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Risk sharing channels in OECD countries: A heterogeneous panel VAR approach

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ABSTRACT

We aim to improve upon the existing empirical literature on international risk sharing channels under three dimensions. First, we generalize dynamic multi-equation approaches, by adopting a Heterogeneous Panel VAR model where the coefficients are allowed to vary across countries. Second, we introduce two new risk sharing channels – government consumption and the real exchange rate – to investigate the role of fiscal policy and international price adjustments. 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 21 OECD countries over 1960–2018, confirms 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-cyclicality. The real exchange rate is driven by the dis-smoothing role played by the nominal exchange rate, only partially offset by relative price adjustments. The evolution of these mechanisms is diverse, but we document the role played by the deterioration of credit market smoothing for the long-run decline in risk sharing started at the beginning of the century. However, the annihilation of total risk sharing at the start of the century reflects mostly the nominal exchange rate effect. Our results are strikingly different across countries, especially if we take into account the (dis-) smoothing effects occurring through the real exchange rate. Even considering only traditional risk sharing channels, the country-specific magnitude of risk sharing on impact ranges from around 10% to over 50%. In addition, dynamics are also quite diverse across countries.

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1. Introduction

The growing importance of risk sharing mechanisms in theoretical and policy models has not been paralleled by an equally developed stream of empirical analyses and testing of such mechanisms. As regards theoretical models, findings

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on the incompleteness of international risk sharing have steered dynamic stochastic macro-models towards the adoption of incomplete market set-ups, or the introduction of capital market frictions, or non-tradables. However, little has been explored empirically in terms of dynamics of the shock absorption mechanisms, arguably of crucial importance in the understanding of business cycles. Remarkably little do we know also on the heterogeneity of responses to idiosyncratic shocks, especially in their impact on consumption smoothing, although heterogeneous-agent set-ups have now become a standard tool of macro-models. Furthermore, while the quantity anomaly puzzle² and the international risk sharing puzzle³ have found explanations – albeit not definitive – with the inclusion of taste shocks or incomplete markets in theoretical models, on the contrary the Backus-Smith puzzle on real exchange rates⁴ continues to baffle researchers. As far as shock-absorption policy is concerned, the identification of multiple decentralization mechanisms of the risk sharing allocation has certainly provided useful guidance and impulse to the use of automatic stabilizers in Europe or to undertakings like financial integration in Eastern Asia. However, not all the channels of risk sharing suggested by theory have been explored empirically (the risk sharing role of the real exchange rate movements being an example⁵).

In this paper, we try to address these deficiencies by developing a theory-based, heterogeneous dynamic framework to empirically characterise risk sharing channels.

Our model builds on the vast literature on regression-based risk sharing estimation, which developed in three main stages. Lewis (1996) and Crucini (1999) implemented a regression-based test on the acceptance or rejection of the null hypothesis of full risk-sharing, while the successive literature introduced a metric for the measurement of the degree of international risk sharing achieved. Asdrubali et al. (1996) developed a variance decomposition scheme which breaks down the overall level of smoothing into different channels (international factor incomes, international transfers, and credit markets). Asdrubali et al. (1996) and Sørensen and Yosha (1998), followed by many others, adopted a panel SUR set-up to estimate risk sharing, considering output as an exogenous variable. Asdrubali and Kim (2004) introduced a multivariate panel VAR model, which allows endogenizing output and taking into account the dynamics and feedbacks among the variables.

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, thus providing a country-level breakdown of international risk sharing mechanisms. As far as we know, this is the first time that heterogeneous panel VAR models are used to estimate risk sharing.⁶ To capture the evolutionary patterns of risk sharing we also estimate our 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 specification 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 smoothing channel – 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 and real exchange rate movements empirically dominate changes in other real variables. Furthermore, we decompose this latter channel into the contributions of relative price and nominal exchange rate adjustments. Therefore, 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 long run.

By applying our methodology to a large macroeconomic dataset of 21 OECD countries over the 1960–2018 period, 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 country heterogeneity in the parameters, as well as for the risk sharing role of government consumption and real exchange rate adjustments, further decomposed into the relative price and nominal exchange rate adjustments. Third, we use our methodology to improve upon and update the measurement of risk sharing for OECD countries.

As Kose et al. (2009) point out, the recent literature presents conflicting views on the role of international risk sharing 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, other analyses found little evidence of increased risk sharing (Kose et al., 2003; Kose et al., 2009; Moser et al., 2005; 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 and measuring individual countries’ shock-absorption capabilities, helps to shed light on the different dynamics of risk sharing in the last 60 years, also at country level. Such dynamics might explain the conflicting results emerging from the risk sharing literature.

² The quantity anomaly puzzle is the finding that cross-country consumption correlations are not higher than cross-country output correlations, as predicted by theory.

