi}^b_{i,t} = \frac{(P^k_i S_i)(\widehat{P}^k_{i,t} + \widehat{s}_{i,t}) - B^b_i \widehat{B^b}_{i,t}}{P^k_i s_i - B^b_i} - \widehat{N}_{i,t} \tag{H.0.2}$$

and

$$\widehat{\phi}^b_{i,t} = \frac{\nu^b_i}{\nu^b_i - \theta^{bdef}\omega}\widehat{\nu}^b_{i,t} + \frac{\theta^{bdef}(1-\omega) - \mu^s_i}{\mu^s_i}\widehat{\mu}^s_{i,t} \tag{H.0.3}$$

Net worth:

$$\begin{aligned}\widehat{N}_{i,t} = \Big\{ & \Big(R^l_i(\sigma^b + \xi)Q_i(1-\theta^{def}_i)S_i\Big)\Big(\widehat{R}^l_{i,t} + \widehat{Q}_{i,t-1} + \widehat{S}_{i,t-1}\Big) \\ & - \sigma^b\Big[D_i\Big(R^d_i\widehat{R}^d_{i,t} - (\theta^{bres}_i R^H_i)(\widehat{R}^H_{i,t} + \widehat{\theta}^{bres}_{i,t}) + (R^d_i - \theta^{bres}_i R^H_i)\widehat{D}_{i,t-1}\Big) \\ & \qquad + R^{ib}_i B^b_i(\widehat{R}^{ib}_{i,t} + \widehat{B}^b_{i,t-1})\Big]\Big\} \\ & * \Big\{R^l_i(\sigma^b + \xi)Q_i(1-\theta^{def}_i)S_i - \sigma^b[(R^d_i - \theta^{bres}_i R^H_i)D_i + R^{ib}_i B^b_i]\Big\}^{-1}\end{aligned} \tag{H.0.4}$$

Deposits:

$$\widehat{D}_{i,t} = \frac{(Q_i s_i)(\widehat{Q}_{i,t} + \widehat{s}_{i,t}) - n_i\widehat{n}_{i,t} - B^b_i\widehat{B}^b_{i,t} + \left(\frac{\theta^{bres}_i}{(1-\theta^{bres}_i)}\right)\widehat{\theta}^{bres}_{i,t}}{Q_i s_i - n_i - B^b_i} \tag{H.0.5}$$

Fraction of deposits to be held as reserves:

$$\widehat{\theta}^{bres}_{i,t} = \rho^{br}_i\widehat{\theta}^{bres}_{i,t-1} + \varepsilon^{bres}_{i,t} \text{ or } \widehat{\theta}^{bres}_{i,t} = \rho^{br}_m\widehat{\theta}^{bres}_{m,t-1} + \varepsilon^{bres}_{m,t} \tag{H.0.6}$$

Banking reserves:

$$\widehat{H}_{i,t} = \widehat{\theta}^{bres}_{i,t} + \widehat{d}_{i,t} \tag{H.0.7}$$

Interest on required reserves:

$$\widehat{R}^{H}_{i,t} = \rho_i^{R^H} \widehat{R}^{H}_{i,t-1} + \varepsilon^{R^H}_{i,t} \tag{H.0.8}$$

Marginal value of borrowed funds:

$$\widehat{\nu}^{b}_{i,t} = \widehat{\Omega}^{b}_{i,t+1} + \widehat{R}^{ib}_{i,t+1} \tag{H.0.9}$$

with

$$\widehat{\Omega}^{b}_{i,t+1} = \frac{\nu_i^d \widehat{\nu}^d_{i,t+1} + (\phi_i^b \mu_i^s)(\widehat{\phi}^b_{i,t+1} + \widehat{\mu}^s_{i,t+1})}{(\frac{1-\sigma}{\sigma^b}) + \nu_i^d + \phi_i^b \mu_i^s} \tag{H.0.10}$$

Marginal value of deposits:

$$\widehat{\nu}^{d}_{i,t} = \widehat{\Omega}^{b}_{i,t+1} + \widehat{R}^{d}_{i,t+1} \tag{H.0.11}$$

Excess value of assets over liabilities:

$$\widehat{\mu}^{s}_{i,t} = \widehat{\nu}^{b}_{i,t} + \left(\frac{1}{R_i^l - \frac{R_i^d}{1-\theta_i^{bres}}} \right) \left(R_i^l \widehat{R}^l_{i,t+1} - \frac{R^d}{1-\theta_i^{bres}} \widehat{R}^d_{i,t+1} \right) - \widehat{R}^{ib}_{i,t+1} \tag{H.0.12}$$

Gross return of capital:

$$\widehat{Z}_{i,t} = \widehat{y}_{i,t} - \widehat{\bar{k}}_{i,t-1} - \widehat{\gamma}^{cd}_{i,t} \tag{H.0.13}$$

Lending rate:

$$\widehat{R}^{l}_{i,t} = \frac{Z_i \widehat{Z}_{i,t} + (1-\delta) Q_i \widehat{Q}_{i,t} - \widehat{Q}_{i,t-1}}{Z_i + (1-\delta) Q_i} \tag{H.0.14}$$

Deposit rate:

$$\widehat{R}^{d}_{i,t} = \widehat{R}_{i,t-1} - \widehat{\pi}_{i,t} \tag{H.0.15}$$

International interbank rate:

$$\widehat{R}^{ib}_{i,t} = \widehat{R}^{*}_{i,t} + \widehat{\tilde{\phi}}_{i,t} \tag{H.0.16}$$

Appendix I

Private default parameters (θ_i^{def})

AT	0.026235	IS	0.049786
AU	0.009847	IT	0.094167
BE	0.027394	JP	0.037267
CA	0.009361	KR	0.026333
CH	0.016513	LU	0.003788
CL	0.016572	MX	0.042172
CZ	0.092778	NL	0.023250
DE	0.038469	NO	0.012394
DK	0.020118	NZ	0.012500
EE	0.017582	PL	0.100528
EL	0.123112	PT	0.044278
ES	0.031728	SE	0.010218
FI	0.005467	SI	0.065139
FR	0.043929	SK	0.093522
HU	0.066906	TR	0.068100
IE	0.082764	UK	0.025739
IL	0.038512	US	0.019722

Appendix J

Real effects of international shocks

Figure J.0.1: International real effects of a monetary policy shock in the United States, Canada

