International shocks and macroeconomics: a new multi-country DSGE platform for policy analysis in OECD countries.

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Abstract

In this paper, a new macroeconometric multi-country DSGE platform is introduced and applied for the analysis of macroeconomic, risk, and policy shocks 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. Applying national, regional and global shocks, the resulting framework proves useful for the study of the effects of disturbances and policy spillovers among heterogeneous economies. Using data and parameterisations on OECD economies, our simulations of shocks reveal distinctive degrees of real and nominal sensitivity which are significant for the design of their own domestic monetary policies.

Keywords: International economic networks, international macroeconomic spillovers, multi-country DSGE model
JEL classification: F41, F42, F47

1. Introduction

International trade and finance are key drivers of the performance of the global economy and, importantly, crucial factors in the transmission of nominal and real disturbances.

This paper addresses three fundamental questions in the current context of commercial and financial exchanges between economies: 1) What are the main features of the international transmission of macroeconomic and financial shocks at the regional level? 2) How can we distinguish the specific impacts of common shocks on heterogeneous members of regional economic networks? and 3) What are the implications of these interactions for the design of macroeconomic policies?

Stressing on a network-based approach to open macroeconomics, this paper presents an overview of a macroeconometric platform developed for the analysis of international shocks. Its potentiality is then exemplified by the empirical assessment of international shocks in three regions within the Organisation for Economic Cooperation and Development (OECD).

This research is motivated by the fact that, despite its wide insertion in the practice of macroeconomic analysis, a crucial component seems to be repeatedly neglected by the Dynamic Stochastic General Equilibrium (DSGE) modelling literature in relation to a regional or even global perspective of macroeconomic analysis. The current conditions of international exchanges of goods, services, assets and others, like financial risks, contribute to explain the need for models with a broader outlook distinguishing in a more precise way the outcomes of interactions between heterogeneous economies.

Within this approach to networks of international exchanges, national units assume different roles in the regions they interact with, that is, they act as *generators* or *receivers* of regional disturbances according to the relevance they hold towards other economies in their common interactive space. This way, characteristic interactions appear within and between regions with important implications for macroeconomic policies. Consequential findings of the paper are that, through economic and financial linkages acting as transmission mechanisms, those shocks display internationally distinctive spillovers on key variables influencing the macroeconomic performance of national and regional economies.

Specifically, the international effects of policy shocks constitute externalities to which national and regional authorities (as in the Euro-zone) have to interactively adjust. Nonetheless, 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 variations in its international environment.

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.

Nevertheless, previous literature is largely dominated by three generic partial attempts to study international interactions: 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, the Euro-zone as an aggregate, and Japan) and 3)

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models of national economies interacting with one large economy representing the rest of the world. Their account of more complex interactions and specific outcomes of relevance for macroeconomic policies 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 further features of the exposure or competitive stances that economies may display towards their economic and financial network-partners.

Given such limitations, new models are required to assess broader conditions for the operation of economies in the context of the international networks they form. Modern tools for macroeconomic analysis must be adapted to reflect the increasing extent of the reach 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.

In our view, a comprehensive framework with a larger set of participants is necessary in order to obtain a corresponding description of crucial comparable characteristics which determine the outcomes of disturbances at different levels of international aggregation by which we mean national, regional or global[2].

That is why the Organisation for Economic Cooperation and Development (OECD) represents 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.

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 systemically-relevant economies, as the United States, Germany and Japan, or regions as NAFTA[3], the Euro-zone and Asia-Pacific[4]. This means, that our regional approach, although it has the ability to include participants which are sharing a single monetary policy, is not restricted to the presence of a monetary union. A region is defined, then, on the basis of network-related interactions (that is, on the grounds of intense commercial or financial exchanges, for example).

Our modelling represents an advancement on the grounds of the representation of macroeconomic heterogeneity within common spaces of international interaction. At the same time, it retains the bases of well-established theoretical foundations within the contemporary DSGE modelling practice.

In addition to country-specific parameterisations[5], a number of innovations are integrated in the main body of the model for the description of international relationships. Two of the most prominent are, first, the sets of bi-directional weights reflecting the comparative relevance of each counterpart in relation to trade and financial exchanges and, secondly, the model's ability to seamlessly adapt to particular sets of countries of interest and generate country-specific foreign variables as required by specific experimental settings.

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 of those variants 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[6] model, encompassing the Christiano, Eichenbaum and Evans (2005) (*CEE*) modelling paradigm as well as issues concerning the international transmission of shocks and contributions from the *New Open Economy Macroeconomics*.

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, the multi-country framework applied in this paper is capable of accounting for a significant number of heterogeneities between economies as well as for regional factors affecting their macroeconomic performance as is the case of regional and global shocks.

In contrast to Vector Auto-Regressive (VAR) approaches, the systemic configuration of our DSGE platform enabled us to account for the adjustments occurring in several variables of interest in the aftermath of the shocks, which modified the profile of the corresponding responses.

From the CEE and ALLV frameworks, Calvo (1983) schemes in prices, wages and labour demand contribute to establish a modelling background with nominal rigidities which partially temper the international impacts of disturbances in an economy.

By comparing shocks to the inflation targets with shocks on the discretionary components of monetary policies, we extended the *rules versus discretion* discussion to the international

[2]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, as is the OECD.

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

[4]For the purposes of this paper, this region is composed by Australia, Japan and South Korea.

[5]More accurately, that is partial-parameterisations given that, currently, a fraction of the total number of parameters describing each economy has not been individualised yet by the means of corresponding estimations. Our prioritisation in relation to this estimations, however, focused on those parameters which are deemed as more relevant in the context of macroeconomic policy heterogeneities.

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

arena and exhibited the corresponding implications for individual economies arising from the spillovers of each alternative.

Heterogeneities between countries and between regions intervene in defining characteristic patterns of responses confirming, this way, the ability of the model to carry out analyses at the regional level and to provide valuable information on the country-specific disturbances generated as externalities.

2. Multi-country model with regional and global shocks

In this section we present a log-linearised summary version of the DSGE model[7]. Further descriptions and detailed derivations are included in the supplementary material of this paper.

Under our configuration, the ALLV model is extended to include $i = 1, 2, ..., N$ countries and $r = 1, 2, ..., G$ regions[8] with $G \leq N$ (at the extreme case each country is a region). Each individual economy is characterised by a set of idiosyncratic and common 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 consumption/investment ratios or policy-related indicators.

Each economy, indexed by i, comprises a mass of h households who derive utility from consumption, C (which includes domestic and foreign goods) and real assets, Q/P (with P being the overall price level), and dis-utility from labour, L. The lifetime discounted utility of households is then given by:

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

where β_i^t is a discount rate, b_i measures habit formation, $z_{i,t}$ denotes the prevailing technology level (functioning here as 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[9] elements of this utility function.

Households own productive capital $\widehat{\bar{k}}$ and decide on a utilisation rate $\widehat{u}$ to determine the effectively applied capital $\widehat{k}$ each period t which aggregated to country level is:

$$\widehat{k}_{i,t} = \widehat{u}_{i,t} + \widehat{\bar{k}}_{i,t} \tag{2}$$

Capital accumulation is, in turn, given by:

$$\begin{aligned} \widehat{\bar{k}}_{i,t+1} &= (1-\delta_i)\frac{1}{\mu_i^z}\widehat{\bar{k}}_{i,t} - (1-\delta_i)\frac{1}{\mu_i^z}\hat{\mu}_{z,i,t} \\ &+ \left(1-(1-\delta_i)\frac{1}{\mu_i^z}\right)\widehat{\Upsilon}_{i,t} + \left(1-(1-\delta_i)\frac{1}{\mu_i^z}\right)\widehat{i}_{i,t} \end{aligned} \tag{3}$$

where δ is the depreciation rate, $\mu_{i,t}^z = \dfrac{z_{i,t}}{z_{i,t-1}}$ denotes the speed of technological change, Υ is a stationary technology shock and i is the level of investment.

The dynamics of real wages, $\bar{w}$, are expressed as:

$$\begin{aligned} E_{i,t}\Big[&\eta_{0,i}\widehat{\bar{w}}_{i,t-1} + \eta_{1,i}\widehat{\bar{w}}_{i,t} + \eta_{2,i}\widehat{\bar{w}}_{i,t+1} + \eta_{3,i}(\hat{\pi}_{i,t}^d - \widehat{\bar{\pi}}_{i,t}^c) \\ &+\eta_{4,i}(\hat{\pi}_{i,t+1}^d - \rho^{\widehat{\bar{\pi}}_i^c}\widehat{\bar{\pi}}_{i,t}^c) + \eta_{5,i}(\hat{\pi}_{i,t-1}^c - \widehat{\bar{\pi}}_{i,t}^c) \\ &+\eta_{6,i}(\hat{\pi}_{i,t}^c - \rho_i^{\widehat{\bar{\pi}}^c}\widehat{\bar{\pi}}_{i,t}^c) + \eta_{7,i}\hat{\psi}_{i,t}^z + \eta_{8,i}\hat{L}_{i,t} \\ &+\eta_{9,i}\hat{\tau}_{i,t}^y + \eta_{10,i}\hat{\tau}_{i,t}^w + \eta_{11,i}\hat{\zeta}_{i,t}^h\Big] = 0 \end{aligned} \tag{4}$$

where π^d represents inflation of domestic goods, $\bar{\pi}^c$ is the central bank's consumer inflation target, π^c is actual consumer inflation, L are labour input goods, τ^y and τ^w are tax rates on income and wages, respectively, ζ^h is a labour supply shock. The η's simplify parametric expressions shown in detail in the supplementary material.

Aggregate employment, E, is subject to Calvo-style dynamics described by:

$$\begin{aligned} \widehat{E}_{i,t} = \frac{\beta_i}{1+\beta_i}E_{i,t}\left(\widehat{E}_{i,t+1}\right) + \frac{1}{1+\beta_i}\widehat{E}_{i,t-1} + \\ \frac{(1-\xi_i^E)(1-\beta_i\xi_i^E)}{(1+\beta_i)\xi_i^E}\left(\widehat{L}_{i,t} - \widehat{E}_{i,t}\right) \end{aligned} \tag{5}$$

where ξ^E shows the probability of firms not being able to adjust to their preferred employment level and being forced, instead, to keep the previous period's level.

A proportion, ν^w, of wage payments by firms is financed with loans subject to interest repayments. The log-linearised effective rate of interest on payroll financing, $\hat{R}^f$, is given by:

$$\hat{R}_{i,t}^f = \frac{\nu_i^w R_i^l \widehat{R}_{i,t}^l + \nu_i^w (R_i^l - 1)\widehat{\nu}_{i,t}^w}{\nu_i^w R_i^l + 1 - \nu_i^w} \tag{6}$$

where R^l is the banking gross lending rate.

The scaled (by overall prices) equilibrium rental rate of capital, $\hat{r}^k$, equates to:

$$\hat{r}_{i,t}^k = \hat{\mu}_{i,t}^z + \widehat{\bar{w}}_{i,t} + \hat{R}_{i,t}^f + \hat{L}_{i,t} - \hat{k}_{i,t} \tag{7}$$

Given those overheads, the real marginal cost for intermediate firms, mc, is:

$$\begin{aligned} \widehat{mc}_{k,t} &= \alpha_i \hat{r}_{i,t}^k + (1-\alpha_i)\left[\widehat{\bar{w}} + \hat{R}_{i,t}^f\right] - \hat{\epsilon}_{i,t} \\ &= \alpha_i(\hat{\mu}_{i,t}^z + \hat{L}_{i,t} - \hat{k}_{i,t} + \widehat{\bar{w}}_{i,t} + \hat{R}_{i,t}^f - \hat{\epsilon}_{i,t} \end{aligned} \tag{8}$$

where α, is the capital's share in production and ϵ is a unit-mean stationary shock. In turn, the marginal cost for exporting firms is:

$$\widehat{mc}_{i,t}^x = \widehat{mc}_{i,t-1}^x + \widehat{\pi}_{i,t} - \widehat{\pi}_{i,t}^x - \Delta\widehat{\bar{S}}_{i,t} \tag{9}$$

[7] Log-linearised variables, $\hat{x}_t$, represent per cent deviations from steady state values, x. That is: $\hat{x}_t = \dfrac{x_t - x}{x}$.

[8] 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.

[9] Constant Relative Risk Aversion.

where π^x is the inflation of export goods and $\widetilde{S}$ is an average weighted exchange rate (detailed below).

