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New Risk Sharing Channels in OECD Countries: a Heterogeneous Panel VAR
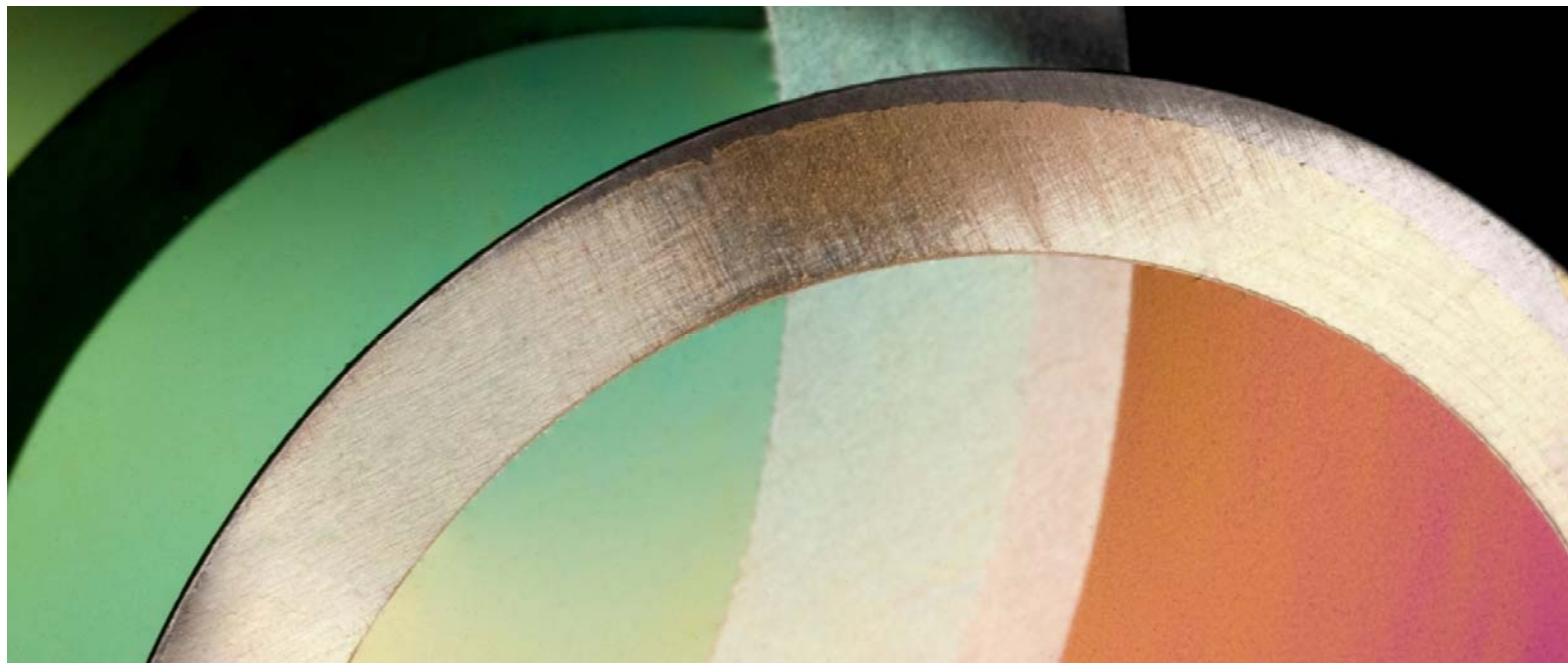
Asdrubali, P

Kim, S

Pericoli, F

Poncela, P

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Contact information
Name: Pilar Poncela
Address: Via Enrico Fermi, 2749. I - 21027 Ispra (VA) Italia
Email: pilar.poncela@ec.europa.eu
Tel.: (+39) 0332783965

Contents

Authors

Asdrubali, Pierfederico, Dep. of Economics and Social Sciences, John Cabot University

Kim, Soyoung, Dep. of Economics, Seoul National University

Pericoli, Filippo, Joint Research Centre, European Commission

Poncela, Pilar, Joint Research Centre, European Commission

Abstract

We aim to improve upon the existing empirical literature on international risk sharing under three dimensions. First, we generalize dynamic multi-equation approaches to the estimation of risk sharing channels, by adopting a Heterogeneous Panel VAR model. Within this framework, the coefficients representing the extent of risk sharing achieved through the different mechanisms are allowed to vary across countries. Second, we introduce two new risk sharing channels – namely, government consumption and the real exchange rate (that we further decompose into relative prices and the nominal exchange rate) – which allow us to investigate the role of fiscal policy and international price adjustments in the absorption of macroeconomic shocks. Third, we establish a better link between the "channels" empirical model and a theoretical formulation of the risk sharing condition which allows for PPP violations. Our empirical analysis, for a set of 21 OECD countries over 1960-2016, contributes to identifying the geographical structure and dynamics of risk sharing channels and to describing their evolution in the latest half-century. For the OECD sample as a whole, we confirm through 2016 the strong smoothing role played by credit markets and the small degree of risk sharing achieved through factor incomes. Interestingly, government consumption tends to have a dis-smoothing effect, due to its counter-cyclical movements. Another noteworthy result is the negative risk sharing effect of the real exchange rate, driven by the dis-smoothing role played by the movements of the nominal exchange rate, only partially offset by relative price adjustments. The evolution of these risk sharing mechanisms is diverse, but the most important channels – namely credit markets and real exchange rate adjustments – exhibit slightly positive trends for the first half of the period, negative trends afterwards, and a recovery in more recent years. Our results demonstrate that the extent of risk sharing is strikingly different across countries, especially if we take into account valuation effects through the real exchange rate. Even considering only traditional risk sharing channels, the country-specific magnitude of risk sharing on impact ranges from around 15% to over 80%. In addition, dynamics are also quite diverse across countries; for example, risk sharing through credit markets, while quite effective on impact, provokes dis-smoothing for about two thirds of the countries from the second year onwards. Our approach is of particular interest for policy makers, as it allows identifying the strengths and the weaknesses of the institutional and behavioral risk sharing mechanisms at work in different countries.

1 Introduction

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In open economies with complete markets, the maximization of a large class of utility functions implies that domestic consumption growth should be independent of idiosyncratic variables (notably domestic output growth). Econometrically, β should be zero in cross-sectional regressions of the form:

$$\log\left(\frac{C_t^j}{C_{t-1}^j}\right) - \log\left(\frac{C_t}{C_{t-1}}\right) = \alpha + \beta\left[\log\left(\frac{GDP_t^j}{GDP_{t-1}^j}\right) - \log\left(\frac{GDP_t}{GDP_{t-1}}\right)\right] + u_t^j \qquad (1.1)$$

where C, C^j, GDP, and GDP^j are world consumption, domestic consumption, world GDP, and domestic GDP, respectively, the disturbance term may include a measurement error and/or preference shocks and the α intercept captures the effect on consumption growth of unobservables which are constant across countries.[1]

Early tests (Lewis 1996, Crucini 1999) focused on the acceptance or rejection of the null hypothesis ($\beta=0$), but the successive literature interpreted $1-\beta$ as a measure of the *degree* of international risk sharing achieved by the countries under study.

The empirical literature on risk sharing was spurred by Asdrubali et al. (1996), who developed a variance decomposition scheme which breaks down the overall level of smoothing, *$1-\beta$,* into several regression coefficients, each quantifying a different implementing mechanism, or "channel" (international factor income, international transfers, and credit markets):

$$1-\beta = \beta_K + \beta_T + \beta_C \qquad (1.2)$$

Where the RHS β_z's are interpreted as the degree of risk sharing achieved by each channel. The history of the "channels" literature, at least from a methodological viewpoint, is the history of the econometric techniques introduced to best estimate the coefficients in (1.2).

Asdrubali et al. (1996) and Sørensen and Yosha (1998), followed by many others, adopted a panel SUR set-up, which constitutes a parsimonious and tractable estimation approach that takes into account various non-spherical disturbances, including cross-equation correlated errors. Asdrubali and Kim (2004) picked a different point on the trade-off curve between simplicity and thoroughness, and introduced a multivariate panel VAR model which allows endogenizing output and taking into account the dynamics and feedbacks among the variables. In fact, a VAR model treats all the variables in the system, including output, as endogenous, and allows dynamic feedback among those variables. In addition, such a framework can explicitly extract exogenous shocks and trace their dynamic effects. As a consequence, one can distinguish the effects of different kinds of shocks (e.g., shocks to GDP and to each smoothing channel) at different time horizons. At the same time, the VAR approach addresses the endogeneity problem arising in a static SUR specification, by accounting for the feedback from each component of output or each smoothing channel onto output. Additionally, within this methodology it is possible to answer several other relevant

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[1] See the seminal papers by Mace (1991), Cochrane (1991) and Townsend (1994).

policy questions, like identifying the speed of adjustment to shocks, or whether the different channels have acted as substitutes or complements.[2]

The methodological contributions of our paper are threefold. First, we generalize the panel VAR approach in Asdrubali and Kim (2004) by allowing for country heterogeneity in risk sharing. Following recent developments in the econometrics of panel VAR, we employ a specification where the assumption of identical parameters in all countries is relaxed, and each country has its own specific model of risk sharing. The main advantage of this approach is that we can estimate rigorously country-specific risk sharing channels, thus providing a finer geographical description of risk sharing mechanisms with respect to previous contributions.[3] As far as we know, this is the first time that heterogeneous panel VAR models are used to estimate risk sharing. To capture the possible evolutionary patterns of risk sharing we also estimate our panel VAR models using a rolling window and track the time-varying behavior of the different smoothing channels. Second, we provide a sounder theoretical foundation to the channels framework, by linking more closely the empirical model to the risk sharing condition. In particular, our empirical model will ultimately relate output growth with private consumption growth, instead of overall – private and government – consumption growth (as in the standard "channels" literature). In so doing, we introduce a novel risk sharing channel, namely government consumption adjustment. Third, we introduce another fundamental smoothing channel – valuation effects on relative consumption through the real exchange rate adjustments. This had not yet been analyzed in a dynamic channels framework, although real exchange rate behavior has often been discussed in the risk sharing literature. Furthermore, we decompose this latter channel into the contributions of relative price and nominal exchange rate adjustments. Through the smoothing effect of government consumption and of the real exchange rate, we will present a novel perspective on the role of public expenditure in dampening business cycle fluctuations in OECD countries, as well as on the role of the real exchange rate on impact and in the medium run.

We apply our methodology to a large macroeconomic dataset, namely a sample of 21 OECD countries over the 1960-2016 period. This reliable source of data has been repeatedly used to gauge risk sharing estimates among various countries and over different time periods, which will provide for useful comparisons of our results.

As Kose et al. (2009) point out, the recent literature presents conflicting results on international risk sharing, even for advanced economies. While some studies suggest that risk sharing has increased during the recent globalization era (see, for instance, Sørensen et al., 2007, and Giannone and Reichlin, 2006), or alongside with financial integration, some others found little evidence of increased risk sharing (Kose et al. 2003, Moser et al., 2005, Kose et al., 2009, and Bai and Zhang, 2012). Balli et al. (2013) underline that most of these findings relate to a period of financial upturn fueled by the creation of the European Monetary Union (EMU). Our approach, applied to a long time span encompassing distinctive sub-periods up to 2016 and measuring individual countries' shock-absorption capabilities, helps to shed light on the different dynamics of risk sharing in the last 50 years, also at country level. Such dynamics might explain

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[2] Recent reviews of the literature on risk sharing can be found in Ahrend, Arnold and Moeser (2011), who point out the need to develop collective risk sharing mechanisms, and Pierucci (2014) that reviews the empirical literature on risk sharing and the effects of economic and financial integration on risk sharing.