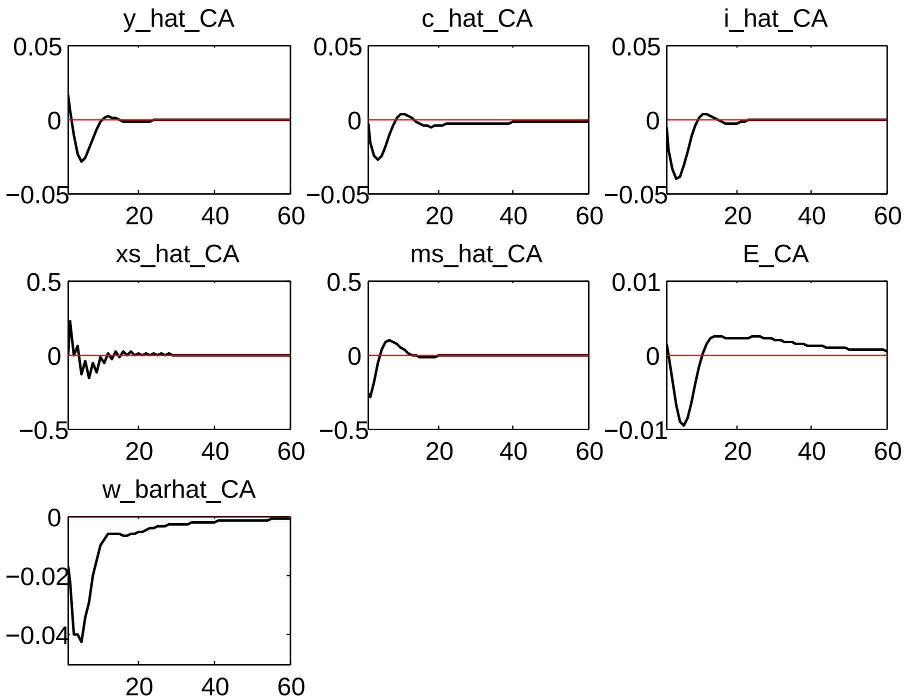


Figure J.0.2: International real effects of a shock to compulsory reserves in the United States, Canada

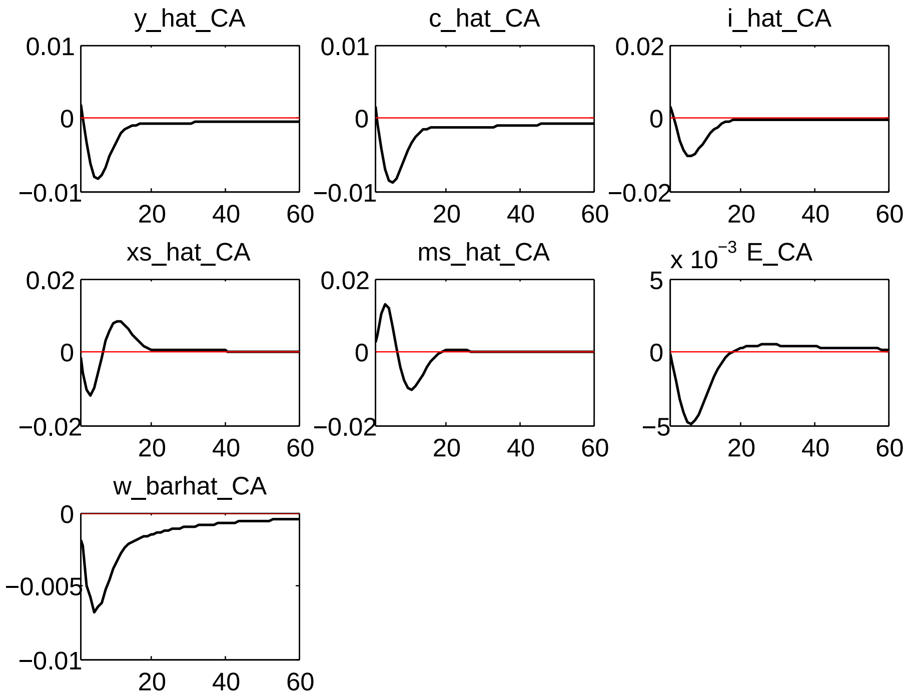


Figure J.0.3: International real effects of a monetary policy shock in the United States, Mexico

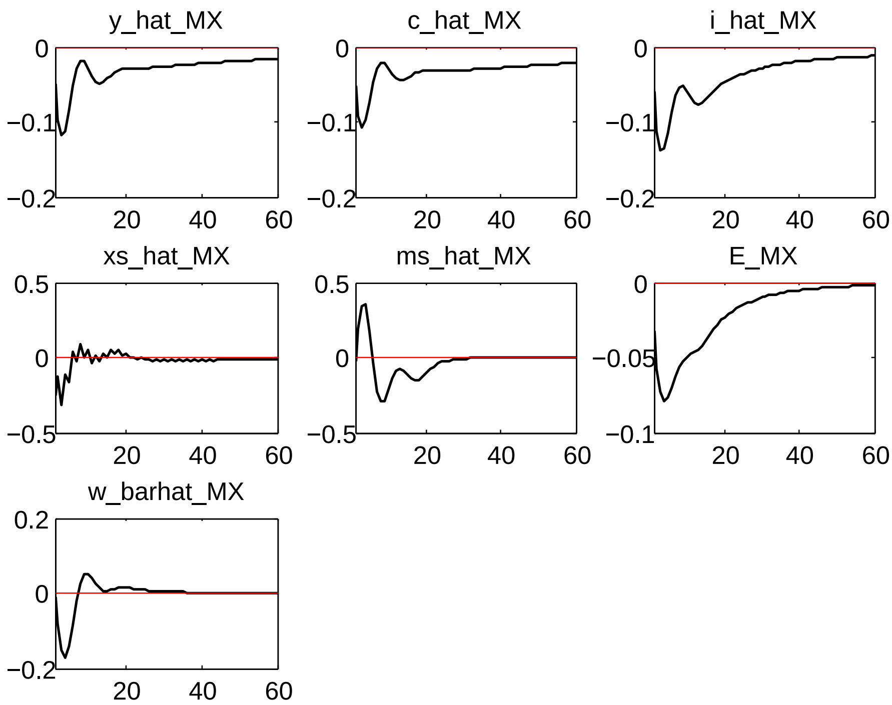


Figure J.0.4: International real effects of a shock to compulsory reserves in the United States, Mexico

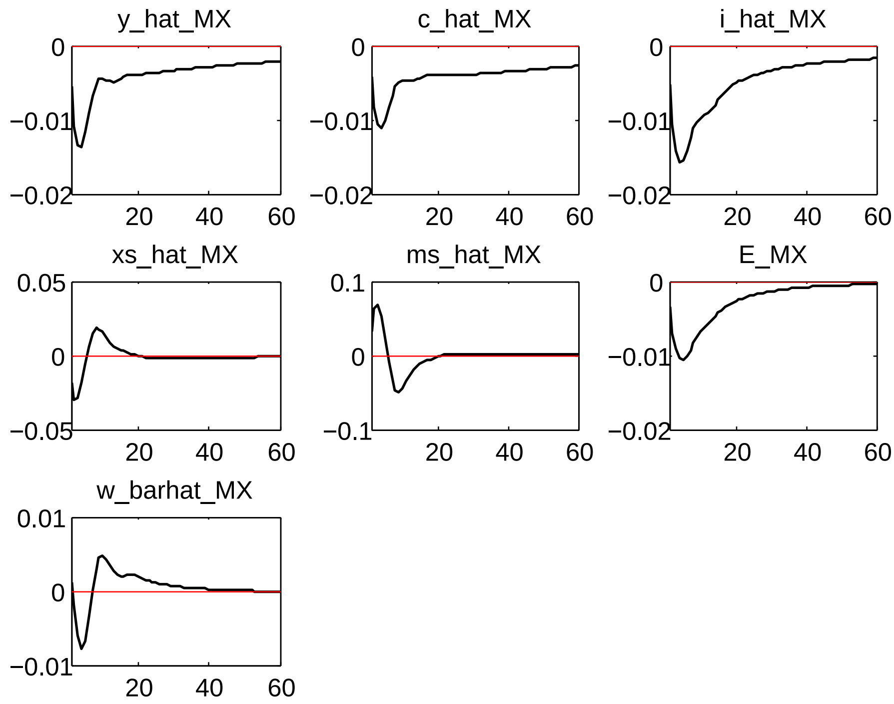


Figure J.0.5: International real effects of a monetary policy shock in Japan, Australia