Each economy's Phillips curve (with marginal costs used as proxy for economic activity) for intermediate firms is given by:

$$\begin{aligned}\left(\hat{\pi}_{i,t}-\hat{\bar{\pi}}^{c}_{i,t}\right)&=\frac{\beta_i}{1+\kappa_{d,i}\beta_i}\left(E_t\hat{\pi}_{i,t+1}-\rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right)+\\&\frac{\kappa_{d,i}}{1+\kappa_{d,i}\beta_i}\left(\hat{\pi}_{i,t-1}-\hat{\bar{\pi}}^{c}_{i,t}\right)-\frac{\kappa_{d,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{d,i}\beta_i}\hat{\bar{\pi}}^{c}_{i,t}\\&+\frac{\left(1-\xi_{d,i}\right)\left(1-\beta_i\xi_{d,i}\right)}{\xi_{d,i}\left(1+\kappa_{d,i}\beta_i\right)}\left(\widehat{mc}_{i,t}+\widehat{\lambda}_{d,i,t}\right)\end{aligned}\tag{10}$$

with κ_d as a price-indexation parameter, λ_d is a Lagrangian multiplier from the firms' cost-minimisation problem and ρ_π is a persistence parameter.

Similarly, importing firms of consumption goods and investment goods, identified by *mc* and *mi*, display their respective Phillips curve relationships as:

$$\begin{aligned}\left(\hat{\pi}^{m,c}_{i,t}-\hat{\bar{\pi}}^{c}_{i,t}\right)&=\frac{\beta_i}{1+\kappa_{mc,i}\beta_i}\left(E_t\hat{\pi}^{m,c}_{i,t+1}-\rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right)\\&+\frac{\kappa_{mc,i}}{1+\kappa_{mc,i}\beta_i}\left(\hat{\pi}^{m,c}_{i,t-1}-\hat{\bar{\pi}}^{c}_{i,t}\right)-\frac{\kappa_{mc,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{mc,i}\beta_i}\hat{\bar{\pi}}^{c}_{i,t}\\&+\frac{\left(1-\xi_{mc,i}\right)\left(1-\beta_i\xi_{mc,i}\right)}{\xi_{mc,i}\left(1+\kappa_{mc,i}\beta_i\right)}\left(\widehat{mc}^{m,c}_{i,t}+\widehat{\lambda}^{m,c}_{i,t}\right)\end{aligned}\tag{11}$$

$$\begin{aligned}\left(\hat{\pi}^{m,i}_{i,t}-\hat{\bar{\pi}}^{c}_{i,t}\right)&=\frac{\beta_i}{1+\kappa_{mi,i}\beta_i}\left(E_t\hat{\pi}^{m,i}_{i,t+1}-\rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right)\\&+\frac{\kappa_{mi,i}}{1+\kappa_{mi,i}\beta_i}\left(\hat{\pi}^{m,i}_{i,t-1}-\hat{\bar{\pi}}^{c}_{i,t}\right)-\frac{\kappa_{mi,i}\beta_i\left(1-\rho_{\pi,i}\right)}{1+\kappa_{mi,i}\beta_i}\hat{\bar{\pi}}^{c}_{i,t}\\&+\frac{\left(1-\xi_{mi,i}\right)\left(1-\beta_i\xi_{mi,i}\right)}{\xi_{mi,i}\left(1+\kappa_{mi,i}\beta_i\right)}\left(\widehat{mc}^{m,i}_{i,t}+\widehat{\lambda}^{m,i}_{i,t}\right)\end{aligned}\tag{12}$$

and, in the case of exporting firms:

$$\begin{aligned}\left(\hat{\pi}^{x}_{i,t}-\hat{\bar{\pi}}^{c}_{i,t}\right)&=\frac{\kappa_{x,i}}{1+\beta_i\kappa_{x,i}}\left(\hat{\pi}^{x}_{i,t-1}-\hat{\bar{\pi}}^{c}_{i,t}\right)\\&+\frac{\beta_i}{1+\beta_i\kappa_{x,i}}\left(E_t\hat{\pi}^{x}_{i,t+1}-\rho_{\pi,i}\hat{\bar{\pi}}^{c}_{i,t}\right)-\frac{\beta_i\kappa_{x,i}\left(1-\rho_{\pi,i}\right)}{1+\beta_i\kappa_{x,i}}\hat{\bar{\pi}}^{c}_{i,t}\\&+\frac{\left(1-\beta_i\xi_{x,i}\right)\left(1-\xi_{x,i}\right)}{\xi_{x,i}\left(1+\beta_i\kappa_{x,i}\right)}\left(\widehat{mc}^{x}_{i,t}+\widehat{\lambda}^{x}_{i,t}\right)\end{aligned}\tag{13}$$

in all these expressions, ξ, are Calvo parameters indicating the probability of each type of firm not being able to re-optimise their prices each period in which case they are only allowed to use an indexed updating of last period's price.

Key relative-price relationships at any period are depicted as:

$$\widehat{\gamma}^{mc,d}_{i,t}=\widehat{\gamma}^{mc,d}_{i,t-1}+\widehat{\pi}^{m,c}_{i,t}-\widehat{\pi}^{d}_{i,t}\tag{14}$$

$$\widehat{\gamma}^{minv,d}_{i,t}=\widehat{\gamma}^{minv,d}_{i,t-1}+\widehat{\pi}^{m,i}_{i,t}-\widehat{\pi}^{d}_{i,t}\tag{15}$$

$$\widehat{\gamma}^{x,*}_{i,t}=\widehat{\gamma}^{x,*}_{i,t-1}+\widehat{\pi}^{x}_{i,t}-\widehat{\pi}^{*}_{i,t}\tag{16}$$

where γ denotes a relative price involving imported consumption (*mc*), imported investment (*minv*), domestic prices (*d*), exports (*x*) and foreign prices ($*$), respectively.

Tax rates on capital income, τ^k, labour income, τ^y, payroll, τ^w and consumption, τ^c, as well as government expenditure, g, display persistence in time given by ρ_τ and ρ_g, and are subject to national shocks, $\epsilon^{fp\odot}_{i,t}$, and regional/global shocks, $\epsilon^{\odot}_{r,t}$:

$$\hat{\tau}^{k}_{i,t}=\rho_{\tau^k}\hat{\tau}^{k}_{i,t-1}+\sigma_{\tau^k}\epsilon^{fpk}_{i,t}+\sigma_{\tau^k,r}\sum_{r=1}^{G}D^{r}_{i}\epsilon^{\tau,k}_{r,t}\tag{17}$$

$$\hat{\tau}^{y}_{i,t}=\rho_{\tau^y}\hat{\tau}^{y}_{i,t-1}+\sigma_{\tau^y}\epsilon^{fpy}_{i,t}+\sigma_{\tau^y,r}\sum_{r=1}^{G}D^{r}_{i}\epsilon^{\tau,y}_{r,t}\tag{18}$$

$$\hat{\tau}^{w}_{i,t}=\rho_{\tau^w}\hat{\tau}^{w}_{i,t-1}+\sigma_{\tau^w}\epsilon^{fpw}_{i,t}+\sigma_{\tau^w,r}\sum_{r=1}^{G}D^{r}_{i}\epsilon^{\tau,w}_{r,t}\tag{19}$$

$$\hat{\tau}^{c}_{i,t}=\rho_{\tau^c}\hat{\tau}^{c}_{i,t-1}+\sigma_{\tau^c}\epsilon^{fpc}_{i,t}+\sigma_{\tau^c,r}\sum_{r=1}^{G}D^{r}_{i}\epsilon^{\tau,c}_{r,t}\tag{20}$$

$$\hat{g}_{i,t}=\rho_g\hat{g}_{i,t-1}+\sigma_g\epsilon^{fpg}_{i,t}+\sigma_{g,r}\sum_{r=1}^{G}D^{r}_{i}\epsilon^{g}_{r,t}\tag{21}$$

with D being a vector of dichotomous variables indicating whether each country i belongs to the region r impacted by the shock.

A monetary policy rule applies for countries with independent monetary authorities reflecting their responses to deviations in output, inflation and the real exchange rate. It is presented as a *modified Taylor rule* taking into account international spreads, *spr*, between national interest rates and a common international reference:

$$\begin{aligned}\widehat{R}_{i,t}=\rho^{R}_{i}\widehat{R}_{i,t-1}+\left(1-\rho^{R}_{i}\right)\Big[&\widehat{\bar{\pi}}^{c}_{i,t}+r^{\pi}_{i}\left(\hat{\pi}^{c}_{i,t-1}-\widehat{\bar{\pi}}^{c}_{i,t}\right)\\&+r^{y}_{i}\hat{y}_{i,t-1}+r^{e}_{i}\hat{e}_{i,t-1}\Big]\\+r^{\Delta\pi}_{i}\Delta\hat{\pi}^{c}_{i,t}+r^{\Delta y}_{i}\Delta\hat{y}_{i,t}+r^{spr}_{i}spr_{i,t}+\varepsilon^{R}_{i,t}&+\sum_{r=1}^{G}D^{r}_{i}\varepsilon^{R}_{r,t}\end{aligned}\tag{22}$$

where y is the output gap. In this rule the real exchange rate, e, expressed in terms of relative prices also equals to:

$$\hat{e}_{i,t}=-\omega^{c}_{i}\left(\gamma^{c,mc}_{i}\right)^{-(1-\eta^{c}_{i})}\widehat{\gamma}^{mc,d}_{i,t}-\widehat{\gamma}^{x,*}_{i,t}-\widehat{mc}^{x}_{i,t}\tag{23}$$

For the purposes of the monetary rule, the consumer price index, π^c, is a weighted average of domestic and imported consumption prices as given by:

$$\widehat{\pi}^{c}_{i,t}=\left[\left(1-\omega^{c}_{i}\right)\left(\gamma^{d,c}_{i}\right)^{1-\eta^{c}_{i}}\right]\widehat{\pi}^{d}_{i,t}+\left[\left(\omega^{c}_{i}\right)\left(\gamma^{mc,c}_{i}\right)^{1-\eta^{c}_{i}}\right]\widehat{\pi}^{m,c}_{i,t}\tag{24}$$

with ω^c representing the imported component of total consumption, γ indicate relative prices between domestic (d,c) or imported consumption goods (mc,c) and overall prices in each economy.

Subsequently, the output gap includes inputs from capital, labour and a stochastic shock:

$$\widehat{y}_{i,t}=\lambda^{d}_{i}\left[\widehat{\epsilon}_{i,t}+\alpha_i\left(\widehat{k}_{i,t}-\widehat{\mu}_{z,i,t}\right)+\left(1+\alpha_i\right)\widehat{L}_{i,t}\right]\tag{25}$$

Real money balances dynamics are given by:

$$\widehat{\mu}_{i,t} - \widehat{\bar{m}}_{i,t+1} - \widehat{\mu}_{z,i,t} - \widehat{\pi}_{i,t} + \widehat{\bar{m}}_{i,t} = 0 \tag{26}$$

where $\mu_{i,t} = \dfrac{M_{i,t+1}}{M_{i,t}}$ depicts the evolution of money in time.

2.1. Country-specific foreign variables

Country-specific foreign variables are generated attending to the relevance of each international counterpart as reflected by specialised weights. Foreign consumption, for example, is a weighted average of consumption in the rest of the world:

$$\hat{c}^*_{i,t} = \sum_{j=1}^{N-1} w^t_{i,j}\left(\hat{c}_{j,t} + \epsilon^{\hat{c}}_{j,t} + D^r_j D^r_i \epsilon^{\hat{c}}_{r,t}\right) \tag{27}$$

Similarly, other foreign variables are calculated as weighted averages of rest-of-the-world variables including the effects of national and regionally-common shocks:

$$\hat{i}^*_{i,t} = \sum_{j=1}^{N-1} w^t_{i,j}\left(\hat{i}_{j,t} + \epsilon^{\hat{i}}_{j,t} + D^r_j D^r_i \epsilon^{\hat{i}}_{r,t}\right) \tag{28}$$

$$\hat{y}^*_{i,t} = \sum_{j=1}^{N-1} w^t_{i,j}\left(\hat{y}_{j,t} + \epsilon^{\hat{y}}_{j,t} + D^r_j D^r_i \epsilon^{\hat{y}}_{r,t}\right) \tag{29}$$

$$\hat{\pi}^*_{i,t} = \sum_{j=1}^{N-1} w^t_{i,j}\left(\hat{\pi}_{j,t} + \epsilon^{\hat{\pi}}_{j,t} + D^r_j D^r_i \epsilon^{\hat{\pi}}_{r,t}\right) \tag{30}$$

$$\hat{R}^*_{i,t} = \sum_{j=1}^{N-1} w^{fdi}_{i,j}\left(\hat{R}_{j,t} + \epsilon^{\hat{R}}_{j,t} + D^r_j D^r_i \epsilon^{\hat{R}}_{r,t}\right) \tag{31}$$

with countries $i \neq j$[10].