[3] Early analyses of risk sharing (Backus, Kehoe, and Kydland 1992, Pakko 1998) were based on bilateral cross-country income and consumption correlations; however, these measures – even in their more recent specifications as in Brandt et al. (2006) – do not provide an accurate estimate of overall risk sharing (see Artis and Hoffmann 2008) and are not particularly informative on its dynamics. There have been also studies – such as Mélitz and Zumer (1999) or Sørensen, Wu, Yosha and Zhu (2007) – which introduced the idea of varying β coefficients. However, these papers impose a specific structure on β based on the interaction with control variables and, therefore, only focus on the effect on the risk sharing estimates of these interacted variables. Finally, Pierucci and Ventura (2010) and Fuleky, Ventura and Zhao (2015) provide a single-equation error-correction model which allows for heterogeneity but cannot identify the risk sharing channels and their dynamics.

the conflicting results emerging from the recent risk sharing literature. As another example, different views exist on the functioning of risk sharing in the face of a financial shock, such as the subprime crisis of year 2008. By studying the effects of a shock to a risk sharing channel, our VAR approach can uncover the dynamics of the responses to shocks of various origin, and assess the extent of substitutability/complementarity among risk sharing channels.

In summary, in this article we attain several goals: First, we estimate a theoretically-founded VAR model to analyze the magnitude and interrelations of smoothing channels at work within the OECD economies. Second, we generalize the panel VAR approach by allowing for countries heterogeneity in the parameters, as well as for the risk sharing role of government consumption and real exchange rate adjustments that are further decomposed into the relative price and nominal exchange rate adjustments. Third, we use our methodology to improve and update the measurement of risk sharing for a group of industrialized countries commonly used in the empirical analysis over different time periods.

The rest of the paper is structured as follows. In section 2, we describe the method employed. In section 3, we present our empirical results. Finally, in section 4 we present some concluding remarks.

2 Methodology

2.1 Conceptual framework

Consider a world of J stochastic endowment economies, each populated by an infinitely-lived representative agent exhibiting time-separable Von Neumann–Morgenstern expected utility over a composite (per capita) nondurable consumption good, possibly different across countries.[4] Uncertainty is represented by a state variable s^t which summarizes history up to time t, and can take on countably many values at any date t. In this set-up, the Pareto-optimal (per capita) consumption allocations satisfy for all s^t:[5]

$$\rho^j \frac{U_c\left(C_t^j, \delta_t^j\right) R_t^j}{U_c\left(C_{t-1}^j, \delta_{t-1}^j\right) R_{t-1}^j} = \frac{\mu_t}{\mu_{t-1}} \qquad j = 1, \dots, J \tag{2.1}$$

where ρ^j is country j's factor of time preference, $R_t^j = \frac{P_t^* e_t^j}{P_t^j}$ is the real (effective) exchange rate, defined as the price of the world aggregate consumption basket in terms of country j's consumption (e_t^j being the nominal (effective) exchange rate, defined as the price of the world currency basket in terms of country j's currency, P_t^j the price level in country j, and P_t^* the world aggregate price index), δ_t^j is a shift parameter (capturing the effect of factors different from consumption affecting utility, such as tastes, leisure, non-tradables, durables, government consumption, home production),[6] C_t^j is (real) consumption evaluated at domestic price, and μ_t is the Lagrange multiplier associated with the feasibility constraint, divided by the probability of occurrence of state s^t.

This condition states that at the optimum, the discounted growth of marginal utility – evaluated at world prices – is the same in every country and, given aggregate consumption, is independent of individual countries' endowments. The consequences for country consumption growth can be illustrated by specifying a log utility function:

$$U\left(C_t^j, \left[b_t^j\right]\right) = b_t^j \log C_t^j$$

where b_t^j is a multiplicative shock. In this case, after taking logs and differences in both sides of (2.1), we obtain:

$$\log\left(\frac{C_t^j / R_t^j}{C_{t-1}^j / R_{t-1}^j}\right) = \log \rho^j + \log\left(\frac{b_t^j}{b_{t-1}^j}\right) - \log\left(\frac{\mu_t}{\mu_{t-1}}\right) \tag{2.2}$$

The optimal risk sharing solution thus prescribes that real country consumption growth evaluated at world prices – net of preference shifts $\left[\log\left(\frac{b_t^j}{b_{t-1}^j}\right), \log \rho^j\right]$ and given real world aggregate consumption growth represented by $\log\left(\frac{\mu_t}{\mu_{t-1}}\right)$ – must be independent of idiosyncratic country variables, notably endowment. The consequence is consumption smoothing across countries evaluated at world prices, given the RHS terms in (2.2). For example, in the presence of deviations from purchasing power parity

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[4] Generalizations have been developed to a production economy (Cole and Obstfeld 1991, Stockman and Tesar 1995).
[5] See Kollmann (1995) or Cavaliere, Fanelli and Gardini (2008).
[6] See Canova and Ravn (1996).

(PPP), domestic consumption should grow faster when the consumption price is relatively depreciating, thereby smoothing the ratio on the LHS of equation (2.2).

The optimal solution can be decentralized and implemented, fully or in part, through several mechanisms, depending on the commercial, financial and institutional structure of the economy. For example, the existence of complete markets of Arrow-Debreu contingent claims (Arrow 1964), or a specific set of securities (Duffie and Huang 1985), allows economies to implement the full risk sharing solution through portfolio diversification.[7] Such optimal allocation can also be approximated – and under certain assumptions even attained – in a bonds-only economy, provided that the endowment shocks are all transitory (Baxter and Crucini 1995, Levine and Zame 2002, Willen 1999). Similarly, the existence of appropriate supra-national (federal) tax/transfers mechanisms allows subsidizing, at least partially, those countries whose endowment has been hit by a negative shock, drawing from country endowments hit by a positive shock. In addition, risk sharing can be provided through self-insurance, that is by asset accumulation (saving) and depletion (dissaving) through (domestic or international) lending and borrowing. Furthermore, we consider the risk sharing role of domestic government consumption, which can operate as a clearing house, absorbing output shocks before they hit domestic (private) consumption. For example, during a recession, a reduction in government consumption may free resources for private consumption. Finally, the optimal risk sharing allocation may be reached through movements in the real exchange rate, eliciting valuation effects and transfers of goods and financial assets. Cole and Obstfeld (1991) have shown that, for certain restrictive parameter choices, commodity trade alone can attain the full risk sharing allocation, even in the absence of international asset markets or international transfers. More generally, they have identified a mechanism that can attain (partial) risk sharing through adjustments in the terms of trade and – depending on its correlation with the terms of trade – in the real exchange rate.[8] In addition, a long-standing literature in open economy macroeconomics (e.g. Obstfeld 1985) has studied the risk sharing properties of the real exchange rate in relation to the nature of the shocks to output. For example, a productivity-driven output shock would be smoothed by the valuation effect of the ensuing real depreciation of the consumption basket. Note that, in the empirical analysis, we divide the real exchange rate adjustments into relative price and nominal exchange rate adjustments to infer the separate roles of these two factors.

This paper aims to quantify the five decentralization mechanisms mentioned above. In fact, the main idea of the "channels" literature is that there is mileage to be gained in allowing these multiple implementation mechanisms to operate jointly, and in exploring their individual contributions to risk sharing. To this purpose, like much of the work on risk sharing channels, we maintain a very general setup by not assuming any specific market or institutional structure for our economies, and let the empirical analysis reveal the extent of risk sharing achieved by each channel. We also refrain from restricting the empirical framework by modelling endogenous frictions leading to market imperfections (such as limited commitment or enforceability).[9] In fact, the stylized facts and statistical linkages that we uncover will help shed some light precisely on the most appropriate market and institutional structure or endogenous market imperfections characterizing the OECD economies in the period under exam.

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[7] A similar mechanism is at work not only through cross-border capital income flows, but also via transboundary labor income flows.

[8] See for example Heathcote and Perri (2002).

[9] As a matter of fact, our model can hold in a decentralized equilibrium independently of asset market completeness, or trade frictions and goods market imperfections (including shipping and trade costs, as well as sticky prices or wages) that can cause large deviations from the law of one price and PPP (see Corsetti, Dedola and Leduc 2008).

2.2 Empirical Model of Risk Sharing Channels

2.2.1 A Baseline Specification

As illustrated by equation (2.2), if risk is fully shared through market or non-market institutions, given preference shifts and given world aggregate consumption, real country consumption growth at world prices should not respond to idiosyncratic shocks to domestic variables, for example real country output growth at domestic prices. We analyze the empirical implication of full insurance starting from the regression coefficient of the (idiosyncratic) real country consumption growth at world prices (i.e. deviation from real world aggregate consumption growth at world prices) on the (idiosyncratic) growth in real country GDP at domestic prices (i.e. deviation from real aggregate GDP growth at world prices) at any lag l:

$$\Delta_l \tilde{c}_t^j = \alpha^j + \beta^j \Delta_l gdp_t^j + u_t^j \tag{2.3}$$

where lowercase letters indicate logs, $\Delta_l = 1 - L^l$ such that applied to any variable z_t produces $\Delta_l z_t = z_t - z_{t-l}$ for any finite l, a tilde indicates a variable at constant world prices, the disturbance may include a measurement error and both the dependent and the independent terms are expressed in deviations from the corresponding (log-difference of the) real world aggregate. In a panel setting, the α^j intercept captures the effect on consumption growth of unobservables constant over time (including ρ^j and some of the time-invariant factors embedded in b_t^j, such as leisure, home production, etc.), whereas the deviation from the aggregate corresponds to a time effect controlling for the influence of aggregate variables, notably aggregate consumption or aggregate income growth.[10] In addition, the varying β^j coefficient captures additional (possibly country-specific) parameters affecting the relation between GDP growth and consumption growth. Full insurance implies that for each country the β coefficient is equal to zero; on the other hand, no insurance implies that this coefficient should be one.[11] A useful – albeit *ad hoc* – interpretation of (2.3) is that countries may pool into risk sharing arrangements only a fraction $1-\beta^j$ of their domestic GDP (growth), whereas the remaining fraction β^j co-moves with domestic consumption (growth) (that is, it is captured by the $\beta^j \Delta_l gdp_t^j$ term).[12] Country-specific preferences (time preference coefficients and other factors such as taste shifts), appearing in equation (2.2) are instead captured by the error term.

As argued by many researchers, such as Dynarski and Gruber (1997) and Fafchamps (2011), the β^j coefficient captures the extent to which the economy manages to smooth consumption in the face of output shocks. In other words,

$$1 - \beta^j(l) = 1 - \frac{cov(\Delta_l \tilde{c}_t^j, \Delta_l gdp_t^j)}{var(\Delta_l gdp_t^j)} \tag{2.4}$$

is an appropriate measure of the extent of country j's consumption smoothing via risk sharing at any time horizon l.

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[10] In some formulations of the risk sharing model, the term $\log(\mu_{t+1}/\mu_t)$ is specified as aggregate consumption growth (e.g. Mace 1991), and at times it is added as a regressor (e.g. Obstfeld 1994). However, in a panel setting it is replaced by the time effect.

[11] Note that if no risk sharing mechanism is at work (including commodity trade), the real exchange rate does not apply and on the LHS we simply have domestic consumption growth.

[12] The existence of a fraction of country output not pooled in the risk sharing agreement is motivated, among other considerations, by transaction costs (Crucini 1999 and references therein) or by the fact that a significant fraction of households own near-zero net worth (e.g., Wolff 1998).

The main contribution of the risk sharing channels methodology consists in a decomposition of the overall risk sharing measure $1-\beta^j$ into the smoothing contributions of the different risk sharing mechanisms mentioned in section 2.1 above, aimed at capturing how GDP shocks propagate through the economy. For every country, we use the following variables:

- *GDP* (Gross Domestic Product)
- *GNI* (Gross National Income) = *GDP + NFI*, where *NFI* stands for net factor income[13]
- *GDI* (Gross Disposable Income) = *GNI + NIT*, where *NIT* stands for net international transfers[14]
- *C+G* (Total Consumption, *TC*) = *GDI - S*, where *S* stands for national savings[15]
- *C* (Private Consumption) = *TC − G*
- *Ĉ* (Private Consumption deflated by relative prices) = *C×P/P**
- *C̃* (Private Consumption in PPP) = *C/R*, where the real effective exchange rate, R = *e×P*/P*; *e* is the nominal effective exchange rate, *P* is the domestic price level and *P** is the world price level.