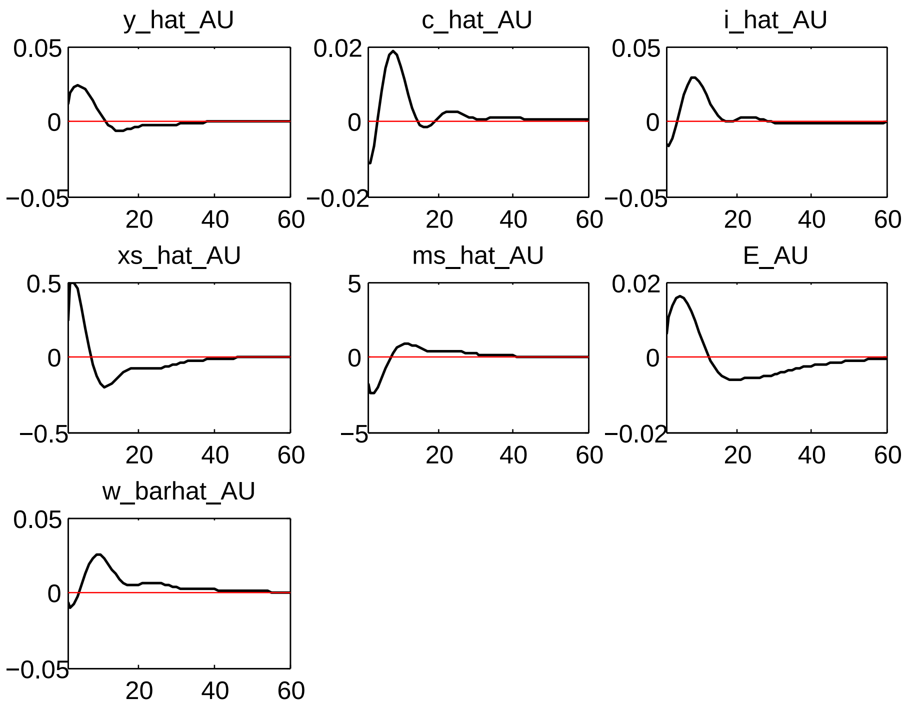


Figure J.0.6: International real effects of a shock to compulsory reserves in Japan, Australia

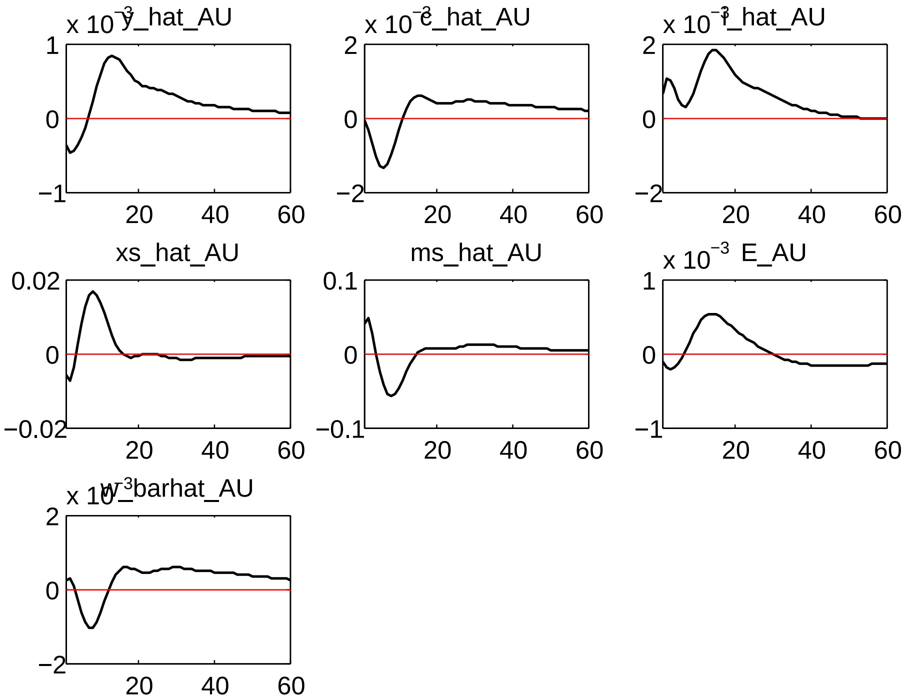


Figure J.0.7: International real effects of a monetary policy shock in Japan, Korea

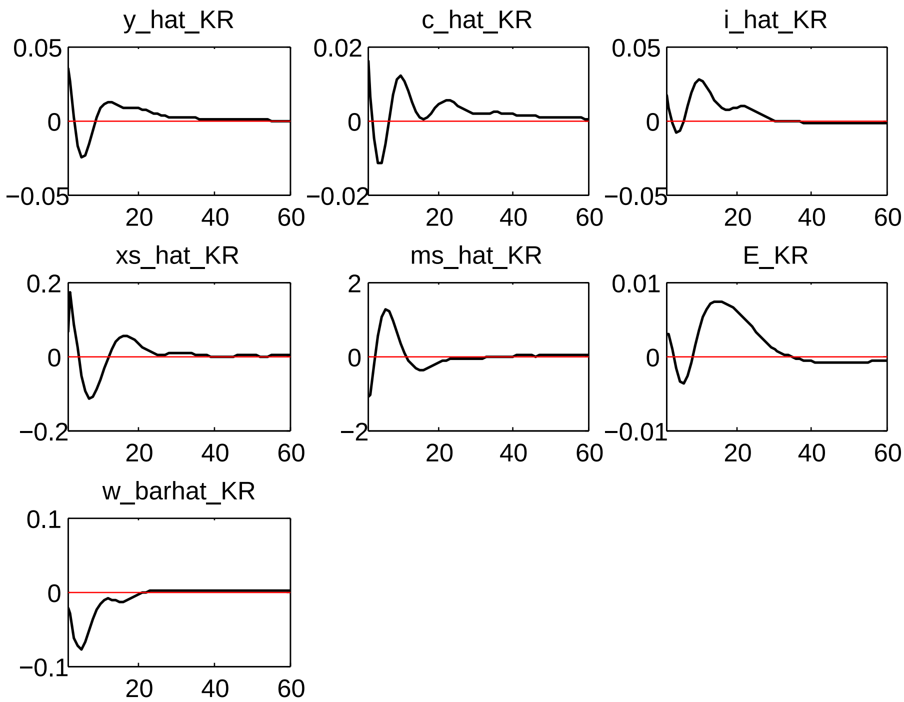


Figure J.0.8: International real effects of a shock to compulsory reserves in Japan, Korea