In these cases two dichotomous variables are required to delimit the extent of regional shocks without excluding non-affected economies from the calculation[11]. Also, two types of weights are used in these expressions. Trade weights, $w^t_{i,j}$, reflect the strength of bi-lateral commercial flows between pairs of countries while financial weights, $w^{fdi}_{i,j}$ similarly measure bi-lateral relationships in terms of exchanges of investments between countries (see the Data section below).

The monetary policy rule's real exchange rate is given by:

$$\hat{e}_{i,t} = \sum_{j=1}^{N-1} w^t_{i,j}\left(\widehat{S}_{i,j,t} + \widehat{P}_{j,t} - \widehat{P}^c_{i,t}\right) \tag{32}$$

where P^c reflects the level of consumption prices.

An uncovered interest rate condition is expressed as:

$$\widehat{R}_{i,t} - \widehat{R}^*_{i,t} = E_{i,t}\Delta\widetilde{\widehat{S}}_{i,t+1} - \tilde{\phi}^a_i \widehat{a}_{i,t} + \widehat{\tilde{\phi}}_{i,t} \tag{33}$$

where R^* is the country-specific foreign interest rate and the risk premium, $\tilde{\phi}$, for each economy is given by:

$$\widehat{\tilde{\phi}}_{i,t} = \rho^{\tilde{\phi}}_i \widehat{\tilde{\phi}}_{i,t-1} + (\varepsilon^{\tilde{\phi}}_{i,t} + D^r_i \varepsilon^{\tilde{\phi}}_{r,t}) \tag{34}$$

$\widetilde{S}$ is a weighted average nominal exchange rate:

$$\widetilde{S}_{i,t} = \sum_{j=1}^{N-1} w^{fdi}_{i,j} S_{i,j,t} \tag{35}$$

where $S_{i,j,t}$ is the corresponding pairwise nominal exchange rate and net foreign assets held by households, a, follow the law of motion:

$$\begin{aligned}\hat{a}_{i,t} = {} & y^*_i\left(-\widehat{mc}^x_{i,t} - \eta^f_i \widehat{\gamma}^{x,*}_{i,t} + \widehat{y}^*_{i,t} + \widehat{\tilde{z}}_{i,t}\right) \\ & + (c^m_i + i^m_i)\gamma^f_{i,t} - c^m_i\left[-\eta^c_i\left(1-\omega^c_i\right)\left(\gamma^{c,d}_i\right)^{-\left(1-\eta^c_i\right)}\widehat{\gamma}^{mc,d}_{i,t} + \widehat{c}_{i,t}\right] \\ & - i^m_i\left[-\eta^{inv}_i\left(1-\omega^{inv}_i\right)\left(\gamma^{i,d}_i\right)^{-\left(1-\eta^{inv}_i\right)}\widehat{\gamma}^{mi,d}_{i,t} + \widehat{i}_{i,t}\right] \\ & + \frac{R_i}{\pi_i \mu^z_i}\hat{a}_{i,t-1}\end{aligned} \tag{36}$$

A linearised resource constraint holds for each economy in the form of:

$$\begin{aligned}& \left(1-\omega^c_i\right)\left(\gamma^{c,d}\right)^{\eta^c_i}\frac{c_i}{y_i}\left(\widehat{c}_{i,t} + \eta^c_i\widehat{\gamma}^{c,d}_{i,t}\right) + \\ & \left(1-\omega^i_i\right)\left(\gamma^{i,d}\right)^{\eta^i_i}\frac{i_i}{y_i}\left(\widehat{i}_{i,t} + \eta^i_i\widehat{\gamma}^{id}_{i,t}\right) \\ & + \frac{g_i}{y_i}\widehat{g}_{i,t} + \sum_{j=1}^{N-1}\left[\left(\omega^c_j\right)\left(\gamma^{x,*}_{j,t}\right)^{\eta^c_j}\frac{c_j}{y_i}\left(\widehat{c}_{j,t} - \eta^c_j\widehat{\gamma}^{x,*}_{j,t} + \widehat{\tilde{z}}^*_{j,t}\right)\right] \\ & + \sum_{j=1}^{N-1}\left[\left(\omega^i_j\right)\left(\gamma^{x,*}_{j,t}\right)^{\eta^i_j}\frac{i_j}{y_i}\left(\widehat{i}_{j,t} - \eta^i_j\widehat{\gamma}^{x,*}_{j,t} + \widehat{\tilde{z}}^*_{j,t}\right)\right] \\ & = \lambda_d\left(\widehat{\epsilon}_{i,t} + \alpha_i\left(\widehat{k}_{i,t} - \widehat{\mu}_{z,i,t}\right) + (1-\alpha_i)\widehat{L}_{i,t}\right) \\ & - \left(1-\tau^k_i\right)r^k_i\frac{\bar{k}_i}{y_i}\frac{1}{\mu_z}\left(\widehat{k}_{i,t} - \widehat{\bar{k}}_{i,t-1}\right)\end{aligned} \tag{37}$$

with ω^i showing the participation of imports in domestic investments.

A clearing condition in the money market is given by:

$$\begin{aligned}\nu^w_i \bar{w}_i L_i(\widehat{\nu^w}_{i,t} + \widehat{w}_{i,t} + \widehat{L}_{i,t}) = {} & \frac{\mu_i \bar{m}_i}{\pi_i \mu^z_i}\left(\widehat{\mu}_{i,t} + \widehat{\bar{m}}_{i,t}\right. \\ & \left. - \widehat{\pi}_{i,t} - \widehat{\mu}_{z,i,t}\right) - q\widehat{q}_{i,t}\end{aligned} \tag{38}$$

with cash balances, M, and financial assets, Q, stationarised as $\bar{m}_{i,t} = \dfrac{M_{i,t}}{z_{i,t-1}P_{i,t-1}}$ and $q_{i,t} = \dfrac{Q_{i,t}}{z_{i,t}P_{i,t}}$, respectively.

2.2. Monetary unions

The rule in Equation (22) 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:

$$\begin{aligned}\widehat{R}_{m,t} = {} & \rho_{Rm}\widehat{R}_{m,t-1} + (1-\rho_{Rm})\left[\widehat{\pi}^c_{m,t} + r_{\pi m}\left(\hat{\pi}^c_{m,t-1} - \widehat{\pi}^c_{m,t}\right)\right. \\ & \left. + r_{ym}\hat{y}_{m,t-1}\right] + r_{\Delta\pi m}\Delta\hat{\pi}^c_{m,t} + r_{\Delta ym}\Delta\hat{y}_{m,t} + r_{sprm}spr_{m,t} + \varepsilon^R_{m,t}\end{aligned} \tag{39}$$

[10] Throughout this paper, whenever we equate an i-th value to a weighted average of j-th values, $i \neq j$ prevails.

[11] The two dichotomous variables contribute to indicate whether any incumbent country i and each of the other j countries reside within the reach of a common regional or global shock to each variable.

with a common inflation target:

$$\widehat{\bar{\pi}}^{c}_{m,t} = \rho_{\pi m}\widehat{\bar{\pi}}^{c}_{m,t-1} + \varepsilon^{\widehat{\bar{\pi}}^{c}}_{m,t} \tag{40}$$

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

Regional variables for this rule are calculated as:

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

for the M economies in the region m which constitute the monetary union. Relative normalised weights, w^{y}_{i}, for each economy in the region are calculated on the basis of their participation in the aggregate output of the involved countries:

$$w^{y}_{i} = \frac{Y_{i,\bar{t}}}{\sum_{i=1}^{M} Y_{i,\bar{t}}} \tag{41}$$

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

3. Data and estimation

3.1. Data and transformations

For estimation purposes we make use of a panel of quarterly data between 1980Q1 and 2014Q3[12]. Keeping the main data structure in ALLV and the correspondence with their definitions in the model, the stationary variables we included are:

- GDP deflator (`gdpdefl`)

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

  Data from Oxford Economics.

- Real wage (`unitcost`)

$$\widehat{w}_{i,t} = \Delta \ln\left(\frac{\texttt{unitcost}_{i,t}}{\texttt{gdpdefl}_{i,t}}\right)$$

  Data from Oxford Economics.

- Real consumption (`rcons`)

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

  Data from OECD Quarterly National Accounts.

- Real investment (`invreal`)

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

  Data from OECD Quarterly National Accounts.

- Employment (`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 (`realgdp`)

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

  Data from OECD Quarterly National Accounts.

- Consumer prices (`consdefl`)

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

  Data from Oxford Economics.

- Risk premium (`spread`), as the spread between short-term interest rates and the Federal Reserve's 3-Month Treasury Bill:

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

  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)).

3.2. International and bi-lateral weights

One of the main features of the model is its inclusion of 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, weighting schemes are aimed to distinguish the relevance each counterpart has from the perspective of an economy.

The bi-directional nature of these indicators allows to distinguish specific commercial and financial relationships at the national level between the economies in our panel (that is, how relevant is economy j to economy i and vice versa).

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 (as accounted by both inward and outward FDI flows between 2009 and 2012):

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

with

$$w^{fdi}_{i,j} = \frac{\texttt{meanoutfdi}_{i,j} + \texttt{meaninfdi}_{i,j}}{\sum_{j=1}^{N-1} \texttt{meanoutfdi}_{i,j} + \sum_{j=1}^{N-1} \texttt{meaninfdi}_{i,j}}$$

and $w^{fdi}_{i,i} = 0$.

Data 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 pairwise combination as:

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

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

with

$$w^t_{i,j} = \frac{\texttt{meanexports}_{i,j} + \texttt{meanimports}_{i,j}}{\sum_{j=1}^{N-1} \texttt{meanexports}_{i,j} + \sum_{j=1}^{N-1} \texttt{meanimports}_{i,j}}$$

and $w^t_{i,i} = 0$.

Data from IMF, Direction of Trade Statistics database.

Finally, weightings within a region as in Equation (41) are calculated using the relative participation in output aggregated to the specific regional level being used:

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

for each of the M members of the defined region.

Data for 2013 from OECD, Annual National Accounts.

All these weights 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.

3.3. Estimation and simulation

With this information (except for the weights) included in the *observable set*, estimations of relevant national parameters are performed using the Dynare ® computing platform (Adjemian et al. (2011)) under the assumption of *partial information*[13].

This empirical application proceeds in two stages: first we perform estimations using actual macroeconomic series from which we get an enhanced set of selected country-specific parameters.

For the second stage, we incorporate the obtained information on national parameters into the model's calibration 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 results of these simulations are presented on a pre-established set of macroeconomic variables:

Output gap	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.

4. International shocks in the OECD: an empirical assessment

In this section we employ our model for the analysis of the consequences of key international shocks in three OECD regions. Our particular focus on the international implications of such shocks also provides information on the heterogeneous effects they have on member economies of each region and on the implications for the management of fiscal and monetary policies.

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

4.1. Estimation on the NAFTA region

The first estimation corresponds to the region comprising the members of the North American Free Trade Agreement (*NAFTA*). Priors and posteriors from the estimation are included in the supplementary material. After calibrating the model with the information provided by this estimation, we executed the simulation of shocks.

4.1.1. Intra-regional shocks

We begin with the study of the effects that policy-relevant disturbances in the United States have on the rest of the countries in the NAFTA region (that is, Canada and Mexico).

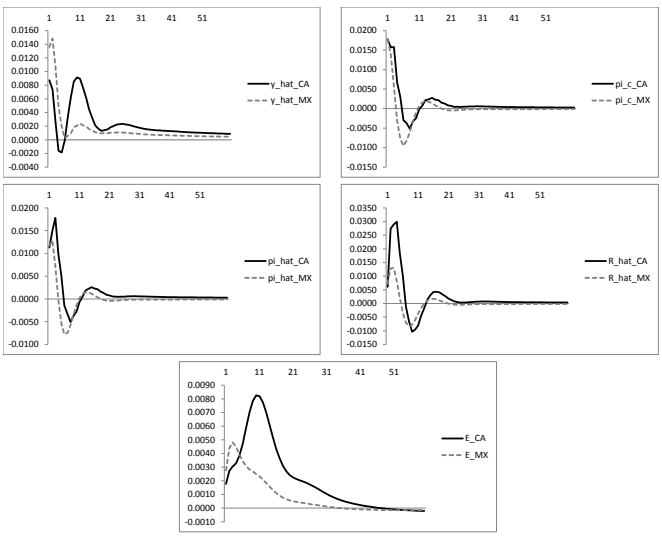
There is no doubt that the US economy is a strong force in the global economy, amounting to 35.8 per cent of the OECD's real output in 2013, as it is for the NAFTA region where it represented 83.2 per cent of the total real GDP (also in 2013). Similarly, the commercial and financial weights we have calculated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

4.1.1.1 Monetary policy shock in the US

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 1 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 1: International effects of a monetary policy shock in the US, NAFTA region.