The econometric model is based on the idea that, if two successive income measures do not co-move, the smoothing mechanism represented by their difference is at work. For instance, to the extent that *GDP* and *GNI* do not perfectly co-move, it means that cross-border factor income flows have provided a smoothing (or dis-smoothing) effect whenever the correlation of the two measures is non-negative (or negative). By the same token, to the extent that *GNI* and *GDI* do not perfectly co-move, it means that international transfers have provided further smoothing (or dis-smoothing). Take the following identity:

$$GDP_t^j = \frac{GDP_t^j}{GNI_t^j} \times \frac{GNI_t^j}{GDI_t^j} \times \frac{GDI_t^j}{(C+G)_t^j} \times \frac{(C+G)_t^j}{C_t^j} \times \frac{C_t^j}{\hat{C}_t^j} \times \frac{\hat{C}_t^j}{\tilde{C}_t^j} \times \tilde{C}_t^j \tag{2.5}$$

After taking logs, applying the $\Delta_l = 1 - L^l$ operator and taking deviations from cross-sectional aggregates we obtain:

$$\begin{aligned}
\Delta_l gdp_t^j = {} & \left(\Delta_l gdp_t^j - \Delta_l gni_t^j\right) + \left(\Delta_l gni_t^j - \Delta_l gdi_t^j\right) \\
& + \left(\Delta_l gdi_t^j - \Delta_l (c+g)_t^j\right) + \left(\Delta_l (c+g)_t^j - \Delta_l c_t^j\right) \\
& + \left(\Delta_l c_t^j - \Delta_l \hat{c}_t^j\right) + \left(\Delta_l \hat{c}_t^j - \Delta_l \tilde{c}_t^j\right) + \Delta_l \tilde{c}_t^j
\end{aligned} \tag{2.6}$$

where lowercase letters again indicate logs and all the terms are expressed in deviations from the corresponding (log-difference of the) real world aggregate. Multiplying both sides by $\Delta_l gdp_t^j$ and taking expectations:

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[13] Net factor income is the difference between income inflows and outflows accruing to the residents in a country due to their international net asset holdings and cross-border labor compensation.

[14] Net international transfers correspond to the net flows of money accruing to residents in a country as a consequence of cross-border financial transfers without an economic counterpart.

[15] National savings include not only private savings (by households and firms), but also public savings by the government.

$$var\left(\Delta_l gdp_t^j\right) = cov\left(\Delta_l gdp_t^j, \Delta_l gdp_t^j - \Delta_l gni_t^j\right) + cov\left(\Delta_l gdp_t^j, \Delta_l gni_t^j - \Delta_l gdi_t^j\right)$$

$$+ cov\left(\Delta_l gdp_t^j, \Delta_l gdi_t^j - \Delta_l(c+g)_t^j\right) + cov\left(\Delta_l gdp_t^j, \Delta_l(c+g)_t^j - \Delta_l c_t^j\right)$$

$$+ cov\left(\Delta_l gdp_t^j, \Delta_l c_t^j - \Delta_l \hat{c}_t^j\right) + cov\left(\Delta_l gdp_t^j, \Delta_l \hat{c}_t^j - \Delta_l \tilde{c}_t^j\right) + cov\left(\Delta_l gdp_t^j, \Delta_l \tilde{c}_t^j\right)$$

Dividing both sides through by $var(\Delta_l gdp_t^j)$, we obtain a constrained sum of simple regression coefficients:

$$1 = \frac{cov\left(\Delta_l gdp_t^j, \Delta_l gdp_t^j - \Delta_l gni_t^j\right)}{var\left(\Delta_l gdp_t^j\right)} + \frac{cov\left(\Delta_l gdp_t^j, \Delta_l gni_t^j - \Delta_l gdi_t^j\right)}{var\left(\Delta_l gdp_t^j\right)}$$

$$+ \frac{cov\left(\Delta_l gdp_t^j, \Delta_l gdi_t^j - \Delta_l(c+g)_t^j\right)}{var\left(\Delta_l gdp_t^j\right)}$$

$$+ \frac{cov\left(\Delta_l gdp_t^j, \Delta_l(c+g)_t^j - \Delta_l c_t^j\right)}{var\left(\Delta_l gdp_t^j\right)}$$

$$+ \frac{cov\left(\Delta_l gdp_t^j, \Delta_l c_t^j - \Delta_l \hat{c}_t^j\right)}{var\left(\Delta_l gdp_t^j\right)}$$

$$+ \frac{cov\left(\Delta_l gdp_t^j, \Delta_l \hat{c}_t^j - \Delta_l \tilde{c}_t^j\right)}{var\left(\Delta_l gdp_t^j\right)} + \frac{cov\left(\Delta_l gdp_t^j, \Delta_l \tilde{c}_t^j\right)}{var\left(\Delta_l gdp_t^j\right)}$$

or,

$$1 - \beta^j(l) = \beta_F^j(l) + \beta_T^j(l) + \beta_C^j(l) + \beta_G^j(l) + \beta_P^j(l) + \beta_e^j(l) \tag{2.7}$$

For each country and for each lag *l*, the overall risk sharing measure *1-β* is decomposed into 6 regression coefficients, which aim to capture the five risk sharing mechanisms mentioned in section 2.1.[16] Following the literature on risk sharing channels (e.g., Sørensen and Yosha 1998), the first coefficient on the RHS – β_F – measures international factor income risk sharing, namely the percentage of a shock to output growth that is smoothed through cross-border flows of factor incomes; the second – β_T – the percentage of the shock to output growth that is further smoothed by international current transfers; the third – β_C – the additional smoothing provided by domestic and international credit markets through asset increase/decrease; the fourth – β_G – the further amount of smoothing provided by government consumption; the fifth – β_P – the smoothing achieved through relative price adjustments; the sixth – β_e – the final degree of smoothing achieved through adjustments of the nominal effective exchange rate. Note that the empirical literature on risk sharing channels has always made the alternative assumption that government consumption is a perfect substitute of private consumption, and thus is part of the country "consumption aggregate" – that is, it is to be modelled as a smoothing target, not a smoothing channel; hence, equations (2.5), (2.6) and (2.7) would stop short of the last three terms. Our set-up instead adds a smoothing channel via government consumption, allowing for the possibility of imperfect substitutability with private consumption. In so doing, our framework allows for both roles of government consumption, thereby linking the empirical model to the theory (couched in terms of *private* consumption), while maintaining the comparison with previous work. Additionally, our set-up introduces

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[16] Equations (2.5) and (2.6) further break down the real exchange rate channel into its components, namely relative prices and the nominal exchange rate.

another novel channel – movements of the real exchange rate – which helps smooth the real PPP value of the (per capita) consumption growth of the country.

2.2.2 A Heterogeneous Panel VAR

Heterogeneous-parameter equation systems based on (2.3) are a natural approach to the estimation of the coefficients in (2.7). However, static estimators such as in Mélitz and Zumer (1999) or Sørensen, Wu, Yosha and Zhu (2007), and single-equation error-correction models allowing for heterogeneity such as in Pierucci and Ventura (2010) and Fuleky, Ventura and Zhao (2015) may fall short of capturing the complex dynamics of risk sharing channels introduced by Asdrubali and Kim (2004) or Becker and Hoffmann (2006). Indeed, notwithstanding its success and its wide use in empirical analyses of risk sharing, the standard regression-based static approach has various shortcomings in comparison to the VAR-based approach. First, in the standard approach, dynamic aspects of risk sharing are not fully taken into account, as the right-hand side of the model only includes contemporaneous idiosyncratic GDP and the univariate structure imposed on the error term is limited. An advantage of the VAR is that it provides a complete description of the moments of the data at all leads and lags.[17] Hence, the dynamic risk sharing profile is a closed-form function of the VAR parameters. If we were to obtain an estimate of the risk sharing profile from a sequence of regression equations at different horizons l = 1, 2, . . . , L, the analytic link between the different β_l's for l = 1, 2, . . . , L would remain blurred. We think it is preferable to model the patterns of temporal (and cross equation) dependence by using a VAR. In addition to capturing dynamic dependence properly, a VAR model can trace how dynamic properties of risk sharing change over time in the presence of GDP shocks by exploiting impulse response functions. Second, the standard approach leads to consistent estimates of the parameters only if idiosyncratic GDP is exogenous. Since we estimate the VAR in reduced form, all the variables in the RHS are predetermined, which allows us to tackle the issue of endogeneity. Third, in a VAR set-up we can easily discuss the interactions among risk sharing channels. Shocks to risk sharing channels can be identified in the VAR model and impulse responses to risk sharing channels can be analyzed.

Panel VARs take into account both the cross-sectional and time dimension. We will not restrict the dynamic behavior of the economies to be the same across countries, but allow for heterogeneity, given that our time dimension T is large enough and our sample includes several recession periods where the behavior of the different countries has been diverse. Additionally, the sample includes countries from different parts of the world and might be affected by different economic policies.[18] In our VAR-based approach, to obtain estimates of risk sharing for any horizon *l*, we will consider, for each country j, the conditional moments of the vector: [19]

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[17] Cavaliere et al. (2008) conclude that the lack of risk sharing in Europe found in numerous static studies could be due to the rich dynamic structure underlying consumption streams.

[18] However, to avoid the curse of dimensionality (see Canova and Ciccarelli 2013), our starting point will be a panel VAR without dynamic interdependencies across countries.

[19] Given the identity in (2.6), for every country *j* and period *t*, the $\Delta \tilde{c}_t^j$ equation can be written as an exact linear combination of the other equations included in our VAR setup and, therefore, does not add any new information into the system but rather induces exact multicollinearity. Hence we did not include this variable in the VAR.

$$X_t^j = \begin{bmatrix} \Delta gdp_t^j \\ \Delta gdp_t^j - \Delta gni_t^j \\ \Delta gni_t^j - \Delta gdi_t^j \\ \Delta gdi_t^j - \Delta(c+g)_t^j \\ \Delta(c+g)_t^j - \Delta c_t^j \\ \Delta_l c_t^j - \Delta_l \hat{c}_t^j \\ \Delta_l \hat{c}_t^j - \Delta_l \tilde{c}_t^j \end{bmatrix}$$

Under standard assumptions, X_t^j has a VAR representation of the form:

$$\Phi^j(L)X_t^j = \varepsilon_t^j + d^j \tag{2.8}$$

where $\Phi^j(L)$ is a matrix polynomial in the lag operator L, which satisfies the condition that the roots of $\det(\Phi^j(L))$ lie outside the unit circle. Note that we do not allow X_t^j to have unit roots and to be potentially cointegrated. The term ε_t^j is uncorrelated multivariate white noise with a diagonal variance-covariance matrix and the vector d^j collects country-specific intercepts.

For ease of exposition, we will re-write equation (2.8) in terms of the lag of order p:

$$\Phi_0^j X_t^j = d^j + \Phi_1^j X_{t-1}^j + \cdots + \Phi_p^j X_{t-p}^j + \varepsilon_t^j \tag{2.9}$$

for j=1,…,N countries, where Φ_0^j, Φ_1^j,…,Φ_p^j are the matrices of coefficients embedded in the polynomial matrix $\Phi^j(L)$.

Following Asdrubali and Kim (2004) and Becker and Hoffman (2006), we identify the impulse response functions by imposing a recursive zero restriction on contemporaneous structural parameters where contemporaneously exogenous variables are ordered first in X_t (Sims 1980), following the logic of National Accounts.[20] This is equivalent to applying the Choleski decomposition to the variance-covariance matrix of the error term of the reduced form of the VAR.

Asdrubali and Kim (2004) for panel VAR models and Becker and Hoffman (2006) for panel error correction models (ECM) assumed that the parameters for all the countries were the same, and pooled all the data to estimate the model. However, differences in risk sharing patterns have often been conjectured as being linked to uneven economic evolutions of OECD countries. For example, Kalemli-Ozcan et al. (2014) relate the recent collapse in risk sharing of peripheral European Union (EU) countries (namely, Portugal, Italy, Ireland, Greece and Spain) to the fact that their governments did not save during the expansionary phases of the business cycle and were not able to borrow on the international markets during the crisis due to the high levels of outstanding public debt. The great recession and the subsequent sovereign debt crisis in Europe led to an asymmetric behavior of the different member countries of the EU, and therefore the homogeneous-parameter model could be improved upon by allowing for country heterogeneity.