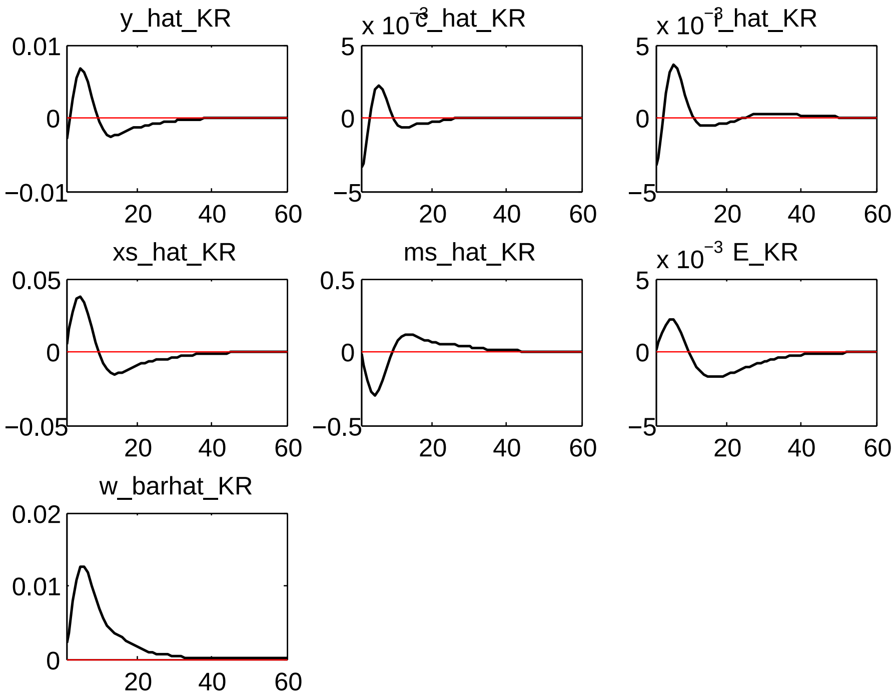


Figure J.0.9: International real effects of a monetary policy shock in the Euro-zone, Germany

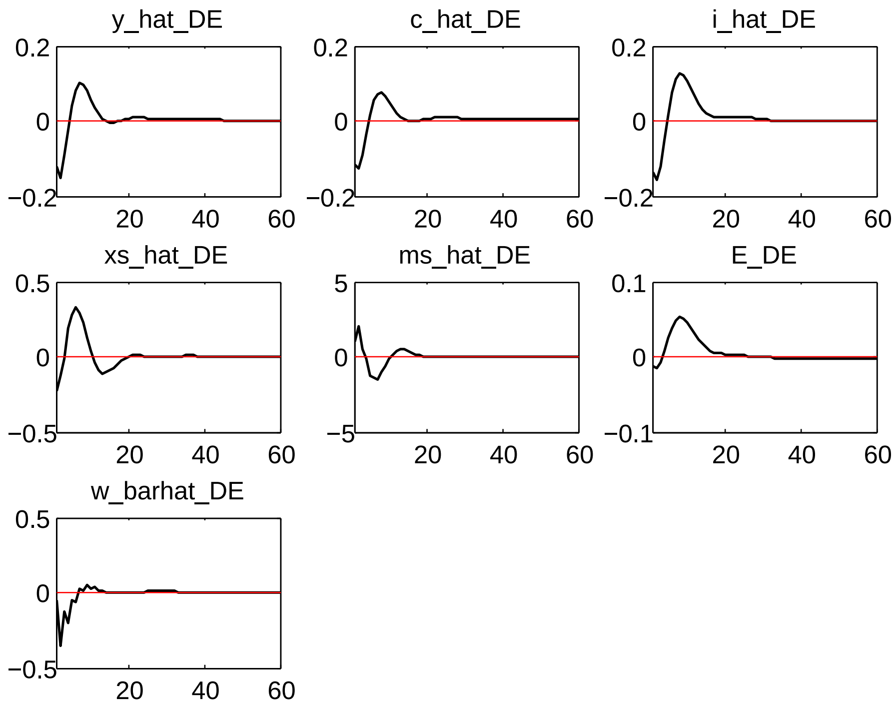


Figure J.0.10: International real effects of a shock to compulsory reserves in the Euro-zone, Germany

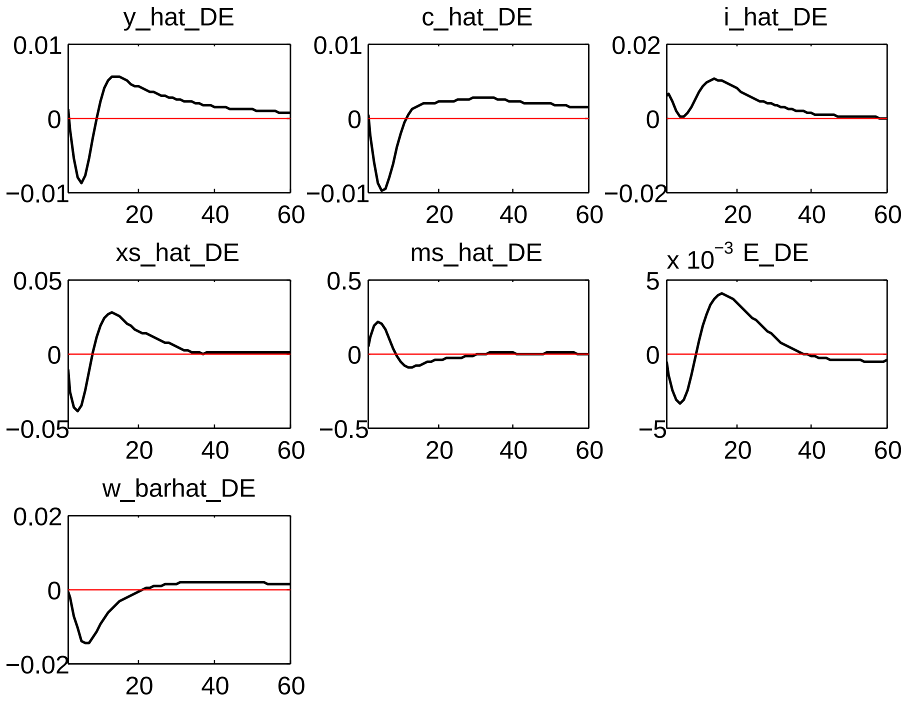


Figure J.0.11: International real effects of a monetary policy shock in the Euro-zone, France