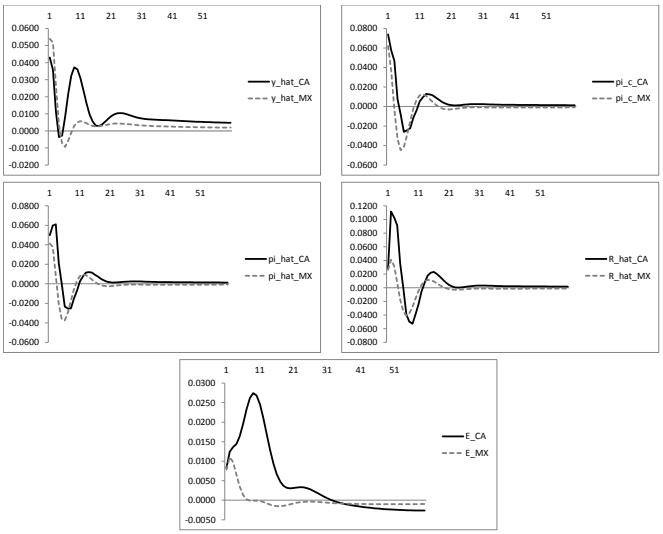
The increase in the interest rate has a negative effect on the US levels of activity in terms of output and employment. A substitution effect is then generated by the means of which the other two economies in the region experience an increase in the US demand for imports benefiting their production and 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.

4.1.1.2 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: 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.

Figure 3: International effects of a monetary policy target shock in the US, Canada.

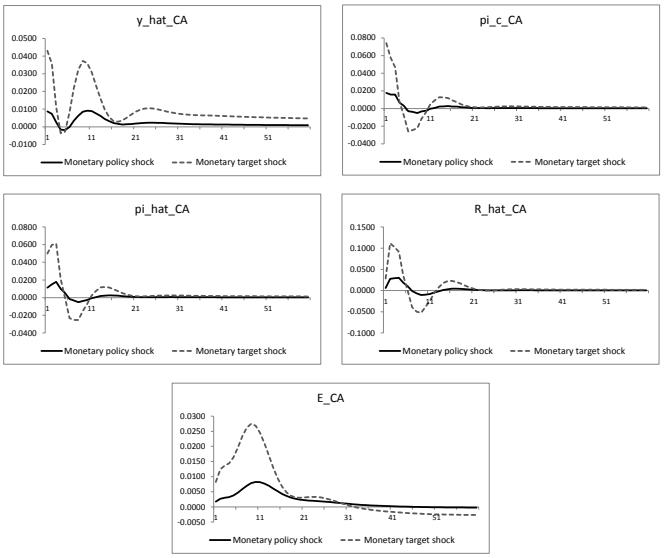
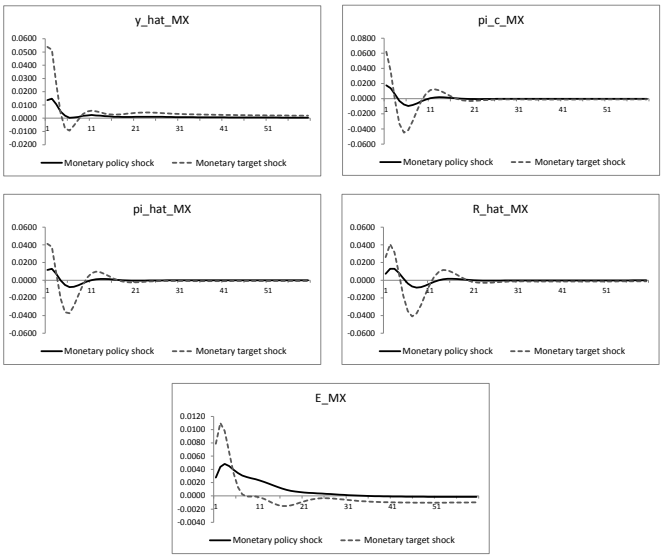


Figure 4: International effects of a monetary policy target shock in the US, Mexico.



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).

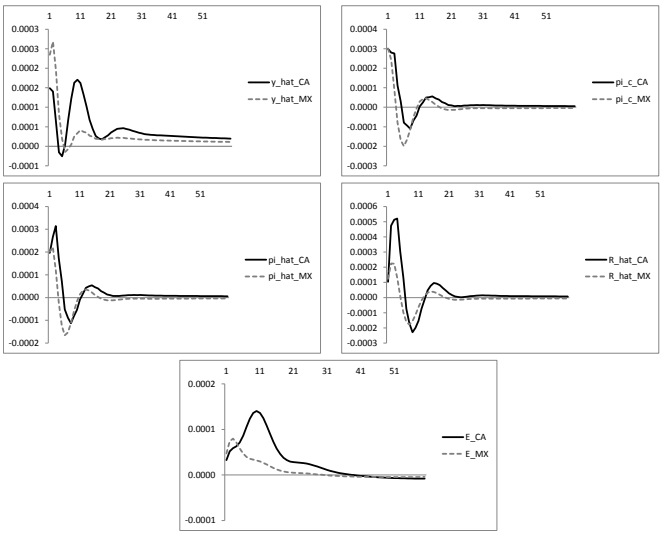
Between the two recipient countries, Canada exhibits larger sensitivity to the US shock mainly in terms of output variability, interest rate and, especially, employment.

Comparing the international effects of the two types of shocks, shown in Figures 3 and 4, 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.

4.1.1.3 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 (by inducing a contraction of the policy rate of only 2.9 per cent of every unit-increase in the risk premium). In effect, this international impact reveals a non-accelerating mechanism of contagion between linked economies.

Figure 5: International effects of a shock to the US risk premium, NAFTA region.



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[14] appear to have a role in this comparatively higher exposure to nominal instability.

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

4.1.1.4 Nominal externalities of fiscal policy in the US

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.

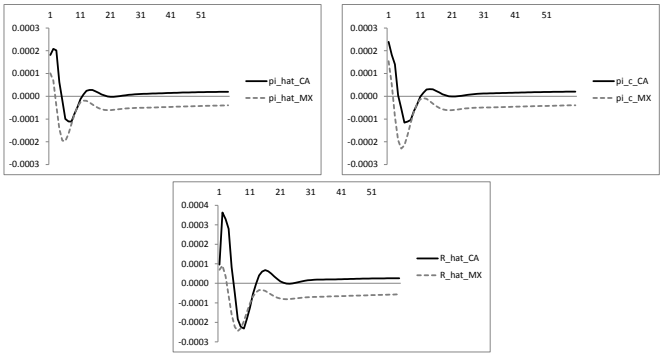
A negative shock to the income tax in the US ($\epsilon^{fpy}_{US,t=0}$), for example, brings a degree of nominal instability in both receiving countries with mostly immediate increases in their inflation levels and interest rates. Mexico seems to display the most immediate responses while Canada, in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

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.

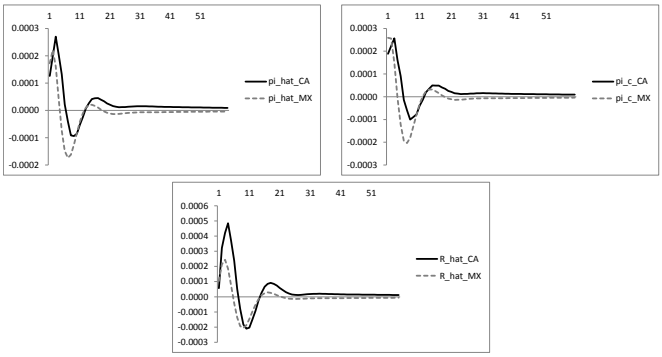
Figure 6: International nominal effects of a fiscal policy shock (income tax) in the US, NAFTA region.



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 Mex-

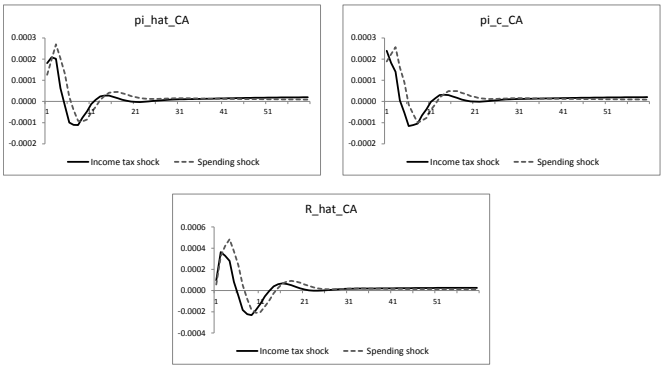
Figure 7: International nominal effects of a fiscal policy shock (government spending) in the US, NAFTA region.



ico's nominal variables when compared to the previous shock 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 (keeping 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 8 and 9 that a shock on US spending generates later responses than a shock on income tax rates.

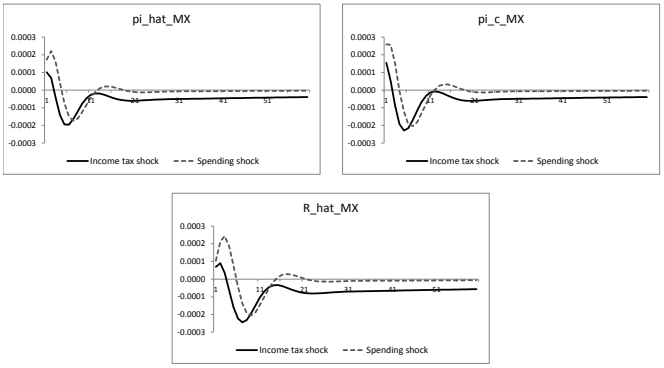
Figure 8: Comparative international nominal effects of fiscal policies in the US, Canada.



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 considerable instability after such disturbances.

Figure 9: Comparative international nominal effects of fiscal policies in the US, Mexico.



4.1.2. Regional shocks

In this section we simulate the occurrence of a regional-level shock, that is, a shock that simultaneously affects all the economies in the NAFTA 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 and elasticities towards other members of the region and the rest of the world) and on the linkages they have both with their regional partners and with the rest of the world.

The shocks consists of 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.

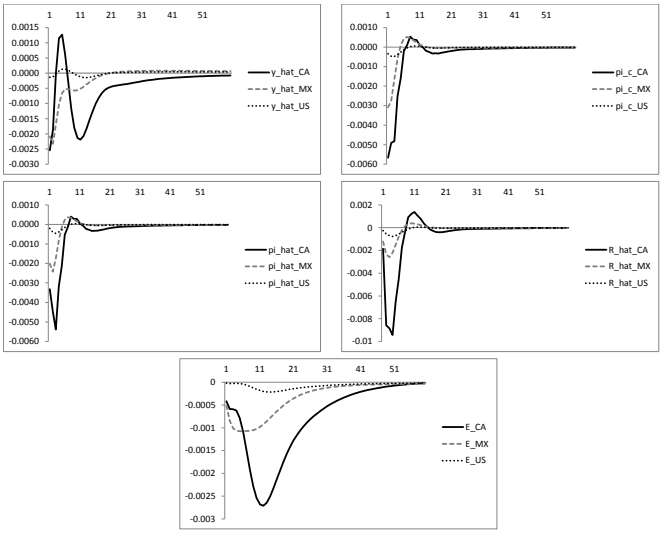
4.1.2.1 Output shock in the rest of the world for NAFTA countries

We first examine a shock with a high likelihood of occurrence after a major international disruption as the recession that followed the 2008-2009 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 10.

Figure 10: 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. 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 37 binds for global production.) and, therefore, prices and production fall in all three NAFTA 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 before returning to equilibrium levels[15] 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.

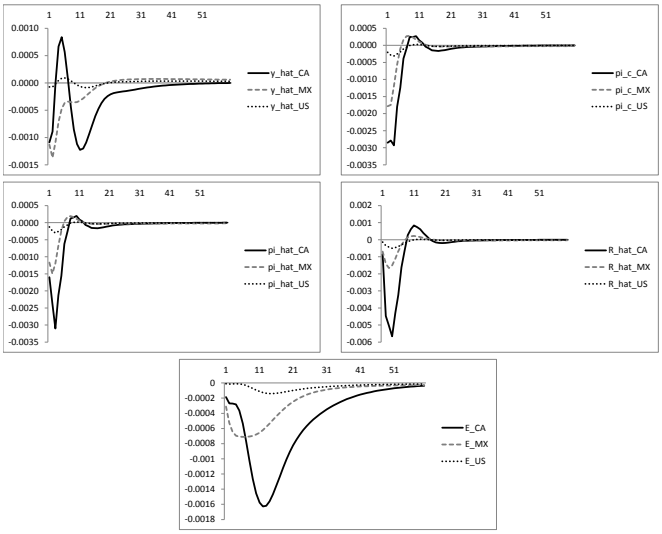
The impacts on the US economy are clearly small in comparative terms, similar in dynamics as those on Canada. These two countries share a considerably delay in the response in employment reaching the largest downturn deviation 12 quarters after the initial impact in Canada and after 14 quarters in the US while in the case of Mexico the maximum deviation is reached in the fifth quarter.