The econometric tool that allows us to cope with cross-sectional heterogeneity (while keeping the dynamic feedback among the variables and considering them as endogenous)

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[20] GNI logically follows GDP, in the sense that you need an output to generate dividends, interests, rents, etc. By the same token, GDI follows GNI because taxes presuppose a taxable income; and so on.

relies on heterogeneous panel VARs.[21] Asdrubali and Kim (2004) compute impulse response functions after a GDP shock hits the system. In this paper we follow their approach, normalizing the impulse response functions by the total/cumulated effect of a GDP shock on GDP after 5 years to 100 and rescaling the effect smoothed through each channel as a ratio to the total effect on GDP. A positive (negative) number is interpreted as smoothing (dis-smoothing). Notice that since we are using impulse response functions to evaluate risk sharing, we can compute it k lags after a shock is produced, $k = 0,1,2,…$ We will make explicit the lag we are using whenever it is needed.

The impulse response functions will be given as the coefficients of the following sum:

$$X_t^j - \mu^j = \sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j$$

where μ^j is the unconditional mean of X_t^j and the matrices D_k^j are those of the moving average representation of the system in terms of the structural shocks. Given the identification restrictions, they are functions of the reduced form parameters. These impulse response functions have a simple and elegant interpretation. Given the identity in (2.6), denoting as ( )$_z$ for $Z = Y, F, T, C, G, P, e$ the 1st, 2nd,…, 7th row of the moving average representation of the VAR, it follows that:

$$\left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_Y = \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_F + \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_T + \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_C + \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_G$$
$$+ \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_P + \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_e + \Delta \tilde{c}_t^j$$

The first implication of this identity is that we can recover analytically the impulse response function for $\Delta \tilde{c}_t^j$, the unsmoothed response of consumption at world prices to the GDP shock. Then, the dynamic multipliers at each lag l=0,1, …., L relative to each GDP shock are linked by the following relation:

$$\frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_Y$$
$$= \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_F + \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_T + \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_C$$
$$+ \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_G + \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_P + \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \left(\sum_{k=0}^{\infty} D_k^j \varepsilon_{t-k}^j \right)_e + \frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \Delta \tilde{c}_t^j$$

where $\varepsilon_{t-l,Y}^j$ denotes the shock associated to GDP of country j at time t-l. In other words, the response of GDP to a GDP shock at each lag can be broken down into a smoothing (or dis-smoothing) component (the first 6 terms in the RHS) and an unsmoothing component (the last term).[22] As explained above, the last term cannot be included in the system because of its linear dependence, and will be recovered analytically, by subtracting the total effect of a GDP shock from the sum of the effects smoothed through each one of the channels. The same argument holds for shocks to each smoothing channel, all enjoying the same property that the relative multipliers sum to the own channel multiplier.[23]

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[21] See Canova and Ciccarelli (2013) for a survey on panel VAR models.

[22] Just solve for $\frac{\partial}{\partial \varepsilon_{t-l,Y}^j} \Delta \tilde{c}_t^j$ in the last equation in order to recover the unsmoothed part at each lag.

[23] This result is the IRF counterpart of equation (2.7).

2.2.3 Estimation and Data

Given that we allow for heterogeneity, the pooled estimator is not consistent (see Pesaran and Smith, 1995, and Rebucci, 2010). Instead of pooling the information and estimating a unique set of parameters, as it is done in the homogeneous panel VAR model, given that T is large enough in our data set, we will estimate the model for each country j. Since we are ultimately interested in estimating an average impulse response function for the entire sample, we follow the suggestion by Canova (2007, chapter 8) and compute the impulse response functions for each country and average them over the cross section. Let ω be the vector that collects the population mean parameters and ω^j the same vector for the parameters of country j=1,…,N. Let h_k be the impulse response function evaluated at lag k=1,…,K, a well-defined continuous function of the parameters of the system. To simplify the notation we drop the index k relative to the lag and make the following assumption regarding the impulse responses across countries j=1,…,N at every lag k:

$$h(\omega^j) = h(\omega) + v_h^j \tag{2.10}$$

where v_h^j, j=1,…,N, are iid (0,σ²) and represent the deviation of country j's effect from the "typical" or average effect. While the overall measure of risk sharing for each country will be given in terms of the total parameters for each country, ω^j, the measure of global risk sharing for a set of countries, which can be labeled as *h*, will be computed as the mean group estimator as follows:

$$\hat{h}_{MG} = \frac{1}{N}\sum_{j=1}^{N} h(\hat{\omega}^j) \tag{2.11}$$

An estimate of the variance-covariance matrix of the mean group estimator for *h* is given by:

$$\hat{\Sigma}_h = \frac{1}{N(N-1)}\sum_{j=1}^{N}(h(\hat{\omega}^j) - \hat{h}_{MG})(h(\hat{\omega}^j) - \hat{h}_{MG})' \tag{2.12}$$

Notice that we use the cross section to estimate the common or average effects by pooling the estimators of the impulse response functions. The cross correlations among variables in the model are picked up through the contemporaneous cross correlations of the reduced form residuals.

Annual data from OECD National Accounts for the period 1960-2016 are used in our empirical application. In this way, we can compare our findings with other results available in the literature for the same set of countries. The OECD countries included in the analysis are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, and United States. The main sources of data are AMECO – the annual macro-economic database of the European Commission's Directorate General for Economic and Financial Affairs (DG ECFIN) – and the OECD Statistics database. We use the AMECO database since it provides harmonized statistics on all the variables required to perform the analysis and for the whole sample period 1960-2016, leaving some missing information only in a very limited number of cases.

The nominal variables Gross Domestic Product (GDP), Net Factor Income (NFI), Gross National Income (GNI), Net International Transfers (NIT), Gross Disposable Income (GDI), Total Consumption (C+G) and Private Consumption (C) have been taken from AMECO and have been transformed in real per-capita terms, dividing nominal values by population and the consumption deflator. We have computed real effective exchange rates series for country j using import and export weights w_t^i for each time *t* and country *i*, as follows:

$$REER_t^j = \sum_{i=1, i\neq j}^{N} \frac{w_t^i \cdot CPI_t^i \cdot (ER_t^j/ER_t^i)}{CPI_t^j}$$

where CPI_t^j is the Consumer Price Index of country j in year t, and ER_t^j is the nominal exchange rate of country j's currency against the US dollars at time t. Private consumption evaluated at world prices has been computed as $C_t^j/REER_t^j$.

Next, the series in our VAR model have been made stationary by computing their log differences. To build the idiosyncratic shocks of each variable we have computed the difference between each variable and its cross-country weighted average. In order to construct the averages, we have followed the weighting procedure described in Beyer et al. (2001), where the aggregation is performed directly on growth rates but using time-varying weights of countries that are given by their relative share in the aggregate measured in a common currency. Just to define the weights we have used country-wide aggregates instead of aggregates in per capita terms. In this way, for instance, larger countries like Germany or the US have a greater share in the "world" GDP than smaller countries with higher per capita GDP.

3 The Empirical Results

We estimate an individual VAR for each country, compute individual impulse response functions and then pool the estimates to obtain the mean group estimator as suggested in Canova (2007) and Canova and Ciccarelli (2013) for large T panels. We will present the results stemming from the effects of shocks to GDP on individual channels and the effects of shocks to individual channels.

Table 1 shows the individual country and mean-group estimates for the contemporaneous responses of the various channels to a GDP growth shock. These estimates can be compared to those usually obtained in the literature through the static panel regression approach. Recall, however, that our analysis adds the amount smoothed through government consumption and relative price/nominal exchange rate adjustments. For ease of comparison we add several columns containing different aggregates for risk sharing. Column 1 shows the names of the countries in alphabetical order. Columns 2 to 4 show the smoothing taking place through the three standard channels considered in Sørensen and Yosha (1998) and Asdrubali and Kim (2004). Column 5 is the sum of columns 2 to 4 and is reported to allow comparisons with traditional estimates available in the literature. Column 6 introduces private consumption smoothing through the government consumption channel. Column 7 shows total private consumption smoothing and is the sum of the traditional channels plus the government consumption channel. Columns 8 and 9 show the effect of the real effective exchange rates decomposed into the relative price effect (column 8) and the nominal effective exchange rate effect (column 9). Since we transform the variables and take logs and first differences, what appears in columns 8 and 9 are adjustments through inflation differentials and nominal exchange rate growth, respectively. Column 10 shows total smoothing achieved, comprising valuation effects, as the sum of all channels. Our first estimation sample runs from 1960 to 2014.[24]

Overall, for all countries we observe that the credit markets channel is responsible for most of the smoothing (34% for the mean group estimate) and is statistically significant. In the remaining traditional channels, on average, we do not detect a strong contribution to smoothing: risk sharing achieved through the factor markets channel is 1% on average, while no smoothing took place through international transfers. These estimates are consistent with most studies on risk sharing covering OECD countries (or a large subset thereof).[25]

The new findings are, first, that government consumption plays on average a dis-smoothing role, amplifying shocks to GDP growth by 4%. Indeed, while a counter-cyclical government consumption might contribute to output stabilization by dampening business cycle fluctuations, such a counter-cyclical policy action can be detrimental to risk sharing. For example, in our sample a negative output shock leads to an increase in government consumption, which further reduces the resources that the private agents can use for consumption, given the reduced output growth.

Second, as for real exchange rates, there are sound theoretical reasons to expect both a smoothing and a dis-smoothing effect of relative prices. Open-economies real exchange rate models, such as Obstfeld's (1985), suggest that positive productivity shocks generate an excess supply which depreciates the real exchange rate; on the contrary, when differences between tradable and non-tradable sectors are considered, as in the Balassa-Samuelson hypothesis, positive productivity shocks, which mainly benefit

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[24] Years 2015 and 2016 have been dropped to guard against recent outliers such as the real Irish GDP growth rate, which was above 25% in 2015. We have also estimated the model with the sample ending in 2016 (see Appendix 1). The results remain essentially unaltered for all the countries but Ireland. The changes in Irish results hardly affect the mean group estimators.

[25] For example, Sørensen and Yosha (1998), Balli, Kalemli-Ozcan and Sørensen (2012) or Leibrecht and Scharler (2012).

tradables, result in real exchange rate appreciations. Our results from mean group estimators show that the ratio of foreign to domestic price level increases – thus reducing private consumption deflated by relative prices – implying a positive role of relative price adjustments by 18%, but the nominal exchange rate appreciates to increase private consumption at PPP, implying a negative effect of nominal exchange rate adjustments by 30%.[26] Overall, the real exchange rate appreciates, thus decreasing real private consumption at PPP (relative to real private consumption at domestic prices) by 12% on average, which suggests a dis-smoothing effect of real exchange rate adjustments. That is, positive shocks to GDP appreciate the real exchange rate, which leads to an increase in real private consumption at world prices (relative to real private consumption at domestic prices) through valuation effects. Our results on real exchange rates are consistent with the Balassa-Samuelson hypothesis and Corsetti, Dedola and Leduc (2008), who report real exchange rate appreciations following US technology shocks.[27] Our results are also consistent with Backus and Smith (1991) who documented the negative correlation between consumption and the real exchange rate, which is against the full risk sharing hypothesis in the presence of non-tradables (the so-called Backus-Smith puzzle).