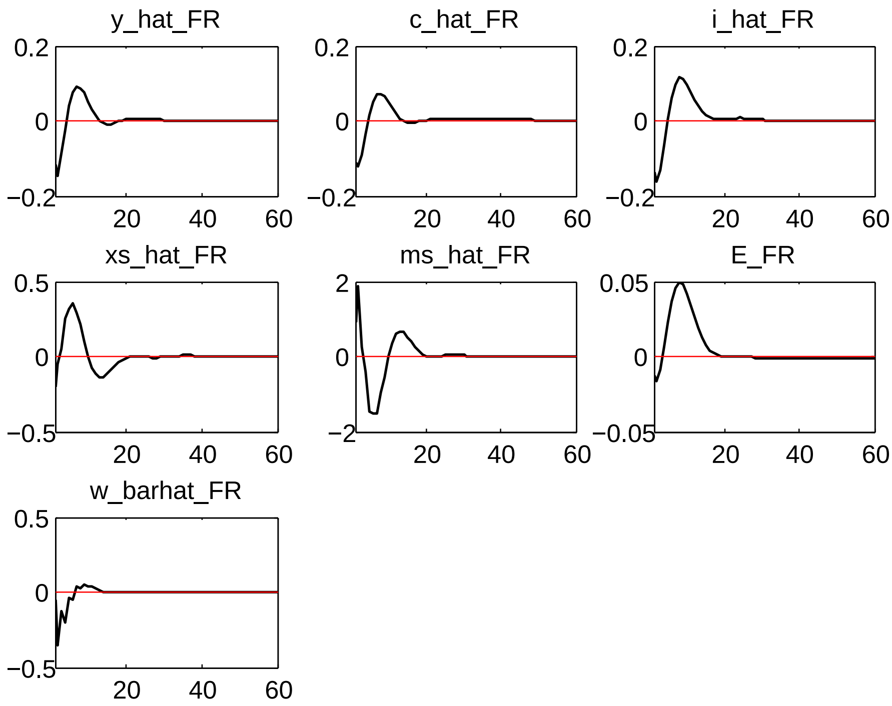


Figure J.0.12: International real effects of a shock to compulsory reserves in the Euro-zone, France

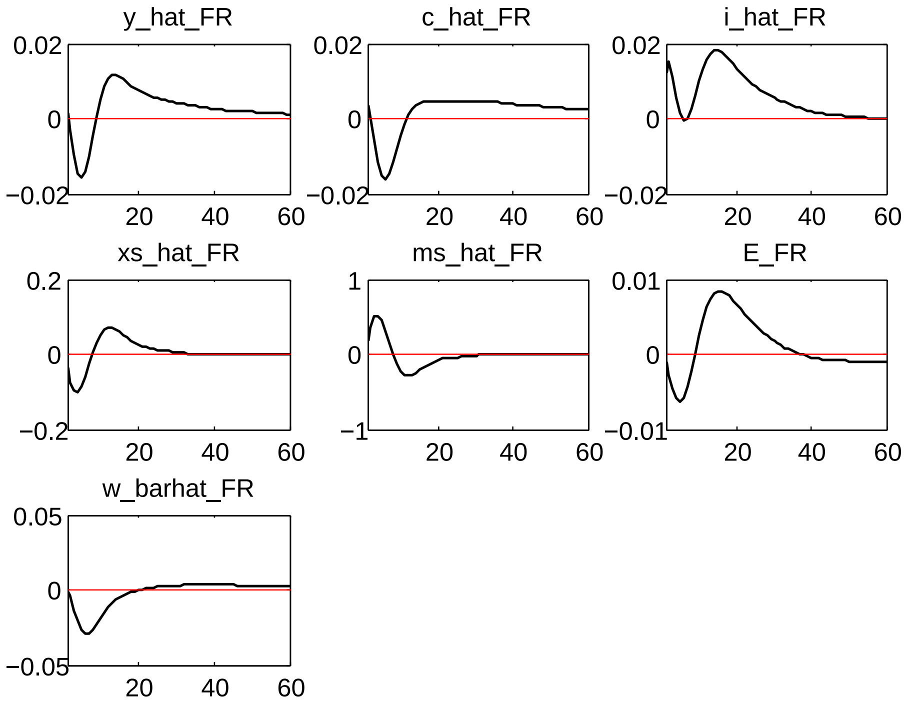


Figure J.0.13: International real effects of a monetary policy shock in the Euro-zone, Spain

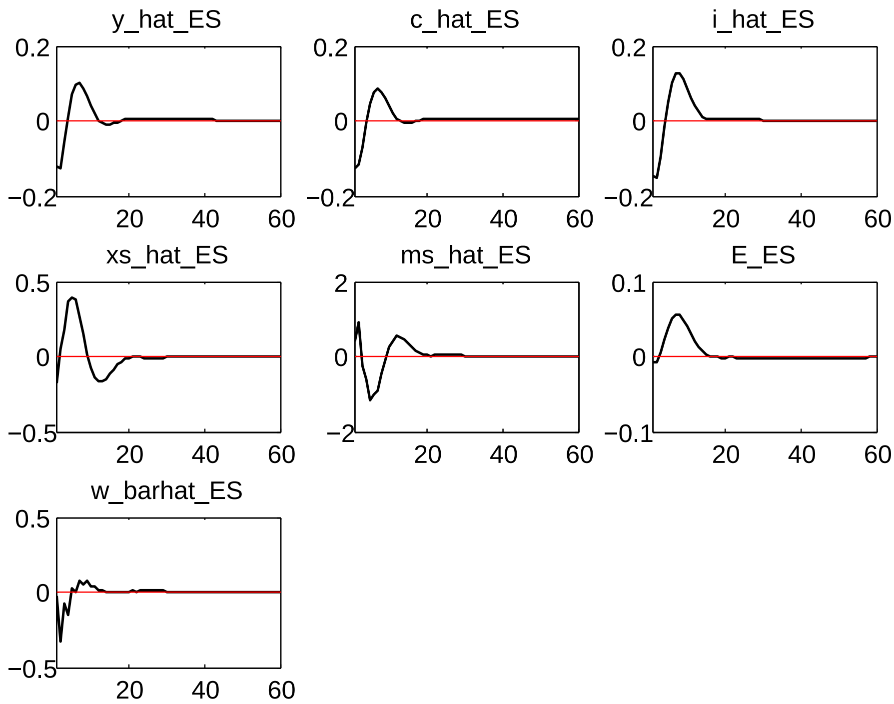
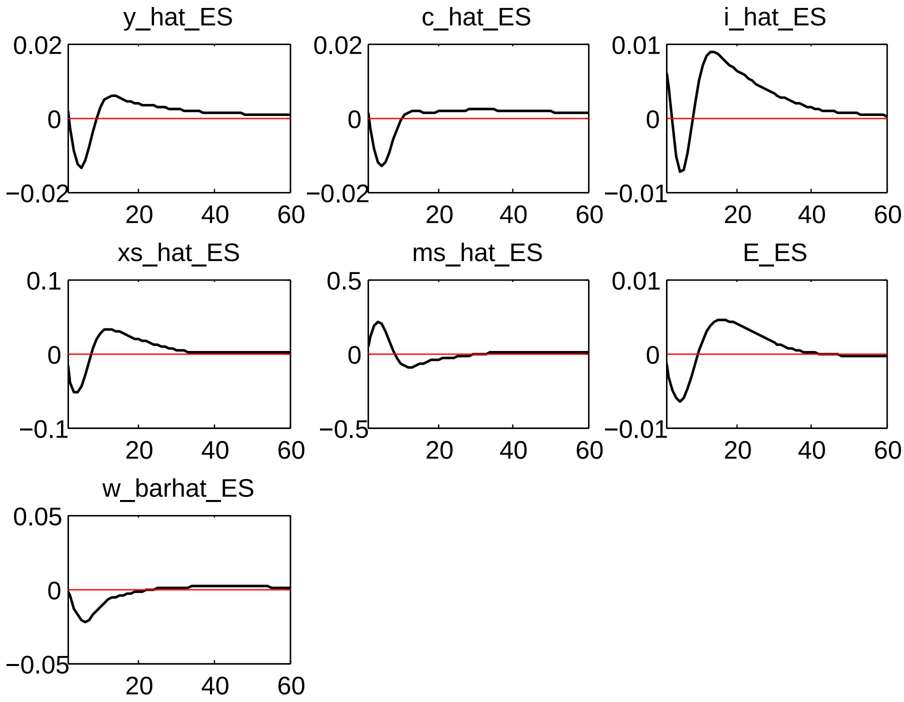