4.1.2.2 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.

Figure 11: Comparative effects of external shocks on the NAFTA region.

External prices shock



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 instability generated by the re-

[15] The US seems to experience a higher long-term equilibrium output after the shock.

gional shock on external prices, however, is less severe in the recipient countries than that of a productive shock as can be perceived in Figure 12.

Table 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.

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 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.

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.

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.) 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).

Figure 12: Regional effects of external shocks on the NAFTA region.

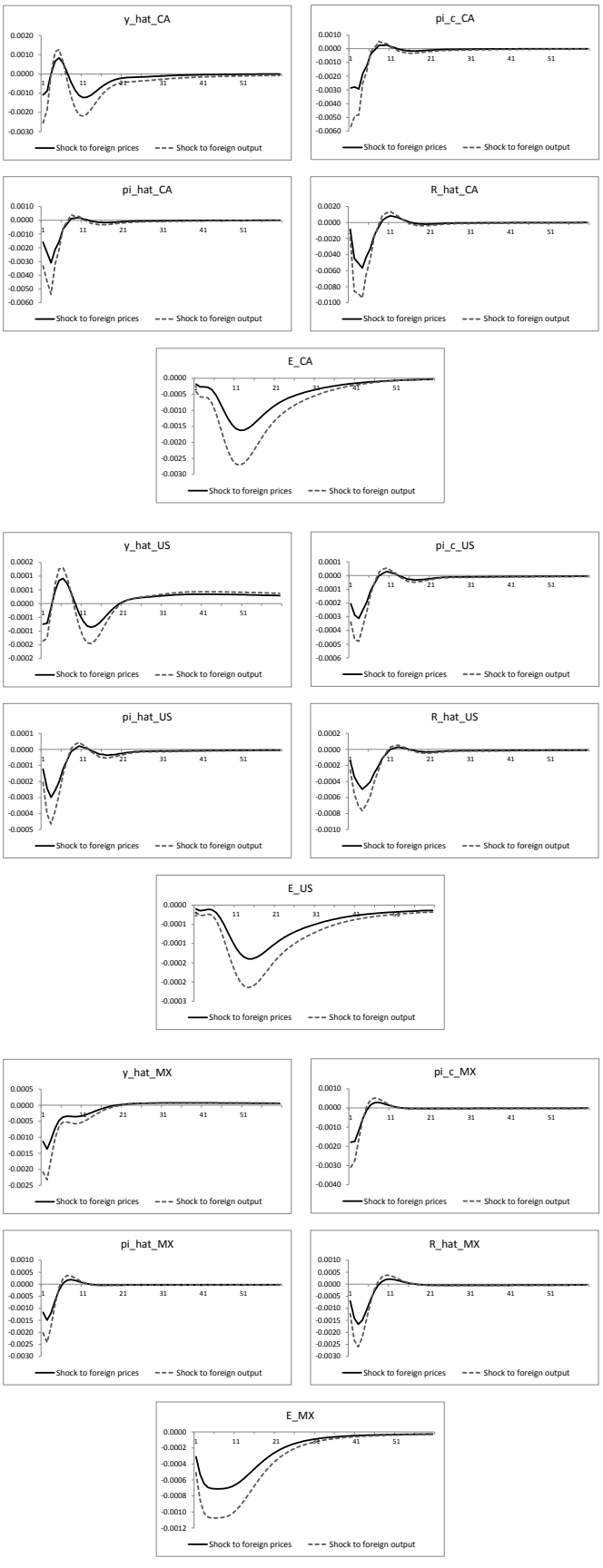


Table 2: Trade openness in the NAFTA region

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 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 regionally-common shocks to the NAFTA region, an important conclusion on macroeconomic coordination emerges since extra-regional policies that assign a greater weight to output stabilisation in comparison to price stabilisation would increase welfare in this receiving region. This is because NAFTA displays greater sensitivity to external output shocks.

This quantification of the countries' exposure to the production and inflation conditions in the rest of the world is also relevant for the design of appropriate policy-responses to external shocks in each economy, a component rarely found in the literature and research on macroeconomic policy[16].

4.2. 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 characterised by the use of a single monetary policy. In our model this is described by Equation 39 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.

[16]The textbook notion of policy responses is generally restricted to responses to the conditions of the domestic economy.

4.2.1. Intra-regional shocks

4.2.1.1 Monetary policy shock in the Euro-zone

The effects of a simulated monetary policy shock (1 standard error increase in the common interest rate) display relatively homogeneous responses across the region (see Figure 13) 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.

The subsequent decline of the shock to 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, partially compensating the previous downturn.

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. This asymmetric rigidity in employment also fits in the inflationary account given above.

4.2.1.2 Shock to the Euro-zone's monetary policy target

A shock to the monetary policy target, in turn, displays more 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[17]. (see Figure 13).

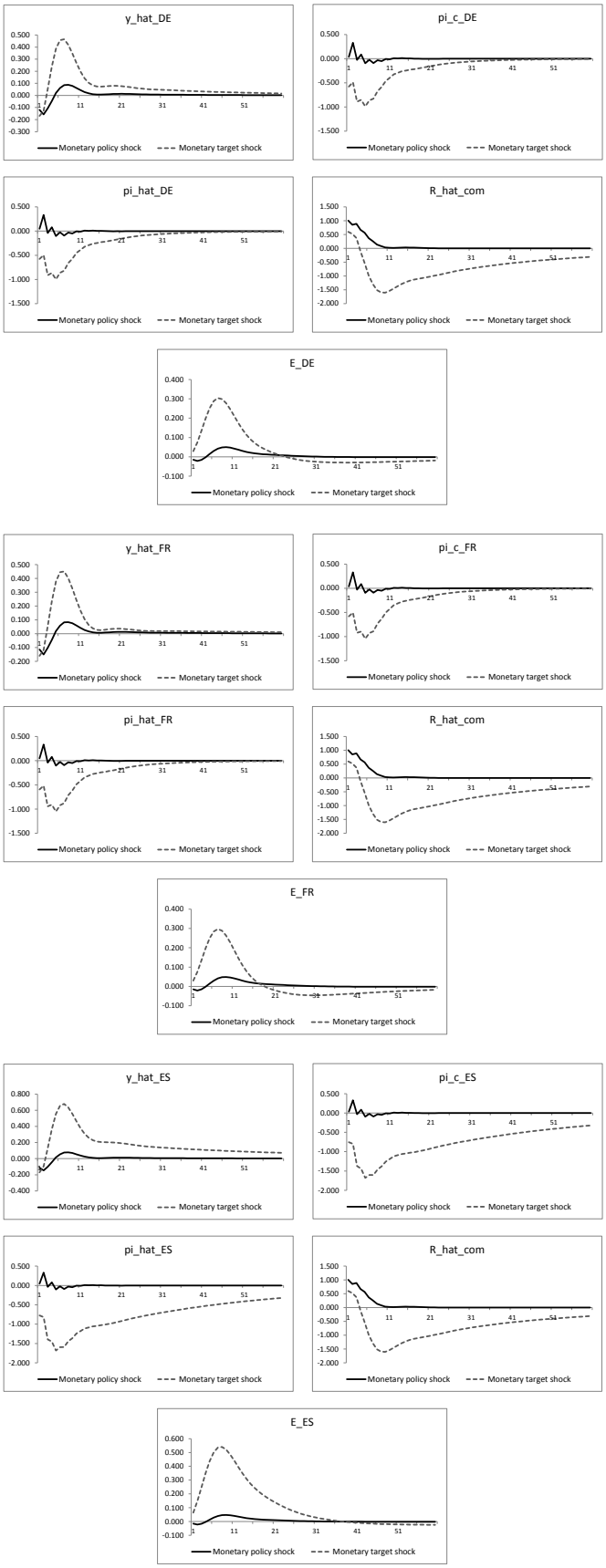
The pattern of the responses in the individual countries are, on the other hand, considerably homogeneous, particularly when compared to the intra-regional dissimilarities found in NAFTA and the Asia-Pacific region when they are exposed to equivalent shocks.

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.

[17]Recall that, in order to compare with a monetary policy shock, which implies a contractionary stance, we use in these section a *negative* shock to the policy target so that it also describes a hardening of the regional monetary policy.

Figure 13: International effects of a monetary shocks in the Euro-zone, Germany.



The return to equilibrium levels of employment is significantly slower than output's as is the interest rate's. The larger impact of the shock on Spanish prices takes a considerably long period to dissipate.

Comparing the implications of these shocks for the region's constituent economies in Figure 13, we notice that the monetary target shock exhibits the most significant responses in our selected map of representative variables.

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.

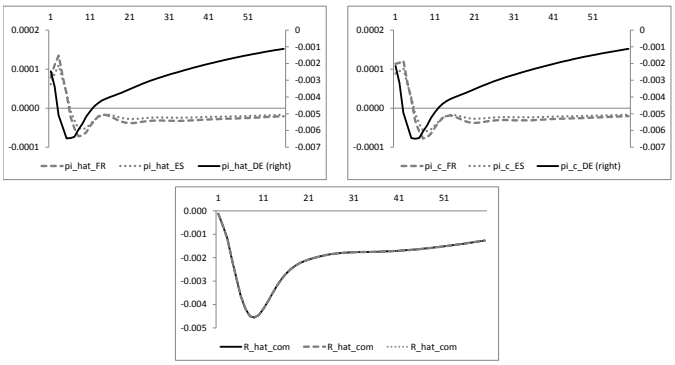
Moreover, we can distinguish the similarities (as those between Germany and France) and heterogeneities in the responses at country-level (noticeably in Spain) to these monetary disturbances, all of them relevant to the common regional monetary authority.

4.2.1.3 Nominal externalities of fiscal policy in Germany

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 14: International nominal effects of a fiscal policy shock (income tax) in Germany, Euro-zone.

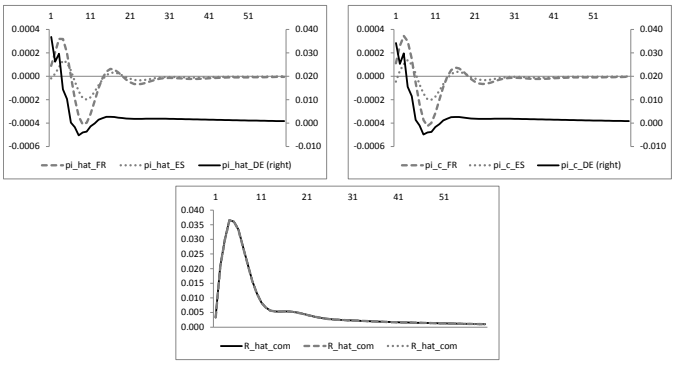


First, we observe in Figure 14 that fiscal spillovers from a negative shock to income tax within the region (left scale) are relatively small. The spillovers to France and Spain share a similar dimension and follow the direct effect of the shock in Germany with a delay of three quarters.

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.

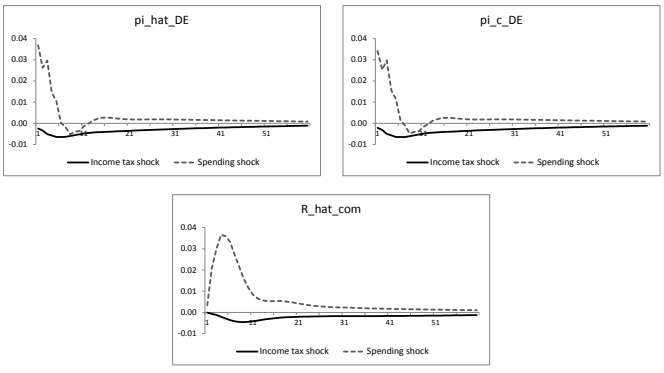
In turn, in Figure 15 we see that larger nominal spillovers (left scale) appear after a government spending shock in Germany which imposes the largest spillovers on France. The international effects of this shock are of a broadly similar size as their equivalents in the NAFTA region and larger than those in Asia-Pacific.

Figure 15: 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 16 - 18) represent a prolonged period of price-instability, especially after a German spending shock to which France's consumer prices display the highest sensitivity.