Third, we note that the degree of risk sharing is strikingly different across countries. This suggests that modeling heterogeneity is crucial. Table 1 also shows heterogeneity across countries in the importance of each channel. The credit channel is the more significant to smooth consumption, as it always cushions, to a greater or a lesser extent, GDP shocks; however, it also exhibits clear heterogeneity in the amount of smoothing achieved. In particular, credit markets smooth over 50% of shocks in Belgium, Finland, and Norway, but less than 15% in Portugal and Spain. For total risk sharing by the three traditional channels, the country-specific magnitude of risk sharing on impact ranges from around 15% to over 80%. The role of relative prices is positive and significant in almost all countries. However, there is a great deal of heterogeneity in the smoothing of the nominal effective exchange rates.[28] This channel displays a huge dis-smoothing effect in Finland, Australia, Sweden and the US, while it has a considerable positive effect in Switzerland. Overall, the real exchange rate appreciates in some countries (such as the US), implying a negative risk sharing role of real exchange rate adjustments; but it depreciates in other countries (such as the Netherlands, Ireland, Norway, and Switzerland), showing a positive risk sharing role. The smoothing role of the factor market channel is significantly positive in Ireland, Italy and the U.S., but significantly negative in Portugal and Canada. Ireland records simultaneously positive GDP growth rates and negative net factor income figures, presumably due to outward income flows originated by foreign investments of multinational companies. The smoothing role of international transfers is always very small although significantly positive in Austria, Germany, Portugal and Spain, but significantly negative in Canada and Norway. As regards government consumption, it does not contribute to significantly smooth private consumption in any country, acting counter-cyclically and thus provoking dis-smoothing in several instances, as indicated by the negative estimates. This is so especially for Austria, Denmark, Finland, France and Sweden, with average dis-smoothing over 10% for the sample period analyzed.

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[26] Although the magnitude is huge in terms of risk sharing, the changes are not too large in terms of the actual unit of changes in each variable. For example, suppose the nominal exchange rate depreciates by 0.5% when GDP increases by 1% under GDP shocks. Then, our risk sharing measure implies that the risk sharing through nominal exchange rate channel is 50%.

[27] Notice that in our results the ratio of foreign to domestic price level increases but the nominal exchange rate appreciates, and this appreciation leads to the real exchange rate appreciation. Presumably, positive productivity shocks generate an excess supply that decreases the domestic price level, but it induces capital inflows, leading to nominal exchange rate appreciation. These offsetting responses of the two real exchange rate components are consistent with the mixed empirical results that characterize the large literature on the Balassa-Samuleson hypothesis (see Peltonen and Sager, 2009).

[28] Notice that some countries share a common currency, the euro, since 1999, while others do not.

1960-2014	Factor mark.	Intern. Transf.	Credit markets	RS on total cons.	Govern. cons.	RS on private cons.	Relative price	Exchange Rate	RS with valuation effect
	(1)	(2)	(3)	(1)+(2)+(3)	(4)	(1)+(2)+(3)+(4)	(5)	(6)	(1)+(2)+(3)+(4)+(5)+(6)
Austria	1	3**	39***	43***	-10**	33***	28	-57	5
Belgium	3	-2	67***	68***	-6	61***	7	-18	51
Denmark	-2	4	22**	25***	-15*	10	34***	-32	12
Finland	-2	-1	68***	65***	-11***	54***	17	-92**	-21
France	-1	-2	32***	29***	-11**	18**	14	-23	10
Germany	2	2*	29***	33***	1	34***	24***	-75*	-17
Greece	1	0	17***	17***	2	19***	15***	-5	29**
Ireland	6*	1	25***	29***	0	30***	0	22*	53***
Italy	2**	0	15***	17***	-8***	9**	-17***	21	13
Netherlands	6	0	33***	39***	0	39***	20***	15	74**
Portugal	-6**	6***	14*	14**	3	17**	32***	-52**	-3
Spain	0	1**	13***	15***	-1	14***	22***	-43*	-7
Sweden	-4	0	46***	43***	-12**	31***	34***	-80**	-15
UK	0	1	18***	19***	-2	17***	13	-18	12
Australia	2	0	46***	47***	1	48***	23***	-113***	-43
Canada	-2*	-1**	47***	44***	-4	40***	23***	-40	22
Japan	-1	1	25***	25***	-6***	19***	22***	16	57
New Zealand	-4	-1	35***	31***	1	31***	22***	-60**	-6
Norway	3	-3***	83***	83***	-6**	77***	23***	16	116***
Switzerland	13	1	29**	44***	-2	42***	11*	91*	143***
United States	2*	1	21***	23***	-3*	20***	18***	-104***	-66*
Mean Group	**1**	**0**	**34*****	**36**	**-4*****	**32**	**18*****	**-30*****	**20**

Table 1 – Estimation results of country-specific impact risk sharing for years 1960-2014. *, ** and *** denote coefficients that are statistically significant at 10%, 5%, and 1%, respectively.

To describe the dynamic behavior of risk sharing channels, Figure 1 shows the Mean Group estimator for the impulse response functions.[29] Its first column of graphs documents the average response to a shock to GDP growth of the various risk sharing channels, and ultimately of consumption growth (at constant world prices). The results are normalized by the total effect of a shock cumulated after 5 years as in Asdrubali and Kim (2004). The first graph in the first column is the response of GDP to a GDP shock, indicating a permanent effect in terms of the GDP level. The dynamic response of GDP resembles those to random walk productivity shocks in Baxter and Crucini (1995) and Baxter (1995), exhibiting a further increase in the second year. The graphs below illustrate the dynamic profile of the different channels. The results document that, on average, most of risk sharing is achieved through the credit markets channel, which on impact is able to smooth around 30% of the shock although it plays a negative role in the second to the fourth years after the shock. The computed short-term response of the credit market channel entails a degree of consumption smoothing that in a standard permanent income framework would be "excessive" (see Asdrubali and Kim 2004). However, this "excess smoothness" would be perfectly compatible with a consumption model based on an isoelastic utility function; in addition, it should be noted that the shock being smoothed here only contains the idiosyncratic GDP component, which could reasonably follow a pattern of intertemporal smoothing different from the overall GDP innovation.

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[29] The dotted lines reported in the plot of the impulse response functions represent 95% confidence intervals computed based on equation (2.12).
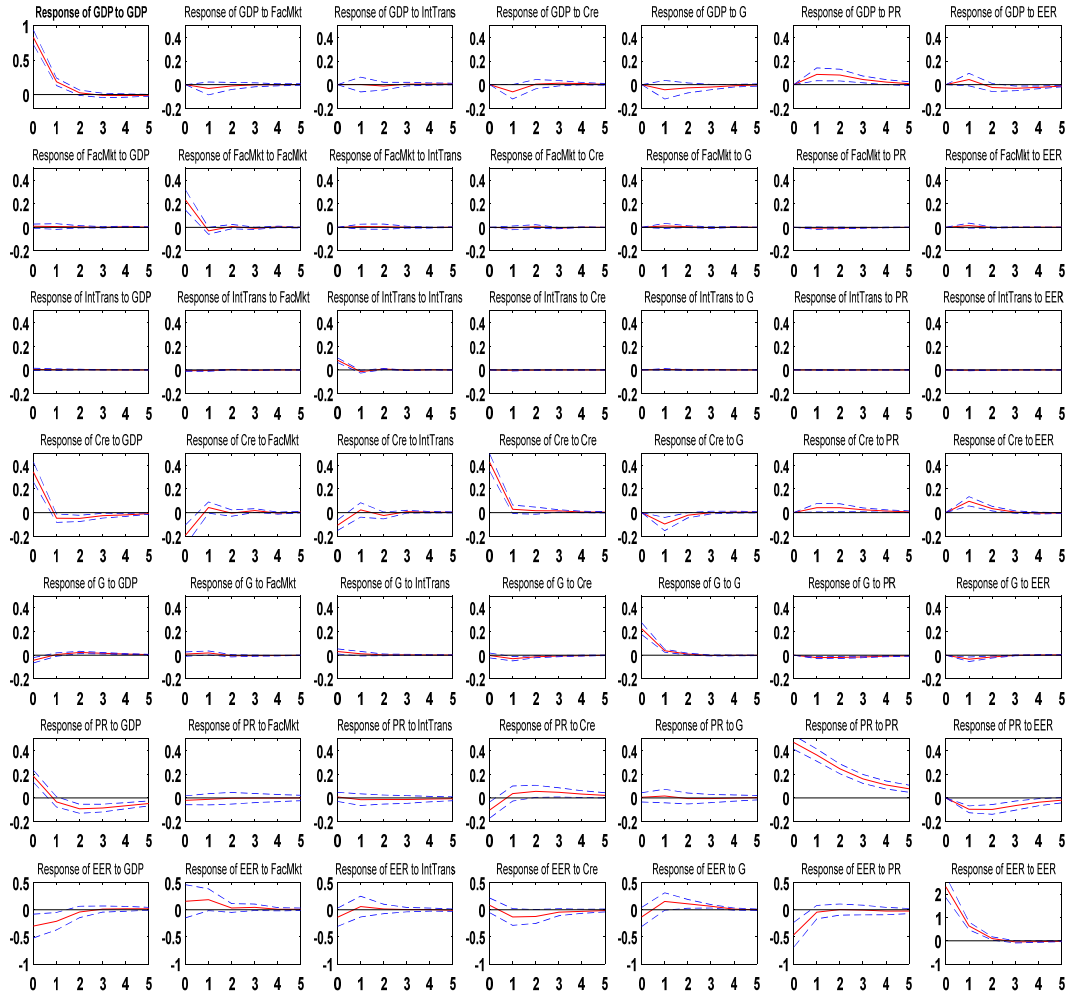
Figure 1. Mean Group impulse response functions from the heterogeneous panel VAR

The factor markets and international transfers channels do not seem to provide any risk sharing at any lag. We detect a significant and positive contribution – around 20% – of the relative price channel in the first period but a persistent negative role in the third to the fifth years. Nominal exchange rate adjustments play a negative role in the first two years.[30] These risk sharing responses through valuation effects are complemented by the repercussions of the changes in real exchange rate components on next period's output (price effect) and thus on next period's consumption smoothing. Such repercussions can be inferred from the 6th and 7th columns, which show an amplifying effect of relative price changes on the next periods' output, and an amplifying effect of nominal exchange rate changes on the second period's output followed by a mitigating effect in successive periods. This evidence suggests that, after a positive output shock, the domestic price level decreases on impact; while such a decrease contributes to contemporaneous risk sharing (the valuation effect), it may also produce

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[30] Nominal exchange rate appreciation may lead to domestic price falls in later periods.

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further output increases in successive periods (the price effect), which in turn would have to be buffered. Conversely, after a positive output shock, the nominal exchange rate appreciates on impact; while such appreciation reduces contemporaneous risk sharing (the valuation effect), it may also produce an output decrease in the next period (price effect), albeit followed by output rises in successive periods. Finally, although government consumption provides dis-smoothing on impact, it plays a positive role in the second and third years after the shock.[31]

Figures 1a to 4a in Appendix 2 show the impulse response functions for selected countries: US, Japan, Germany and Italy. Here we can uncover heterogeneous patterns not evident from the results obtained for the whole set of countries. For instance, the factor markets channel provokes dis-smoothing in Japan, while it has the opposite effect in the US and the two European countries. However, country heterogeneity runs deeper, and involves the dynamics of channels' responses. Additionally, in Japan the credit markets channel does not turn to dis-smoothing the initial shock but keeps smoothing before its effect dies out. . Risk sharing via government consumption provokes a negative contemporaneous smoothing but a positive and persistent lagged smoothing effect in the U.S. and Italy. However, government consumption plays a non-negative role at all horizons with a significant positive effect in the third year in Germany. Dynamic patterns of smoothing through relative price adjustment are also different across countries. In the U.S., Japan, and Germany, we detected contemporaneous positive but lagged negative risk sharing, whereas in Italy we found persistent negative smoothing.

To show a full picture for all the countries and check if heterogeneity is present also in the dynamic behavior of the channels, Figure 2 presents for the 21 countries in our sample the impulse response functions of the total amount of risk sharing, obtained as the sum of the amounts smoothed through the six channels presented in this paper. In the horizontal axis we represent the number of years after a GDP shock hits a country and in the vertical line the total amount of risk sharing achieved each year after the GDP shock. We do not plot confidence bands to avoid cluttering. The values at impact bring out the heterogeneity that we saw in Table 1, ranging from negative to positive smoothing. In this graph, we can see that heterogeneous responses appear not only in the first period but also in later periods. In particular, the heterogeneity in the second period responses is as large as that in the first period.