Figure J.0.14: International real effects of a shock to compulsory reserves in the Euro-zone, Spain



Appendix K

Sample (Chapter 4)

Low variation	High variation
Australia	Chile
Austria	Greece
Belgium	Hungary
Canada	Ireland
Czech Republic	Mexico
Denmark	Poland
Finland	Portugal
France	Spain
Germany	Turkey
Italy	
Japan	
Korea	
Netherlands	
Norway	
Slovak Republic	
Sweden	
Switzerland	
United Kingdom	
United States	

Appendix L

Weight matrices

L.1 Spatial weights ($\boldsymbol{W}$)

Normalised spatial weights $\boldsymbol{W}$ were calculated using the geographical distances, $dist$, between the capital cities of the included countries. Official locations (latitude and longitude) for capital cities were obtained from the World Bank's online database's API[1] and geographical distances were calculated using James P. LeSage's econometric toolbox[2].

The particular mechanism used for the calculation of this matrix is based, in common with previous literature, on inverse-distances between pairs of countries i and j with pairwise entries as:

$$w_{i,j} = \frac{\frac{1}{(dist_{i,j})}}{\frac{1}{\sum_{j=1}^{N-1}(dist_{i,j})}} \tag{L.1.1}$$

L.2 Trade weights ($\boldsymbol{T}$)

Trade weights calculations for each country, i, are based on an openness indicator reflecting the comparative importance of each trading counterpart j during a specific period of time, t. In specific terms each entry is derived from:

$$tw_{i,j,t} = x_{i,j,t} + m_{i,j,t} \tag{L.2.1}$$

by using average measurements of quarterly data comprising the period 1990-2012:

$$\overline{tw}_{i,j} = \bar{x}_{i,j} + \overline{m}_{i,j} \tag{L.2.2}$$

[1] http://api.worldbank.org/countries

[2] Available to download from http://www.spatial-econometrics.com/

Normalisation of this matrix with respect to total foreign trade results in individual entries of $\boldsymbol{T}$ as:

$$\overline{ntw}_{i,j} = \frac{\bar{x}_{i,j} + \overline{m}_{i,j}}{\sum_{j=1}^{N-1} \bar{x}_{i,j} + \sum_{j=1}^{N-1} \overline{m}_{i,j}} \tag{L.2.3}$$

with $i \neq j$ and where $\bar{x}_{i,j}$ and $\overline{m}_{i,j}$ represent, respectively, the mean of exports and imports from country i to country j during the selected period.

The data on total imports and total exports were obtained from IMF, Direction of Trade Statistics, via Thomson Reuters' Datastream©.

L.3 Financial weights ($\boldsymbol{I}$)

The matrix of financial weights $\boldsymbol{I}$ was constructed with data on the relative foreign direct investment positions, normalised with respect to each country's total in relation to the other economies in the sample. The source is IMF's Coordinated Direct Investment Survey.

After normalisation with respect to each country's overall position with respect to its aggregate investment positions, the entries of the matrix constitute summary indicators of both outward and inward positions with respect to each partner:

$$\overline{finv}_{i,j} = \frac{\overline{out}_{i,j} + \overline{inw}_{i,j}}{\sum_{j=1}^{N-1} \overline{out}_{i,j} + \sum_{j=1}^{N-1} \overline{inw}_{i,j}} \tag{L.3.1}$$

with $i \neq j$ and where $\overline{out}_{i,j}$ and $\overline{inw}_{i,j}$ stand, respectively, for the means of total outflows and inflows of direct investments between country i and country j during the time horizon.

L.4 Composite weights ($\boldsymbol{Z}$)

A composite weighting matrix $\boldsymbol{Z}$ was constructed by the means of corresponding entries from each of the previous matrices:

$$\begin{aligned} comp_{i,j} &= 0.20 w_{i,j} + 0.40 ntw_{i,j} + 0.40 finv_{i,j} \\ &\Rightarrow \boldsymbol{Z} = [0.20\boldsymbol{W} + 0.40\boldsymbol{T} + 0.40\boldsymbol{I}] \end{aligned} \tag{L.4.1}$$

with $comp_{i,i} = 0$ being a result of the null diagonals in all of the constituent matrices. Each matrix has been assigned a weight reflecting our focus on the economic components of the weights relative to the purely geographic aspect.