Figure 16: Comparative international nominal effects of fiscal policies in the Euro-zone, Germany.



4.2.2. Regional shocks

4.2.2.1 Shock to the Euro-zone risk premium

Figure 19 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

Figure 17: Comparative international nominal effects of fiscal policies in the Euro-zone, France.

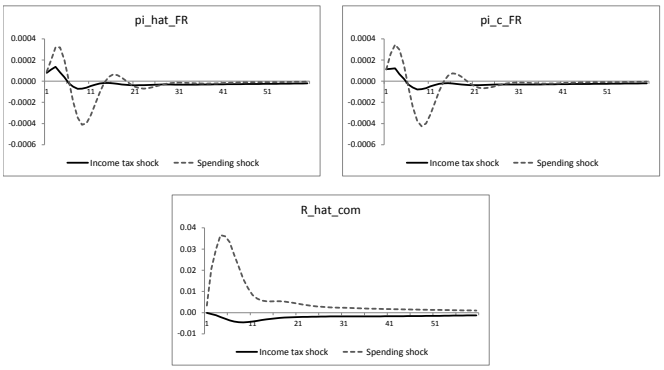
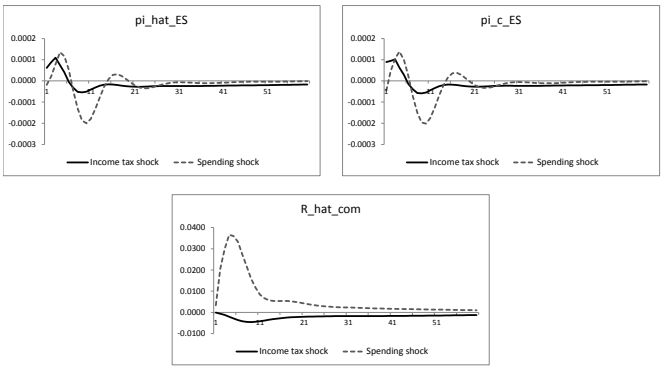


Figure 18: Comparative international nominal effects of fiscal policies in the Euro-zone, Spain.

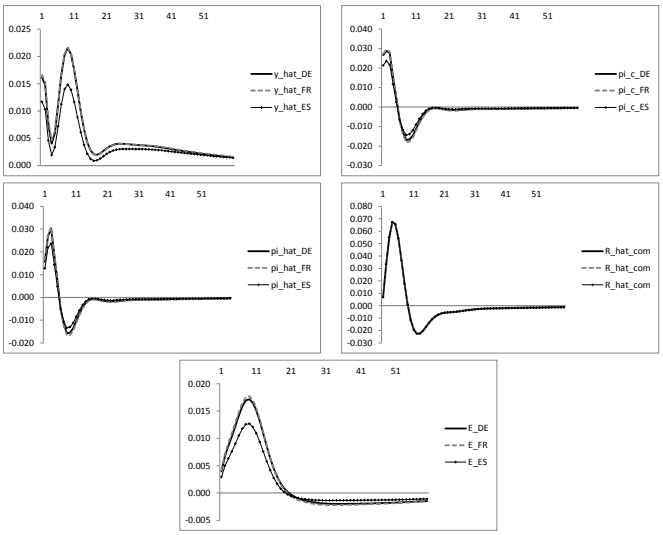


dominant feature of the responses to this shock is a higher degree of homogeneity between countries with Spain displaying a slightly higher resilience mainly in real variables. This difference is likely to be a reflection of a lower Spanish exposure to the impacts of variations in the risk premium owed, in turn, to a more discrete degree of integration to the international bonds markets.

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 high levels of downward-rigidity 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.

Figure 19: International effects of a shock to the risk premium in the Euro-zone.

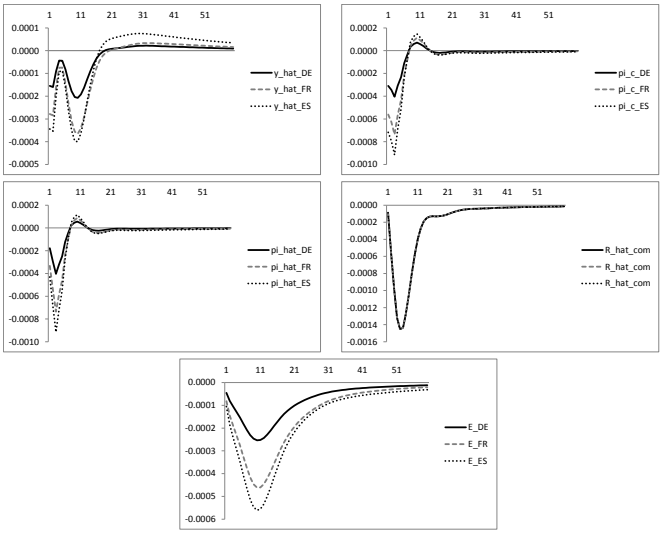


4.2.2.2 *Output shock in the rest of the world for the Euro-zone region*

The effects of a shock to the regionally-external output ($\varepsilon^{\hat{y}^*}_{EUR,t=0}$), shown in Figure 20, 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 20: 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 this particular shock, it is noticeable that, unlike other scenarios for the European region, the member economies display considerable divergences from each other that are comparable to those in the other two regions we analyse in this paper.

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 substantial degree of convergence towards equilibrium is also reached[18].

The largest declines of employment happened in France and Spain although all the three economies responded in a highly synchronised way.

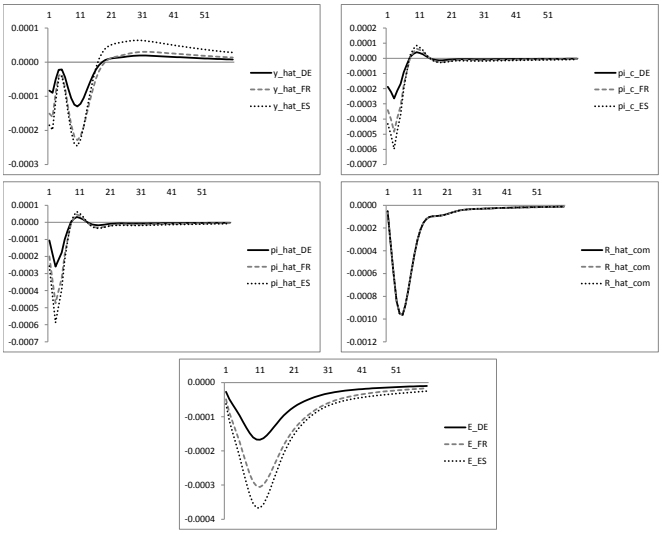
4.2.2.3 *Comparison with a price shock in the rest of the world for Euro-zone countries*

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 21.

The international outcomes of an external prices shock share the same general patterns of the previous scenario. 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 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.

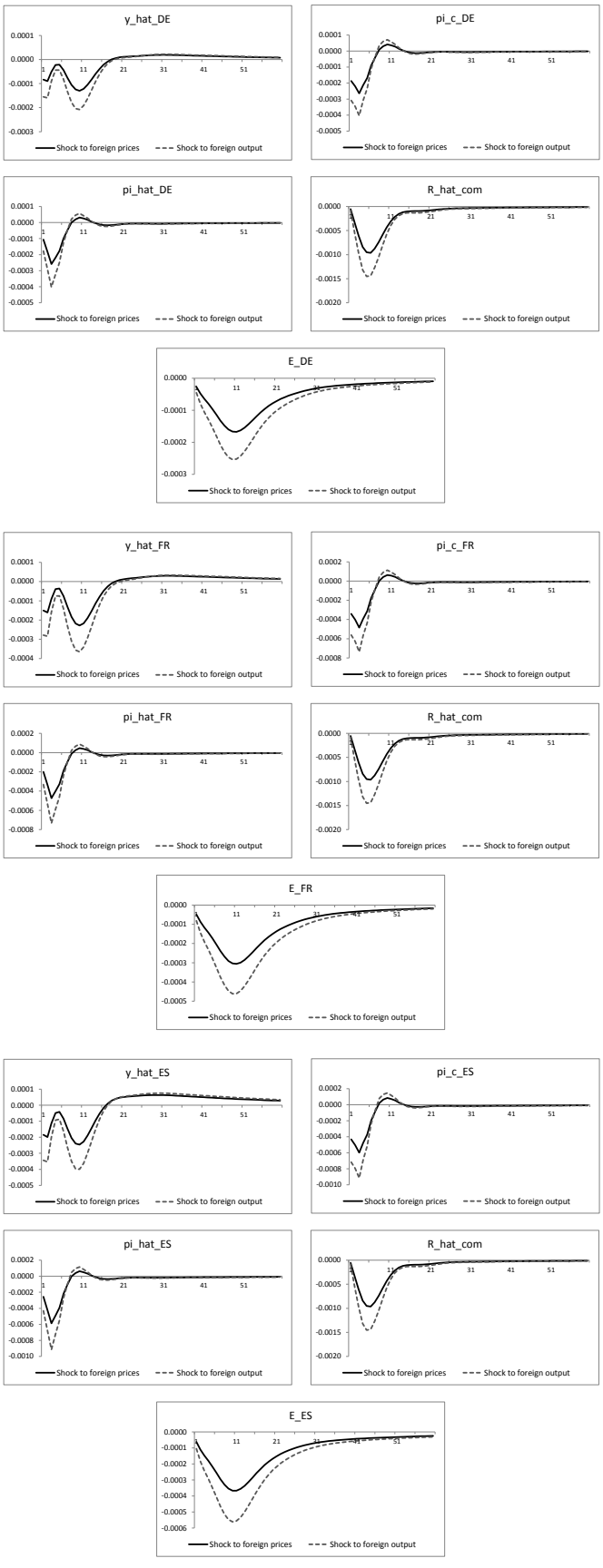
Figure 21: Comparative effects of external shocks on the Euro-zone region.

External prices shock



[18] Although this is less precise than the one recorded in the NAFTA region after an equivalent shock.

Figure 22: Regional effects of external shocks on the Euro-zone region.



Also in Table 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.

Table 3: Differences in the effects of external price vs external output shocks on the Euro-zone region.

Variable	DE		FR		ES	
	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.

4.3. Estimation on the Asia-Pacific region

The next estimation involves major economies in the Asia-Pacific OECD sub-region namely, Australia, Japan and Korea[19]. 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.

4.3.1. 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[20] (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 a monetary shock in Japan reflects into a fall in its output with employment also declining during the early stages of the shock. The recovery from the initial fall is, however, relatively fast even turning into

[19]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 this OECD regional economy, is not included in this estimation.

[20]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.

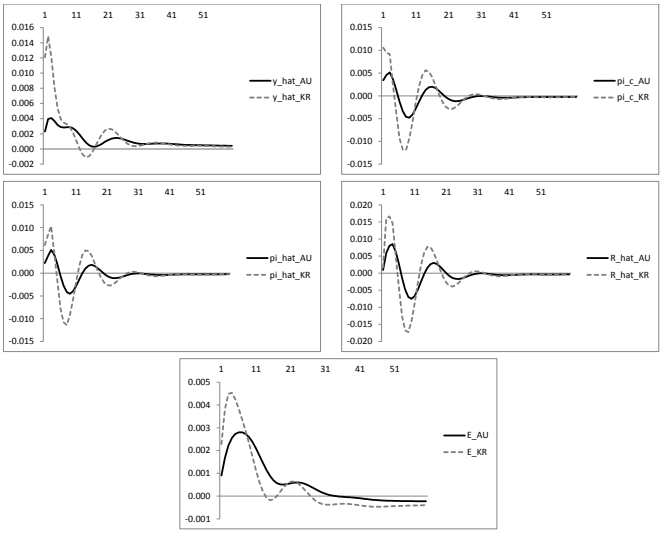
an over-compensating productive expansion in output and an increase of employment, both of them potentially associated to the depreciation in the exchange rate and the stimulus it represents to an exporting leader economy as Japan. This impulse on activity ends in quarter seven when both output and employment return to a path towards pre-shock levels.

4.3.1.1 Monetary policy shock in Japan

In this first scenario, the monetary policy shock on Japan ($\varepsilon^{R}_{JP,t=0}$) consists of a 1 standard error disturbance on the interest rate.

From 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 initial contraction in Japan. In both cases this boost declines as soon as the Japanese recovery begins. From the impact of the shock until the appreciation of the yen, the slowdown in Japan appears to benefit the activity levels of Australia and Korea.

Figure 23: International effects of a monetary policy shock in Japan, Asia Pacific region.