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[31] To some extent this may be the consequence of intertemporal government budget constraints.
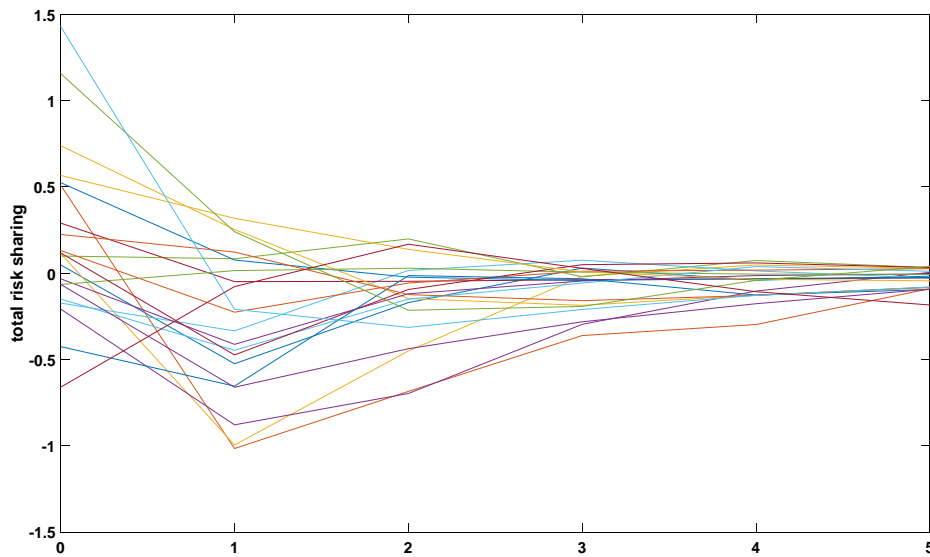
Figure 2. Impulse response functions of total risk sharing including all six channels for the 21 countries in the OECD sample.

Figure 3 decomposes Figure 2 by the impulse response functions for the six channels considered in this paper. We can see that the channels do not behave all alike, with most of the heterogeneity arising through nominal effective exchange rate changes (bottom, right). In addition, the relative price channel also shows a substantial heterogeneity. However, we can see that heterogeneity is also present in the remaining channels. The role of factor markets (top left panel) ranges from smoothing to dis-smoothing depending on the country. The credit markets channel (second row, left panel) always presents a positive behavior on impact but the degree of risk sharing achieved by this channel is quite different across countries. In subsequent years, we observe some dis-smoothing, which in two-thirds of the countries substantially offsets the impact smoothing effect. This result is in line with Asdrubali and Kim (2004), but illustrates that the dis-smoothing role of the credit market channel only involves some countries. International transfers (top right panel) is perhaps the most homogeneous channel and practically does not play a role for any country. Government consumption (second row, right panel) either provokes dis-smoothing on impact or, alternatively, is ineffective. As we have seen also in Table 1, this means that some governments act counter-cyclically, provoking further dis-smoothing. This channel exhibits adjustment dynamics later, however only for part of the countries.

Overall, we can conclude that the degree of heterogeneity is remarkable with respect to the nominal effective exchange rate channels, quite high in the relative price and credit channels, and non-negligible also in factor markets and government consumption channels. Only international transfers do seem to behave similarly for all countries, practically exerting no smoothing.
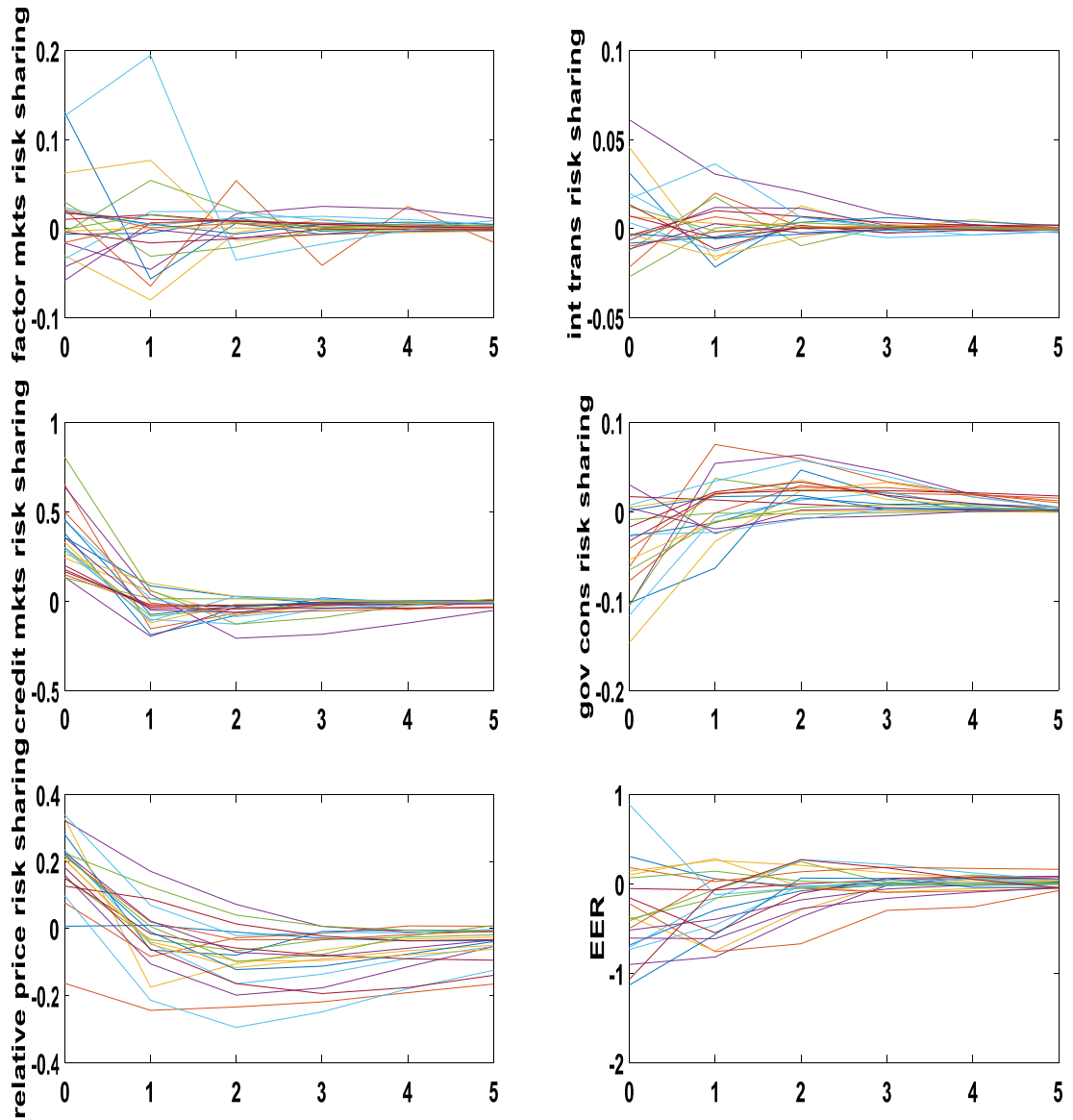
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Figure 3. Impulse response functions for the 6 channels: factor markets, international transfers, credit markets, government consumption, relative prices and nominal exchange rates for the 21 countries in the OECD sample.

Since our sample is quite large and encompasses different periods, risk sharing might have reasonably varied over time. In order to provide a description of the evolutionary pattern of the shock absorption capabilities of risk sharing, we computed rolling-window estimates of the country-specific VARs. The first subperiod covers 1960-1990. We add/remove a year at the end/beginning of the subperiod and repeat the estimation. We proceed in the same way until we reach 2016. For each subperiod, we have computed the Mean Group impulse response functions. Figure 4 shows the evolution of total risk sharing on impact using this method, for the traditional

decomposition (top panel), adding government consumption (medium panel) and including also the effect of the real effective exchange rate (bottom panel). The year that appears on the horizontal axes is the ending year of each subperiod.
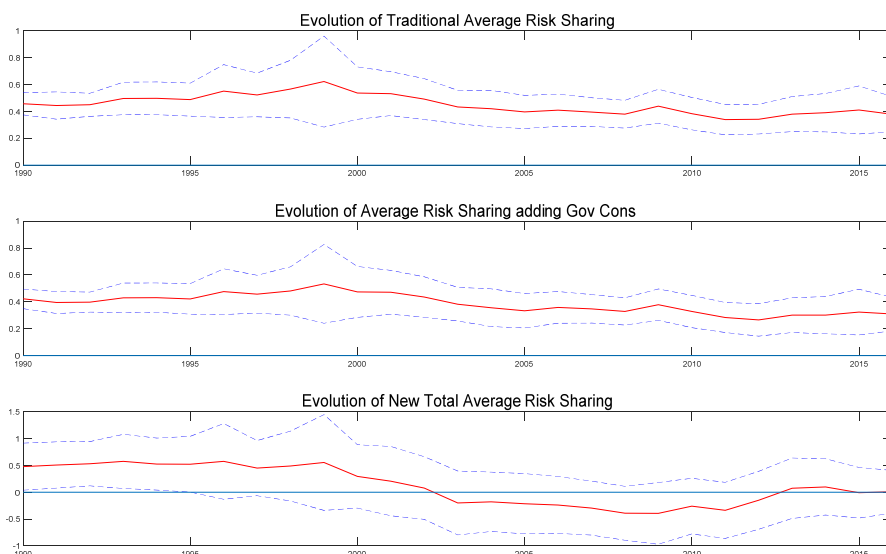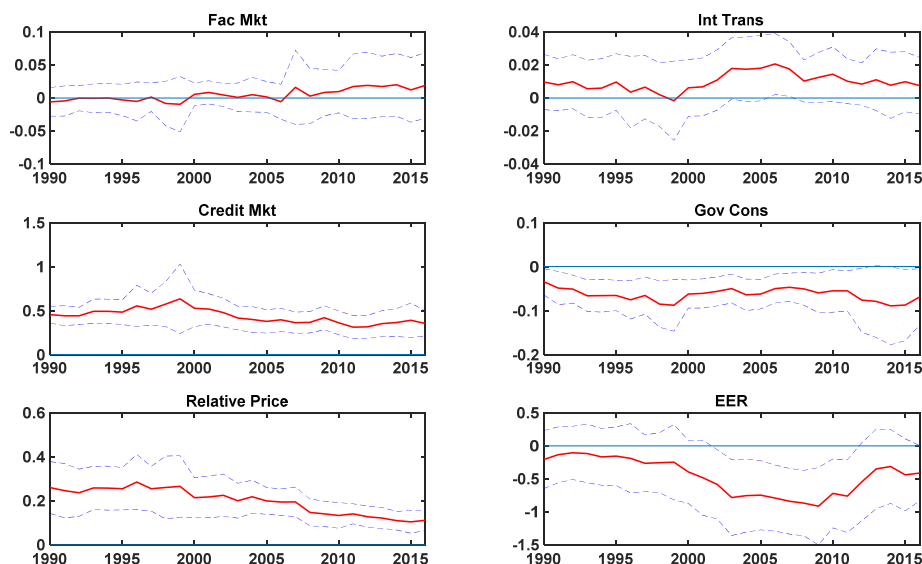

Figure 4. Evolution of risk sharing on impact. Mean Group estimates (continuous red line) with 95% confidence bands (dotted blue line) using a rolling window.