L.5 Features of composite weights

Example OECD-19

Z'Z

	AU	AT	BE	CA	CZ	DK	FI	FR	DE	IT	JP	KR	NL	NO	SK	SE	CH	UK	US
Australia	**0.0102**	0.0050	0.0110	0.0131	0.0044	0.0048	0.0038	0.0164	0.0247	0.0083	0.0200	0.0121	0.0274	0.0054	0.0039	0.0087	0.0085	0.0198	0.0650
Austria	0.0050	**0.0758**	0.0365	0.0096	0.0459	0.0187	0.0104	0.0533	0.1187	0.0372	0.0164	0.0128	0.1001	0.0130	0.0177	0.0272	0.0250	0.0453	0.0587
Belgium	0.0110	0.0365	**0.0925**	0.0234	0.0270	0.0315	0.0177	0.0675	0.1439	0.0491	0.0306	0.0130	0.1108	0.0255	0.0201	0.0559	0.0472	0.0987	0.1261
Canada	0.0131	0.0096	0.0234	**0.0915**	0.0075	0.0104	0.0070	0.0330	0.0504	0.0171	0.0502	0.0167	0.0555	0.0097	0.0063	0.0180	0.0223	0.0606	0.0465
Czech Republic	0.0044	0.0459	0.0270	0.0075	**0.0408**	0.0142	0.0088	0.0371	0.0879	0.0325	0.0132	0.0097	0.0657	0.0109	0.0137	0.0226	0.0208	0.0358	0.0468
Denmark	0.0048	0.0187	0.0315	0.0104	0.0142	**0.0272**	0.0163	0.0359	0.0627	0.0202	0.0143	0.0066	0.0623	0.0164	0.0110	0.0352	0.0183	0.0465	0.0580
Finland	0.0038	0.0104	0.0177	0.0070	0.0088	0.0163	**0.0149**	0.0237	0.0432	0.0126	0.0121	0.0049	0.0395	0.0161	0.0067	0.0148	0.0124	0.0315	0.0418
France	0.0164	0.0533	0.0675	0.0330	0.0371	0.0359	0.0237	**0.1541**	0.1784	0.0546	0.0435	0.0188	0.2036	0.0292	0.0272	0.0573	0.0552	0.1073	0.1589
Germany	0.0247	0.1187	0.1439	0.0504	0.0879	0.0627	0.0432	0.1784	**0.4568**	0.1247	0.0705	0.0326	0.3068	0.0583	0.0899	0.1220	0.1013	0.1864	0.2402
Italy	0.0083	0.0372	0.0491	0.0171	0.0325	0.0202	0.0126	0.0546	0.1247	**0.0461**	0.0252	0.0118	0.0967	0.0168	0.0234	0.0327	0.0323	0.0636	0.0891
Japan	0.0200	0.0164	0.0306	0.0502	0.0132	0.0143	0.0121	0.0435	0.0705	0.0252	**0.1334**	0.0189	0.0714	0.0157	0.0126	0.0247	0.0279	0.0808	0.1697
Korea	0.0121	0.0128	0.0130	0.0167	0.0097	0.0066	0.0049	0.0188	0.0326	0.0118	0.0189	**0.0273**	0.0353	0.0053	0.0046	0.0104	0.0115	0.0310	0.0877
Netherlands	0.0274	0.1001	0.1108	0.0555	0.0657	0.0623	0.0395	0.2036	0.3068	0.0967	0.0714	0.0353	**0.3320**	0.0501	0.0530	0.1067	0.0862	0.1667	0.2524
Norway	0.0054	0.0130	0.0255	0.0097	0.0109	0.0164	0.0161	0.0292	0.0583	0.0168	0.0157	0.0053	0.0501	**0.0230**	0.0081	0.0328	0.0168	0.0378	0.0546
Slovak Republic	0.0039	0.0177	0.0201	0.0063	0.0137	0.0110	0.0067	0.0272	0.0899	0.0234	0.0126	0.0046	0.0530	0.0081	**0.0264**	0.0172	0.0198	0.0277	0.0387
Sweden	0.0087	0.0272	0.0559	0.0180	0.0226	0.0352	0.0148	0.0573	0.1220	0.0327	0.0247	0.0104	0.1067	0.0328	0.0172	**0.1513**	0.0304	0.0777	0.0871
Switzerland	0.0085	0.0250	0.0472	0.0223	0.0208	0.0183	0.0124	0.0552	0.1013	0.0323	0.0279	0.0115	0.0862	0.0168	0.0198	0.0304	**0.0349**	0.0638	0.0894
United Kingdom	0.0198	0.0453	0.0987	0.0606	0.0358	0.0465	0.0315	0.1073	0.1864	0.0636	0.0808	0.0310	0.1667	0.0378	0.0277	0.0777	0.0638	**0.1637**	0.2294
United States	0.0650	0.0587	0.1261	0.0465	0.0468	0.0580	0.0418	0.1589	0.2402	0.0891	0.1697	0.0877	0.2524	0.0546	0.0387	0.0871	0.0894	0.2294	**0.8923**

Z+Z'

	AU	AT	BE	CA	CZ	DK	FI	FR	DE	IT	JP	KR	NL	NO	SK	SE	CH	UK	US
Australia	0.0000	0.0191	0.0267	0.0502	0.0126	0.0222	0.0209	0.0368	0.0608	0.0325	0.2660	0.1213	0.0529	0.0146	0.0117	0.0250	0.0468	0.1615	0.2909
Austria	0.0191	0.0000	0.0408	0.0143	0.1901	0.0364	0.0376	0.0520	0.4085	0.1646	0.0183	0.0163	0.1015	0.0257	0.3340	0.0380	0.1247	0.0544	0.0511
Belgium	0.0267	0.0408	0.0000	0.0183	0.0582	0.0459	0.1001	0.4115	0.1833	0.1086	0.0439	0.0242	0.4537	0.0723	0.0422	0.0773	0.0839	0.1576	0.0797
Canada	0.0502	0.0143	0.0183	0.0000	0.0100	0.0185	0.0194	0.0328	0.0316	0.0201	0.0566	0.0402	0.0588	0.0340	0.0085	0.0207	0.0428	0.1009	0.9710
Czech Republic	0.0126	0.1901	0.0582	0.0100	0.0000	0.0484	0.0296	0.0737	0.3342	0.0667	0.0208	0.0197	0.2030	0.0298	0.2574	0.0434	0.0617	0.0504	0.0353
Denmark	0.0222	0.0364	0.0459	0.0185	0.0484	0.0000	0.0854	0.0709	0.2189	0.0522	0.0291	0.0153	0.1111	0.1804	0.0313	0.3001	0.0608	0.1089	0.0748
Finland	0.0209	0.0376	0.1001	0.0194	0.0296	0.0854	0.0000	0.0455	0.1364	0.0438	0.0256	0.0197	0.1347	0.0660	0.0267	0.3857	0.0277	0.0636	0.0701
France	0.0368	0.0520	0.4115	0.0328	0.0737	0.0709	0.0455	0.0000	0.2588	0.2366	0.0627	0.0385	0.2233	0.0901	0.0596	0.0641	0.1661	0.2685	0.1635
Germany	0.0608	0.4085	0.1833	0.0316	0.3342	0.2189	0.1364	0.2588	0.0000	0.2474	0.0781	0.0703	0.3161	0.1212	0.2143	0.1562	0.2545	0.2143	0.1944
Italy	0.0325	0.1646	0.1086	0.0201	0.0667	0.0522	0.0438	0.2366	0.2474	0.0000	0.0341	0.0269	0.2128	0.0361	0.1026	0.0502	0.1451	0.1180	0.0957
Japan	0.2660	0.0183	0.0439	0.0566	0.0208	0.0291	0.0256	0.0627	0.0781	0.0341	0.0000	0.4213	0.1129	0.0227	0.0131	0.0296	0.0421	0.0866	0.4879
Korea	0.1213	0.0163	0.0242	0.0402	0.0197	0.0153	0.0197	0.0385	0.0703	0.0269	0.4213	0.0000	0.0694	0.0268	0.0465	0.0239	0.0237	0.0695	0.2972
Netherlands	0.0529	0.1015	0.4537	0.0588	0.2030	0.1111	0.1347	0.2233	0.3161	0.2128	0.1129	0.0694	0.0000	0.1388	0.1388	0.1375	0.1994	0.3229	0.2348
Norway	0.0146	0.0257	0.0723	0.0340	0.0298	0.1804	0.0660	0.0901	0.1212	0.0361	0.0227	0.0268	0.1388	0.0000	0.0199	0.2628	0.0381	0.1620	0.1045
Slovak Republic	0.0117	0.3340	0.0422	0.0085	0.2574	0.0313	0.0267	0.0596	0.2143	0.1026	0.0131	0.0465	0.1388	0.0199	0.0000	0.0321	0.0333	0.0343	0.0215
Sweden	0.0250	0.0380	0.0773	0.0207	0.0434	0.3001	0.3857	0.0641	0.1562	0.0502	0.0296	0.0239	0.1375	0.2628	0.0321	0.0000	0.0461	0.1261	0.1139
Switzerland	0.0468	0.1247	0.0839	0.0428	0.0617	0.0608	0.0277	0.1661	0.2545	0.1451	0.0421	0.0237	0.1994	0.0381	0.0333	0.0461	0.0000	0.1279	0.1994
United Kingdom	0.1615	0.0544	0.1576	0.1009	0.0504	0.1089	0.0636	0.2685	0.2143	0.1180	0.0866	0.0695	0.3229	0.1620	0.0343	0.1261	0.1279	0.0000	0.3467
United States	0.2909	0.0511	0.0797	0.9710	0.0353	0.0748	0.0701	0.1635	0.1944	0.0957	0.4879	0.2972	0.2348	0.1045	0.0215	0.1139	0.1994	0.3467	0.0000

Appendix M

Discretionary component of fiscal policy

Figure M.0.1: Discretionary component of fiscal policy by country.