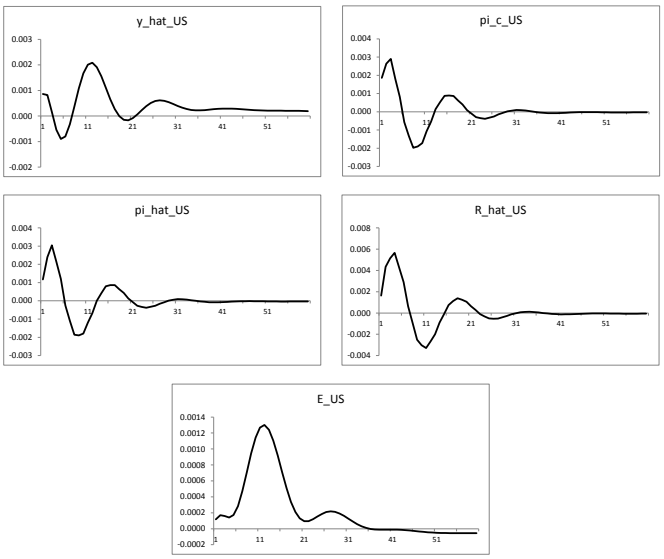


Looking for evidence on an exports shift, we noticed that the US economy experiences an increase in output as the Japanese monetary shock hits and subsequently displays an antagonising cycle to Japanese real variables. At the same time, our international weights indicate that, for Korea in particular, 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 24: 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 effect dissipates. 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 follow the depicted oscillating pattern.

4.3.1.2 Shock to Japan's monetary policy target

Subsequently, an inflation-target shock in Japan's monetary policy ($\varepsilon^{\hat{\pi}^c}_{JP,t=0}$), implying a more restrictive stance, initially reflects into a small increase in the interest rate (see Equation 22) but then a marked downward trend in the rate starts as the economic activity increases and inflation declines (displaying, this way, higher sensitivity to output variations).

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. Japanese 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.

Figure 25: International effects of a monetary policy target shock in Japan, Australia.

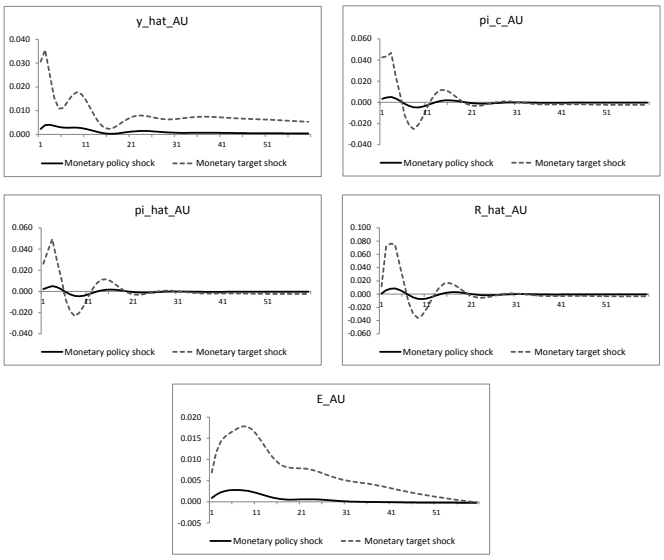
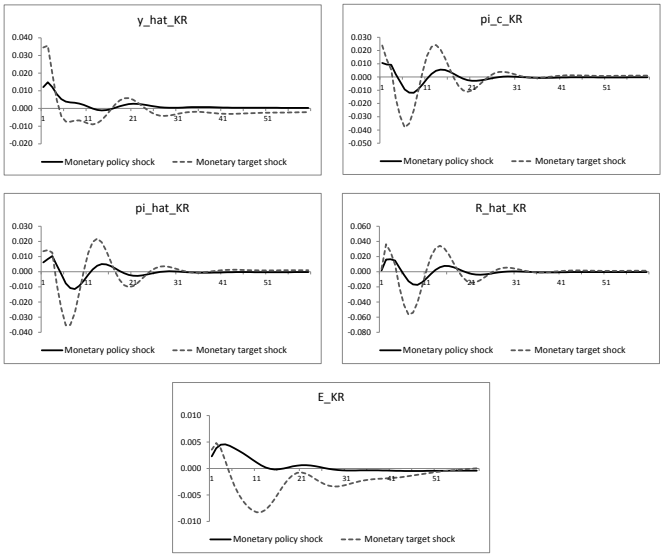


Figure 26: International effects of a monetary policy target shock in Japan, Korea.



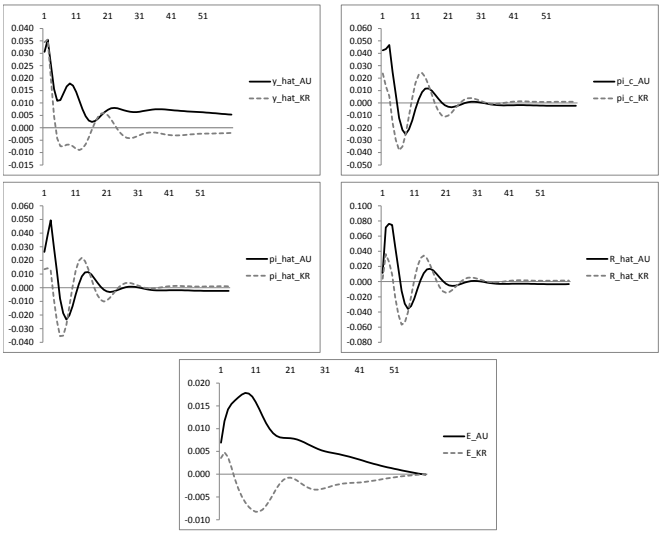
For the other members of the region, the monetary target shock has distinctive consequences mainly in real terms. This time Australia shows the largest variations as a result of its comparatively higher interdependence towards the Japanese economy. This is evident in the case of output and employment 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 a fast decay in activity.

On the other hand, the nominal instability that results from this shock is approximately of the same order in both Australia and Korea.

In comparative terms, a Japanese target shock implies considerably larger disturbances to the regional partners' variables (see Figures 25 and 26) than a monetary policy shock with Australia especially influenced by the international effects of the former (Figure 27).

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 27: International effects of a monetary policy target shock in Japan, Asia Pacific region.



4.3.1.3 Shock to Japan's risk premium

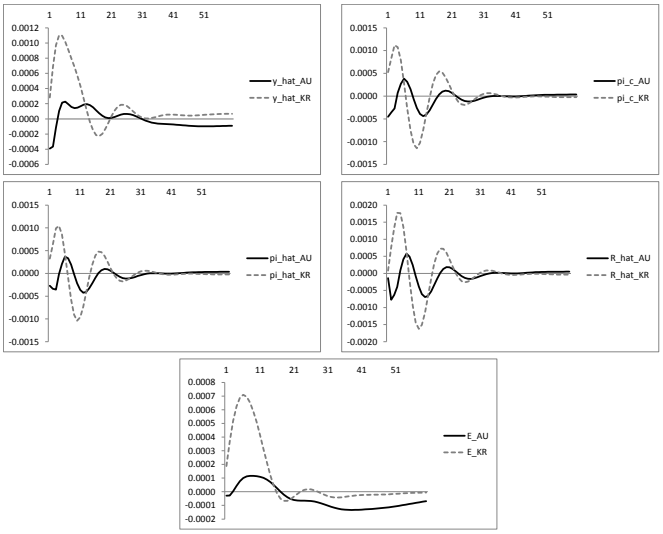
A shock to Japan's risk premium ($\tilde{\phi}_{JP,t=0}$) sets off distinctive patterns in the responses for the region's members. Asynchronous and dissimilar paths are followed by Australia's and Korea's key macroeconomic variables with the second displaying the most dramatic variations in each one of them.

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 (displaying an estimated policy parameter of $r_{JP}^{spr} = -0.0167$) 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 act-

Figure 28: International effects of a shock to Japan's risk premium, Asia Pacific region.



ing 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 less complex leader-follower style of interdependence dominates the international effects of economic shocks.

4.3.1.4 Nominal externalities of Japan's fiscal policy

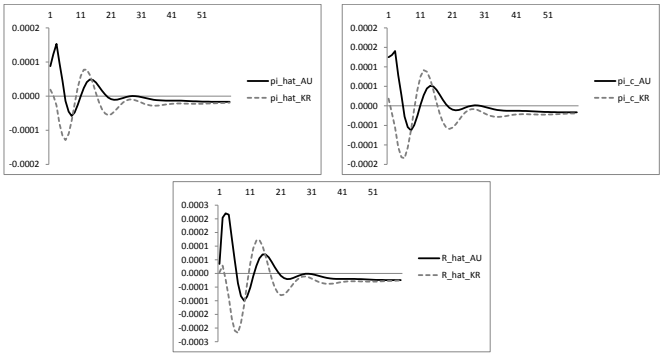
Turning to international cross-policy shocks originated from fiscal policies, a one standard error negative shock to the income tax in Japan ($\epsilon^{fpy}_{JP,t=0}$), also transmits nominal externalities to its regional peers with Australia experiencing the largest increases in inflation as well as in the interest rate immediately after the shock.

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.

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[21]. These increases in Australia's inflation generate upward pressure on the interest rate

[21] 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.

Figure 29: International nominal effects of a fiscal policy shock (income tax) in Japan, Asia Pacific region.

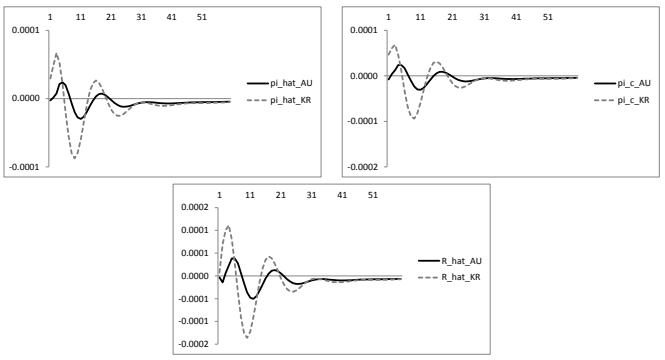


until quarter 3 when the international externality on inflation loses momentum.

Although the shock brings the same degree of instability to their interest rates, the direction of the necessary adjustments in each country are different with Australia's monetary policy being forced to temper an inflationary externality while, in turn, Korea faces a deflationary process.

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 generally the same in both cases.

Figure 30: 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 31: Comparative international nominal effects of fiscal policies in Japan, Australia.

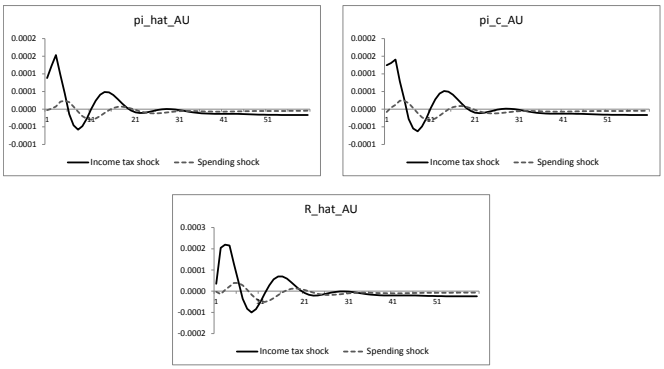
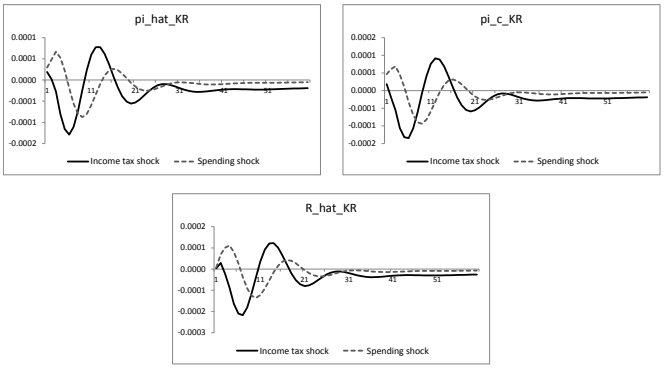


Figure 32: Comparative international nominal effects of fiscal policies in Japan, Korea.