From Figure 4, we observe that risk sharing through the three traditional channels increased slightly through the late 1990s, then decreased henceforth, although it seems to be slightly recovering in the very last years.[32] We observe a similar pattern when we add government consumption smoothing. When taking into account the real effective exchange rate channels, we record a strong decrease in the extent of consumption smoothing at international prices in the last 15 years, so that risk sharing remains positive for the first half of the period, but tends to be zero or negative in the second half. In particular, the extent of risk sharing starts to fall in the late 1990s, and has only slightly recovered to non-negative terrain in the latest years. To shed some light on the mechanisms underlying these patterns, Figure 5 presents the evolution of risk sharing for the different channels. As in Figure 4, the year that appears on the horizontal axes is the ending year of each subperiod. Note that the three most important risk sharing mechanisms are confirmed to be the credit markets, the relative price and the nominal exchange rate channels. All three exhibit the historical pattern described above. However, the annihilation of total risk sharing at the start of the century reflects mostly the nominal exchange rate effect. Indeed, before 2002, risk sharing via nominal exchange rate adjustments is not significant, but decreases sharply afterwards and is significantly negative in later periods, recovering in the most recent years. The role of relative price adjustment has always been positive; we notice a reduction in its effect and in the uncertainty around it, perhaps due to convergence in inflation rates, which

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[32] This is consistent with Sørensen, Wu, Yosha and Zhu (2007) and Leibrecht and Scharler (2012), who detect a rise in these channels for OECD countries from 1993 to 2003 and from 1988 to 2004, respectively, and with Rangvid, Santa-Clara, and Schmeling (2016), who estimate a sample of OECD countries from 1875 to 2012 using rolling windows. However, this evolution is not fully consistent with studies (Kose et al. 2009 or Bai and Zhang 2012) that use different data sources to show a fall in OECD countries' risk sharing during the globalization era.

characterized industrial economies in the last 20 years.[33] Risk sharing through credits markets has always been significantly positive. It started at higher levels but it seems to have stabilized in later times at around 30%. Although not significant, we can observe that risk sharing achieved through the factor markets channel has shown a slightly positive trend since the mid-2000s and especially in the last part of the period. The behavior of risk sharing achieved through international transfers and government consumption has been relatively stable over time, at a level of zero in the former case and dis-smoothing at around 5% in the latter case.

Figure 5. Evolution of risk sharing on impact through the channels. Mean Group estimates (continuous red line) with 95% confident bands (dotted blue lines) using a rolling window.

Our set-up allows analyzing the effect of shocks to each of the 6 risk sharing channels on GDP growth and on the other channels. This perspective will not only shed a light on the feedback mechanisms generated by each shock, but will also uncover patterns of substitutability between channels. The second to sixth columns of graphs in Figure 1 show the cross-country average impulse responses to shocks in each channel of risk sharing. Interestingly, the credit market channel offsets shocks to other risk sharing channels, except for relative price and nominal exchange rate adjustments: shocks to the factor market and international transfer channels are contemporaneously offset by an opposite response of the credit market channel. A shock to the government consumption channel is later offset by the credit market channel. In addition, a positive shock in the relative price leads to a negative response of nominal exchange rate and vice versa, which may imply that they are substitutes. Also interestingly, shocks to the factor market, credit market, and government consumption channels elicit a fall in GDP in the following years while shocks to relative price and nominal exchange rate channels lead to a rise in GDP.[34] These substitutability patterns may help explain the muted – and eventually positive –

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[33] The scarce role of real exchange rate adjustments in the first subperiod – resulting from mutually offsetting relative price smoothing and nominal exchange rate dis-smoothing – is consistent with the results in Sørensen and Yosha (1998) for OECD countries.

[34] Shocks to each channel represent particular types of shocks, which may affect GDP. A static framework would not capture such a feedback relation from channels to GDP, which is one of the advantages of our dynamic framework.

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response of total risk sharing to shocks during the financial crisis, as illustrated in Figures 4 and 5.

Looking at the results by country, we can extract some patterns of behavior. In general, once a channel is hit by a shock, the remaining channels either do not react or react negatively, meaning in this last case, that the channels act to a certain degree as substitutes. This means that, for example, a financial shock hampering the inflow of dividends and interest payments from abroad is partially offset by an enhanced recourse to borrowing in the credit market.

4   Concluding Remarks

We have estimated the degree of risk sharing among industrialized OECD countries using a heterogeneous panel VAR model that can cope with the issue of endogeneity of output and appropriately take into account dynamics and feedback among the channels and the channels and GDP. Since the restriction of homogeneity does not fit well for all the countries in the sample, we have relaxed this assumption. As pointed out by some authors, such as Kalemli-Ozcan et al. (2014), risk sharing was not homogeneous across countries during the recent recession and subsequent sovereign debt crisis, and collapsed in the GIIPS countries (Greece, Ireland, Italy, Portugal and Spain). Then, the heterogeneous panel VAR model is more suited to estimate risk sharing among this set of countries.

On the whole, our results demonstrate that the extent of risk sharing is strikingly different across countries, especially if we take into account valuation effects through the real effective exchange rates. Even neglecting this new channel, the country-specific magnitude of risk sharing on impact ranges from around 15% to over 80%. In addition, dynamics are also quite diverse across countries; for example, risk sharing through lending and borrowing, while quite effective on impact, provokes dis-smoothing for two thirds of the countries on the second year and to more countries on subsequent periods, although the dis-smoothing effect diminishes along the years.

We have also identified new channels for consumption smoothing. Government consumption accounted for 4% of dis-smoothing on average during the sample period. The results also show the negative risk sharing effect of the real exchange rate, driven by the dis-smoothing role played by the movements of the nominal exchange rate, only partially offset by relative price adjustments.

Overall, the average period estimates and impulse responses documented in this study paint a composite picture of the overall behavior of risk sharing channels, both over time and in their functional dynamics. For the OECD sample as a whole, we confirm through 2016 the strong smoothing role played by credit markets and the small degree of risk sharing achieved through factor incomes. The evolution of these risk sharing mechanisms is diverse, but the most important channels – namely credit markets and real exchange rate adjustments – exhibit slightly positive trends for the first half of the period, negative trends afterwards, and a recovery in more recent years.

This study is essentially an exercise in establishing rigorously some stylized facts on risk sharing heterogeneity. Further research should be directed at investigating the causes underlying such different degrees of risk sharing across countries. In this regard, Kalemli-Ozcan, Sørensen and Yosha (2003, 2005) argue that the more specialized a country is, the higher its degree of risk sharing should be, as it will be able to hedge against its domestic developments by investing in other countries. From a policy viewpoint, instead, it would be crucial to identify the most important factors driving a wedge between actual and potential risk sharing capacity, in order to direct future initiatives at the national and supranational level.

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6 Appendix 1: Estimation over the time span 1960-2016

1960-2016	Factor mark.	Int. Transf.	Credit markets	RS on total cons.	Govern. cons.	RS on private cons.	Relative price	Exchange Rate	RS with valuation effects
	(1)	(2)	(3)	(1)+(2)+(3)	(4)	(1)+(2) +(3)+(4)	(5)	(6)	(1)+(2)+(3) +(4)+(5)+(6)
Belgium	2	-2	65***	65***	-6	59	8***	-22	45
Denmark	-3	5*	24**	26**	-15*	11	33	-36	7
Finland	-2	-1	64***	62***	-11***	51	16***	-90**	-23
France	0	-1	30***	29***	-10**	18**	15*	-41	-8
Germany	2	2*	29***	33***	1	34	23***	-71*	-14
Greece	1	0	17***	17***	2	19	15***	-5	29**
Ireland	13***	-1	36***	48***	-3*	45	1***	31***	77***
Italy	2	0	15***	17***	-8***	9	-16***	18	11
Netherlands	6	0	33***	39***	1	39	21***	10	70*
Portugal	-6**	6***	13*	14**	3	17**	32**	-52**	-3
Spain	0	1*	13***	14***	-1	14	22***	-39*	-3
Sweden	-3	0	45***	42***	-12***	30	34***	-73*	-9
UK	0	1	18***	19***	-2	17	13***	-16	14
Australia	2	0	46***	47***	0	48	22***	-113***	-43
Canada	-2	-1**	50***	48***	-4	43	21***	-50*	15
Japan	0	1*	26***	27***	-5***	22	21***	14	56
New Zealand	-4	-1	36***	30***	0	31	23***	-60**	-7
Norway	3	-3***	81***	81***	-7**	75	22***	7	103***
Switzerland	13	2	30**	44***	-3	42	10***	89*	140***
United States	2*	1	20***	23***	-3*	19	18***	-107***	-69*
Mean Group	1	1	35***	36***	-4***	32	18***	-32***	18

Table 1a – Estimation results of country-specific impact risk sharing for years 1960-2016. *, ** and *** denote coefficients that are statistically significant at 10%, 5%, and 1%, respectively.

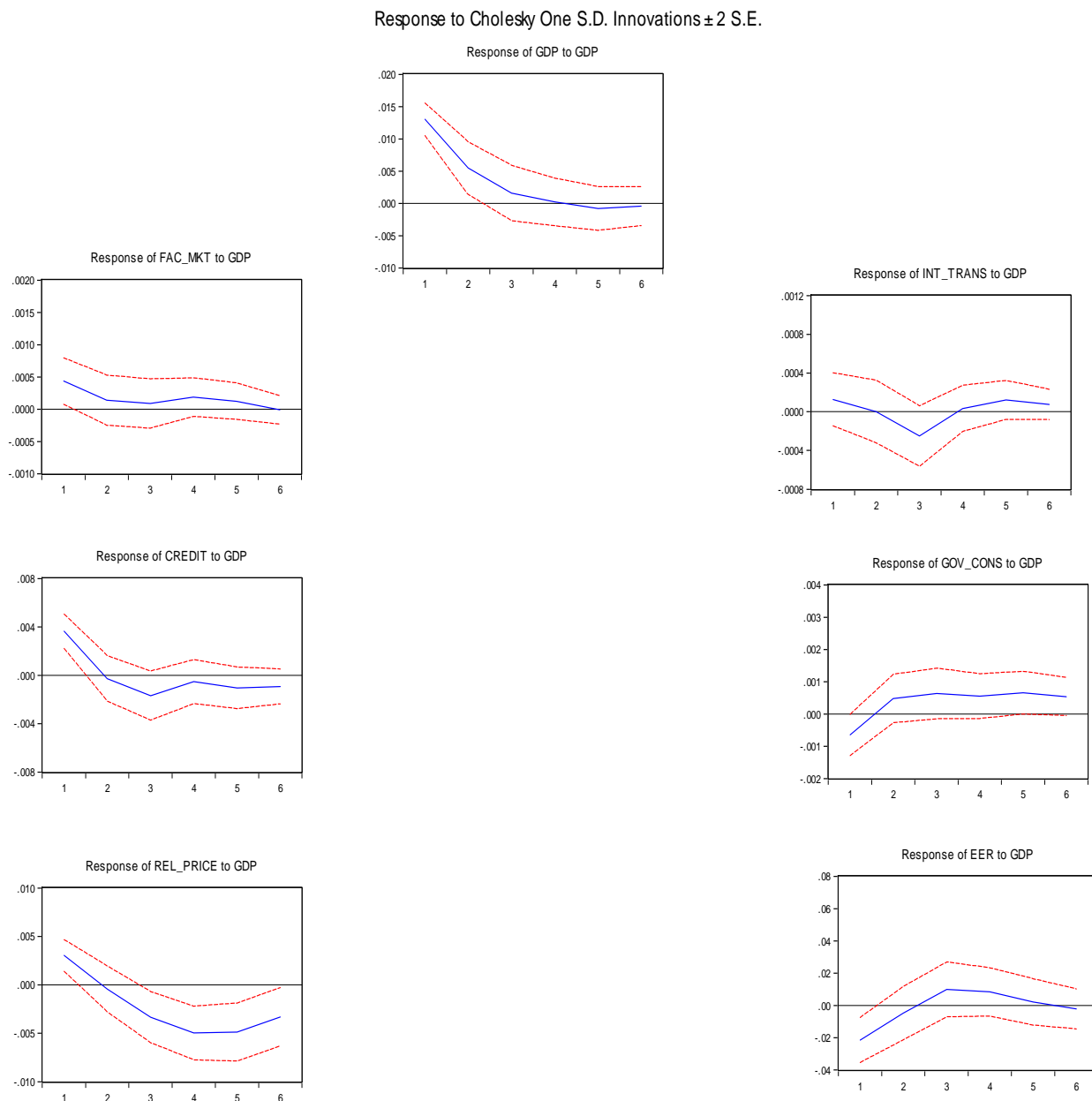# 7 Appendix 2: Impulse response functions for selected countries

Response to Cholesky One S.D. Innovations ± 2 S.E.

Figure 1a – IRFs for the United States, resulting from a VAR over years 1960-2016

Response to Cholesky One S.D. Innovations ± 2 S.E.