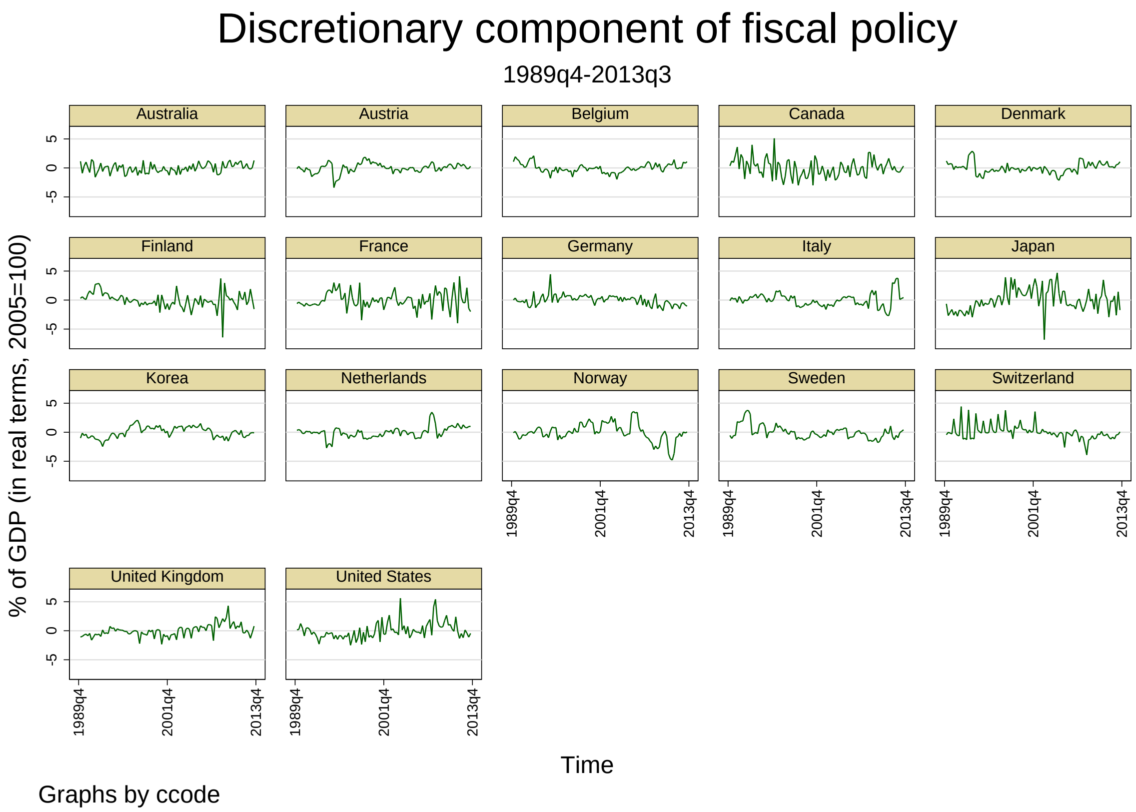


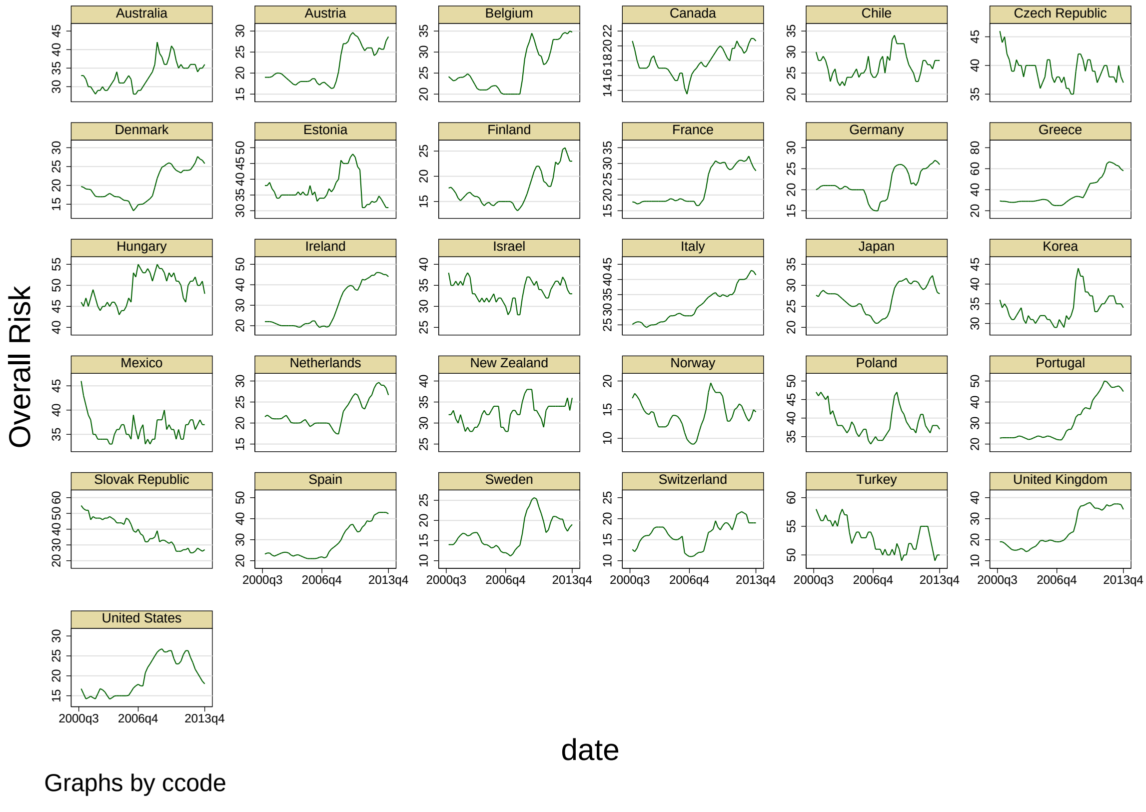
Table M.0.1: Evaluating the discretionary component of government debt.

Fisher-type unit-root test for $\xi_{i,t}^{gdebt}$			
Based on augmented Dickey-Fuller tests			
Ho: All panels contain unit roots		Number of panels = 17	
Ha: At least one panel is stationary		Number of periods = 95	
AR parameter:	Panel-specific	Asymptotics: T $\rightarrow$ Infinity	
Panel means:	Included		
Time trend:	Not included		
Drift term:	Not included	ADF regressions: 1 lag	
		Statistic	p-value
Inverse chi-squared(34)	P	321.3744	0.0000
Inverse normal	Z	-14.7463	0.0000
Inverse logit t(89)	L*	-21.5867	0.0000
Modified inv. chi-squared	Pm	34.8493	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Appendix N

Overall risk index in the OECD

Figure N.0.1: Overall risk by country, 2000-2014.



We use the overall risk series from The Economist Intelligence Unit. Completed with own calculations (interpolation for missing values within the series' original sample).