4.3.2. Regional shocks

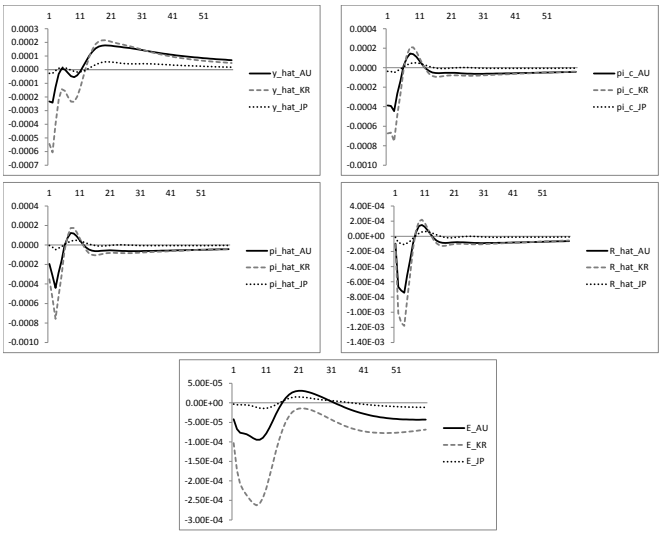
This section describes the implications of two relevant shocks on key macroeconomic extra-regional variables, as are output and inflation, for the performance of the region's member economies. Again, the aim is to expose the economies in the Asia-Pacific region to a common set of disturbances in order to analyse the particular effects they have on each one.

4.3.2.1 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 33. The external recovery also implies an effect of market saturation depressing output, employment, prices and the interest rate in all three countries.

Figure 33: Comparative effects of external shocks on the Asia Pacific region.

External output shock



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 as the main reason of its comparative resilience.

4.3.2.2 Comparison with a price shock in the rest of the world for Asia-Pacific countries

If a shock occurs on 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 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

Table 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

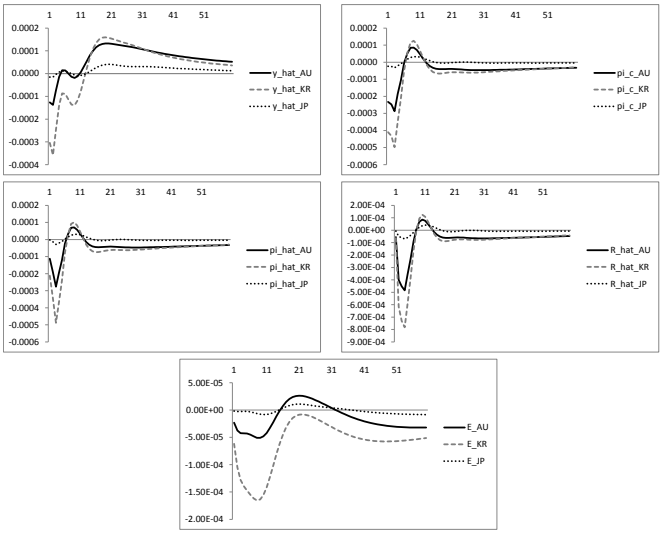
Figures as comparative percentage to the shock on external output.

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.

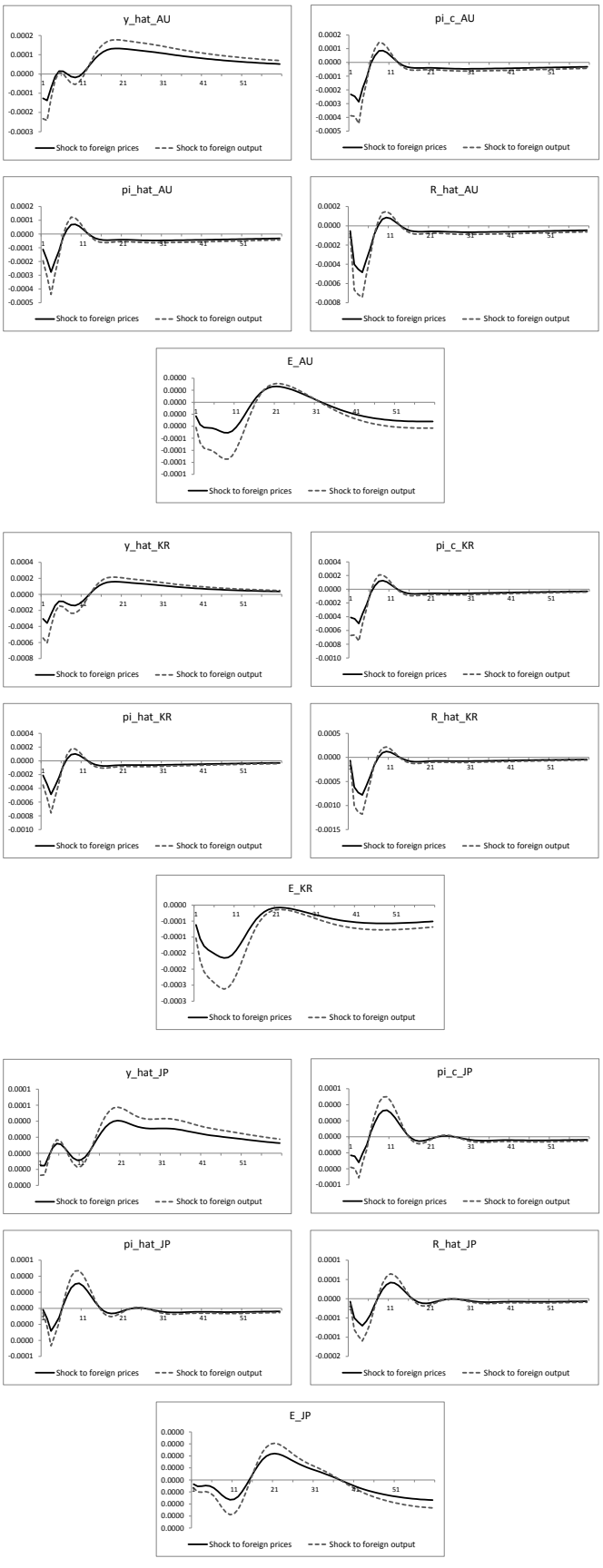
Figure 34: Comparative effects of external shocks on the Asia Pacific region.

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 35: Regional effects of external shocks on the Asia Pacific region.



5. Conclusions

In this paper we have presented and applied an extended macroeconometric DSGE platform for the analysis of the international effects of shocks including those derived from the discretionary components of monetary and fiscal policies in the context of international networks of trade and finance. As a tool for macroeconomic analysis characterised by nominal and real rigidities, this model has allowed us to distinguish the specific relationships between heterogeneous economies and the resulting particularities of the impacts of disturbances occurring at the national, regional and global levels.

Commercial, financial and size weights contributed to achieve a better representation of the heterogeneous relationships between economies in the model and enable it to calculate country-specific foreign variables for each experimental setting.

The distinction between 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, performed in this paper with particular focus on their international impacts. We specifically measured and characterised policy interactions from an international perspective, exploring externalities including the cross-policy effects transmitted between economies linked by commercial and financial exchanges.

The information we obtained on the distinctive impacts of external disturbances among heterogeneous economies provides a more accurate depiction of the particular adjustments that local authorities have to consider in each of the representative scenarios we have studied. Cross-policy international interactions, for example, were evaluated in the form of the nominal responses to foreign fiscal shocks which imposed externalities on variables of interest for the domestic monetary authorities. We measured and contrasted the specific responses to foreign taxation and spending shocks within in each region which gave an account of the disturbances that monetary policies have to accommodate for in their own policy schemes.

We have shown that the differences of the international impacts of shocks can be considerable between the analysed economies, both in terms of their size and their timing and, importantly, they are dependent on the nature of the commercial and financial linkages operating between national and regional units within the OECD.

In addition to information on the direction, size and timing of the responses to shocks, the scenarios we tested provided us with crucial insights on the particular rigidities displayed by key variables in both real and nominal aspects of each economy. Asymmetric features of those rigidities, in employment for example, imply that the shocks have different potentialities in terms of the resulting downward or upward deviations form equilibrium (the response to a positive shock would, therefore, not mirror the one resulting from a negative equivalent shock).

Shocks to the risk premia in leading economies or, as in the case of the Euro-zone, regions exemplified the occurrence of shocks in the overall conditions of the economies and how, without being the direct result of policy decisions, they can also be distinctively transmitted between economies interacting in broader networks.

In turn, the comparison between extra-regional output and price shocks has important implications in the context of international coordination between heterogeneous economies. In each regional case it has revealed that the preferences of foreign authorities in relation to the output-inflation balance will bring about different impacts on the domestic economies' welfare set (as defined by output, prices, the interest rate and employment) and, therefore, distinctively impinge on the space of manoeuvre available to domestic authorities.

6. Acknowledgements

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Appendix A. First order conditions

The household's first order condition with respect to consumption, c, implies:

$$\begin{aligned} E_{i,t}\Big[&-b_i\beta_i\mu_i^z\hat{c}_{i,t+1} + \Big[(\mu_i^z)^2 + b_i^2\beta_i\Big]\hat{c}_{i,t} - b_i\mu_i^z\hat{c}_{i,t-1} \\ &+b_i\mu_i^z(\hat{\mu}_{i,t}^z - \beta_i\hat{\mu}_{i,t+1}^z) + (\mu_i^z - b_i\beta_i)(\mu_i^z - b_i)\hat{\psi}_{i,t}^z + \\ &\frac{\tau_i^c}{1+\tau_i^c}(\mu_i^z - b_i\beta_i)(\mu_i^z - b_i)\hat{\tau}_i^c + (\mu_i^z - b_i\beta_i)(\mu_i^z - b_i)\hat{\gamma}_{i,t}^{c,d} \\ &-(\mu_i^z - b_i)(\mu_i^z\hat{\zeta}_{i,t}^c - b_i\beta_i\hat{\zeta}_{i,t+1}^c)\Big] = 0 \end{aligned} \tag{A.1}$$

where ψ and μ^z are scaling terms, τ^c is the rate of consumption tax, $\gamma^{c,d}$ is the relative price of domestic consumption with respect to general prices and ζ^c is a preference shock in consumption.

The first order condition with respect to investment, i, is:

$$\begin{aligned} &E_{i,t}\Big\{\hat{\Upsilon}_{i,t} - \hat{\gamma}_{i,t}^{i,d} \\ &-(\mu_i^z)^2\tilde{S}''\Big[(\hat{i}_{i,t} - \hat{i}_{i,t-1}) - \beta_i(\hat{i}_{i,t+1} - \hat{i}_{i,t}) + \hat{\mu}_{i,t}^z - \beta_i\hat{\mu}_{i,t+1}^z\Big]\Big\} \\ &= 0 \end{aligned} \tag{A.2}$$

where $\gamma^{i,d}$ is the relative price of domestic investment with respect to general prices, $\tilde{S}''$ is a parameter of the function describing the transformation of investments into physical capital (see CEE and ALLV).

The first order condition with respect to real balances is:

$$\begin{aligned} E_{i,t}\Big[&-\mu_i\hat{\psi}_{i,t}^z + \mu_i\hat{\psi}_{i,t+1}^z - \mu_i\hat{\mu}_{i,t+1}^z + (\mu_i - \beta_i\tau_i^k)\hat{R}_{i,t} \\ &-\mu_i\hat{\pi}_{i,t+1} + \frac{\tau_i^k}{1-\tau_i^k}(\beta_i - \mu_i)\hat{\tau}_{i,t+1}^k\Big] = 0 \end{aligned} \tag{A.3}$$

with τ^k as the tax rate on capital revenue, R is the gross nominal interest rate and π is the rate of overall inflation.

The first order condition with respect to capital is:

$$E_{i,t}\Bigg[\hat{\psi}^z_{i,t} + \hat{\mu}^z_{i,t+1} - \hat{\psi}^z_{i,t+1} - \frac{\beta_i(1-\delta_i)}{\mu^z_i} - \frac{\mu^z_i - \beta_i(1-\delta_i)}{\mu^z_i}\hat{r}^k_{i,t+1} + \frac{\tau^k}{(1-\tau^k)}\frac{\mu^z_i - \beta_i(1-\delta_i)}{\mu^z_i}\hat{\tau}^k_{i,t+1}\Bigg] = 0 \tag{A.4}$$

where r^k is the rental rate of capital.

The first order condition with respect to the utilisation rate of capital, u, is:

$$\widehat{u}_{i,t} = \frac{1}{\sigma_{a,i}}\widehat{r}^k_{i,t} - \frac{1}{\sigma_{a,i}}\frac{\tau^k}{(1-\tau^k)}\widehat{\tau}^k_{i,t} \tag{A.5}$$

where σ_a represents the cost of changes to the capital utilisation rate.

The first order condition with respect to cash holdings, q, is:

$$\hat{q}_{i,t} = \frac{1}{\sigma^q_i}\left[\widehat{\zeta}^q_{i,t} + \frac{\tau^k_i}{1-\tau^k_i}\widehat{\tau}^k_{i,t} - \widehat{\psi}_{z,i,t} - \frac{R_i}{R_i - 1}\widehat{R}_{i,t-1}\right] \tag{A.6}$$

with ζ^q as a money demand shock.

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