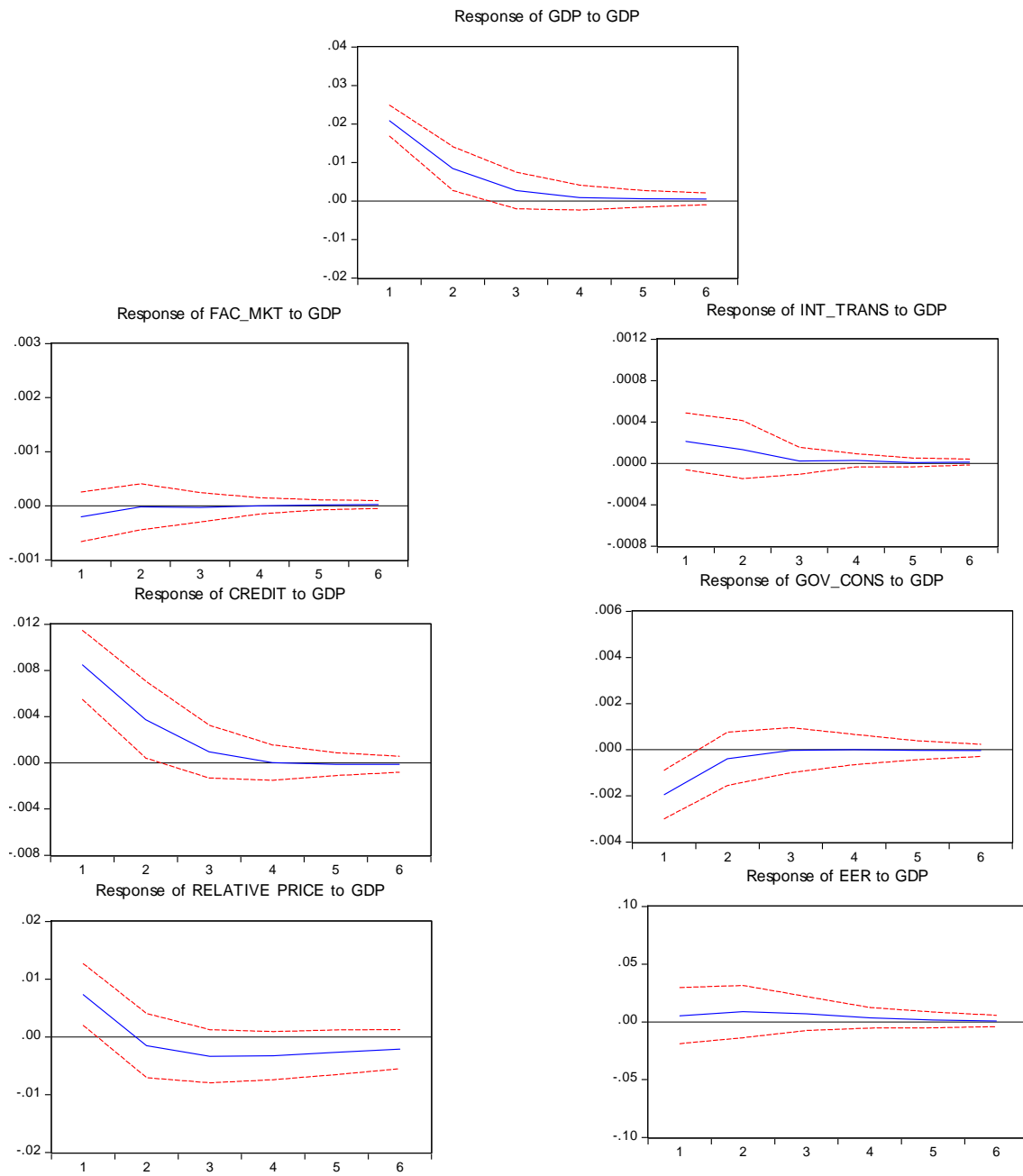Figure 2a – IRFs for Japan, resulting from a VAR over years 1960-2016

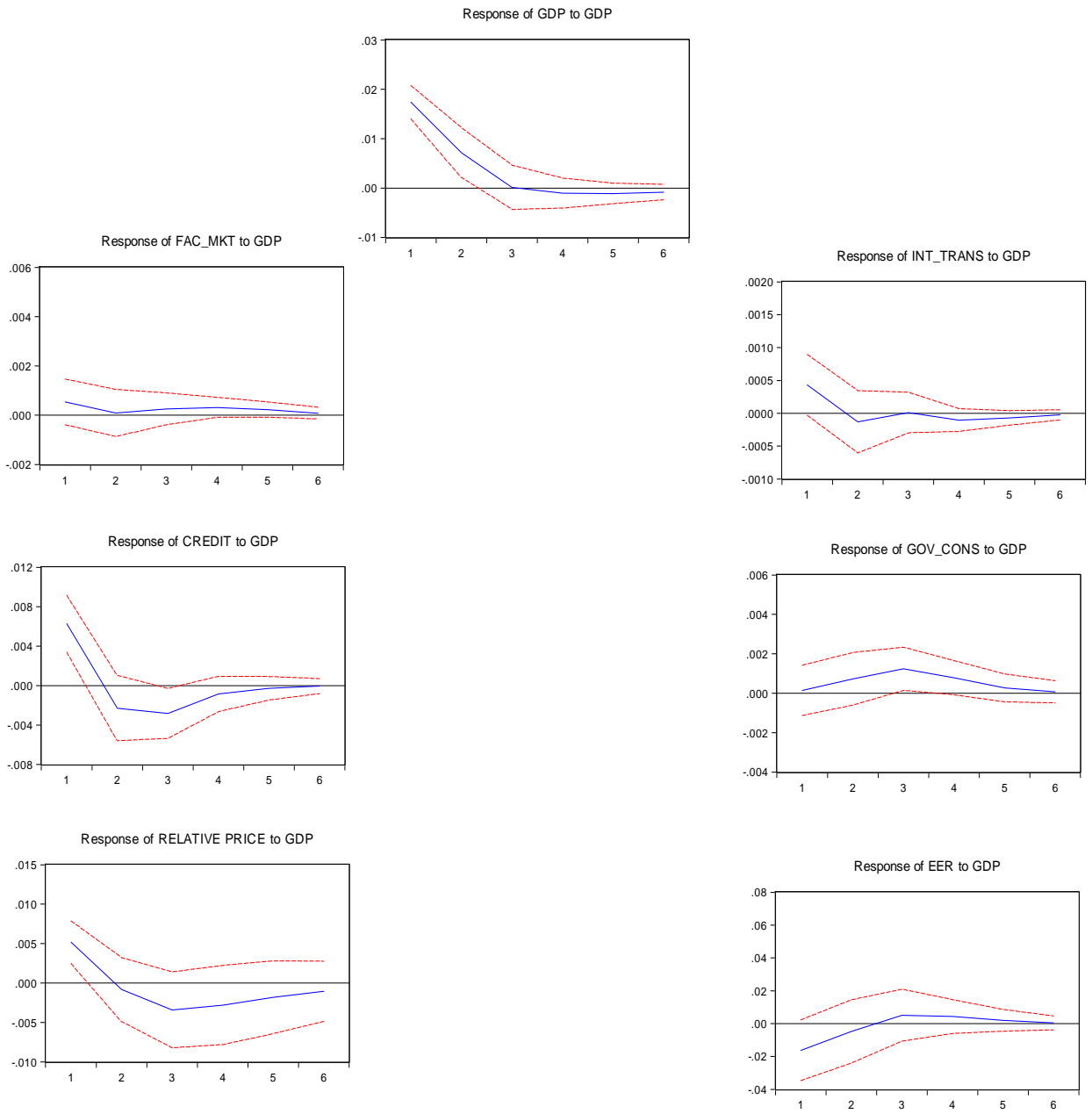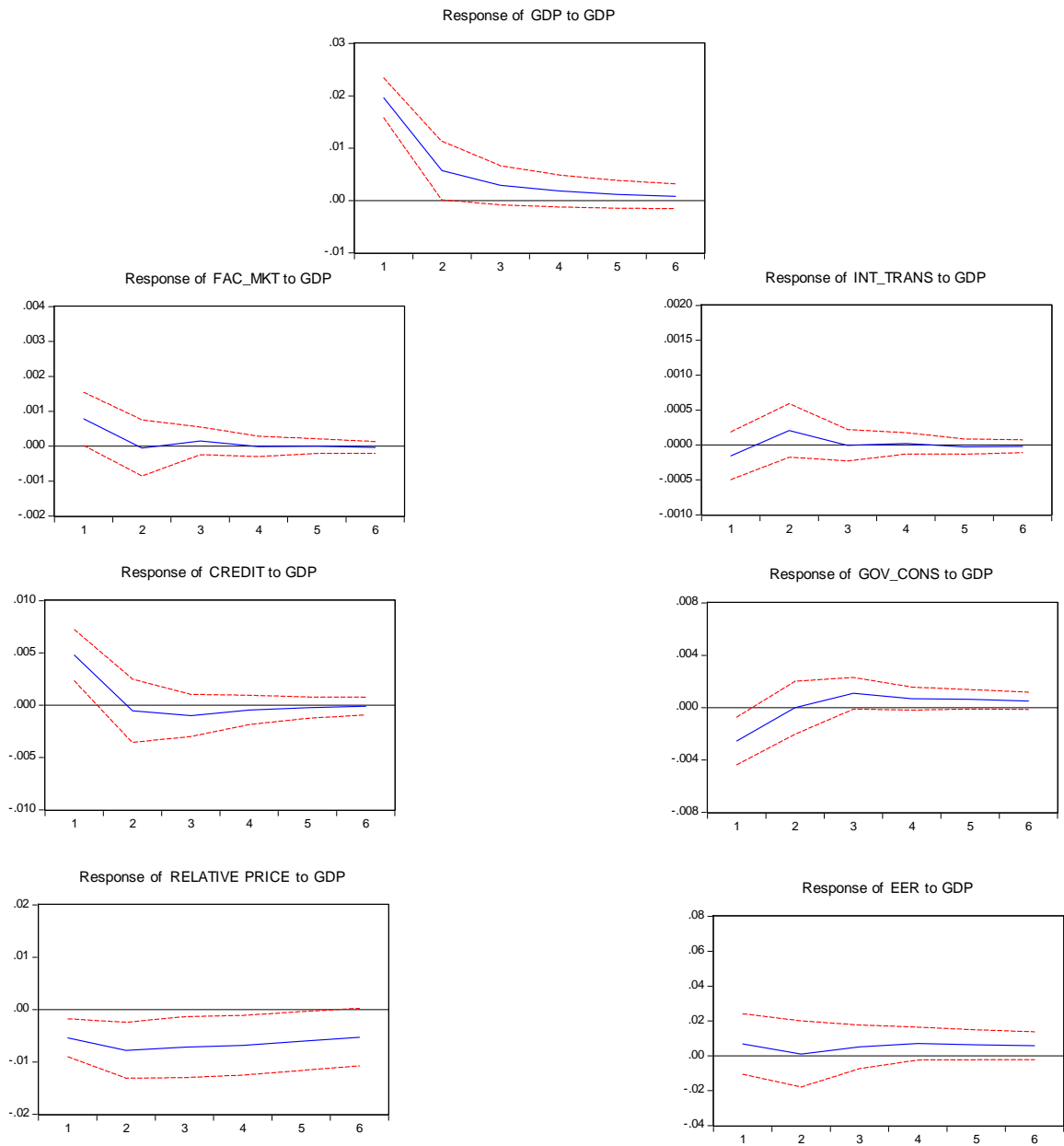Response to Cholesky One S.D. Innovations ± 2 S.E.

Response of GDP to GDP

Response of FAC_MKT to GDP

Response of INT_TRANS to GDP

Response of CREDIT to GDP

Response of GOV_CONS to GDP

Response of RELATIVE PRICE to GDP

Response of EER to GDP

Figure 3a – IRFs for Germany, resulting from a VAR over years 1960-2016

Response to Cholesky One S.D. Innovations ± 2 S.E.

Figure 4a – IRFs for Italy, resulting from a VAR over years 1960-2016

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