³ The international risk sharing puzzle is the finding that, by many measures, international risk sharing is not complete, contrary to theory.

⁴ The Backus-Smith puzzle is the finding that bilateral real exchange rates are not positively correlated with real consumption ratios, contrary to theory.

⁵ Exceptions include Cole and Obstfeld (1991), Corsetti et al. (2008a), Corsetti et al. (2008b) and Berka et al. (2012). These studies, however, do not incorporate the real exchange rate in a structured channels framework.

⁶ There have been studies – such as Méliitz (1999) or Sørensen et al. (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. More recently, Pierucci and Ventura (2010) and Fuleky et al. (2015), provide a single-equation error-correction model which allows for heterogeneity but cannot identify the risk sharing channels and their dynamics.

The rest of the paper is structured as follows. In Section 2, we illustrate our channels methodology and empirical results for the multi-good case, where PPP does not necessarily hold and a role for real exchange rate adjustments is possible. Then, in Section 3 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. 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 context, a large class of multi-good economic models featuring unfettered international trade in goods or assets yield the Pareto-optimal (per capita) consumption allocation described by the so-called "fundamental risk sharing condition", linking the (weighted) discounted marginal utility of country j with that of the aggregate. This condition satisfies for all s^t and j :⁷

$$(\rho^j)^t \frac{U_c(C^j(s^t), \delta^j(s^t))}{\mu^j(s^t)} = \Lambda^{j*} (\rho^*)^t \frac{U_c(C^*(s^t), \delta^*(s^t))}{\mu^*(s^t)} \tag{1}$$

where ρ^j is country j 's factor of time preference, C^j is country j 's (real) consumption basket of domestic- and foreign-produced goods, δ^j is a shift parameter (capturing the effect of factors different from consumption affecting utility, such as tastes, leisure, durables, home production (see [Canova and Ravn, 1996](#)), μ^j is the shadow price of consumption in country j , asterisks denote the corresponding variables at the (average) world level and Λ^{j*} is a time-invariant term.⁸

Computing the ratio of (1) at two successive dates for country j and the aggregate (per capita) eliminates the time-invariant term, yielding, for all j and t :

$$\rho^j \frac{U_c(C_t^j, \delta_t^j) / \mu_t^j}{U_c(C_{t-1}^j, \delta_{t-1}^j) / \mu_{t-1}^j} = \rho^* \frac{U_c(C_t^*, \delta_t^*) / \mu_t^*}{U_c(C_{t-1}^*, \delta_{t-1}^*) / \mu_{t-1}^*} \tag{2}$$

where to economize on notation we adopted the convention $x(s^t) \equiv x_t$. This condition states that at the optimum, the discounted growth of marginal utility – when evaluated in the same units – is the same in every country (and on average), and given aggregate variables, is independent of individual countries' endowments. The consequences for country consumption growth (per capita) can be illustrated specifying a constant relative risk aversion (CRRA) utility function.

In this case, using the price ratio – expressed in comparable terms through the nominal exchange rate – as a measure of the shadow price ratio, a country's consumption growth (in deviations) will be:⁹

$$\log \left(\frac{\frac{C_t^j}{R_t^{1/\gamma}}}{\frac{C_{t-1}^j}{R_{t-1}^{1/\gamma}}} \right) - \log \frac{C_t^*}{C_{t-1}^*} = \frac{1}{\gamma} \left[\left(\log \frac{b_t^j}{b_{t-1}^j} - \log \frac{b_t^*}{b_{t-1}^*} \right) + (\log \rho^j - \log \rho^*) \right] \tag{3}$$

where γ is the risk aversion coefficient and b_t^j is a multiplicative shock.¹⁰

The planner's optimal risk sharing solution thus prescribes that country consumption growth relative to the world, evaluated at "risk-adjusted" (in the sense that the real exchange rate is powered to $1/\gamma$) world prices through the real (effective) exchange rate $R_t^j = \frac{P_t^j e_t^j}{P_t^*}$ – net of relative preference shifts and other consumption confounders – must be independent of idiosyncratic country variables, notably endowment.¹¹ The consequence is consumption smoothing across countries evaluated at (risk-adjusted) world prices, given the RHS terms in (3). In particular, following an output growth shock, the ensuing real exchange rate change should elicit a corresponding change in consumption growth, thus smoothing (risk-adjusted) PPP consumption growth. Note the change in perspective brought about by a multi-good context relative to a one-good economy. In the former, cross-country smoothing should take place not in terms of consumption, but rather in terms of (risk-adjusted) PPP consumption. In the example above, a real exchange rate depreciation induced by a positive output growth shock must elicit a rise in relative consumption growth, which therefore – unlike relative (risk-adjusted) PPP consumption growth – will *not* be smoothed.¹²

⁷ See [Kollmann \(1995\)](#) or [Cavaliere, Fanelli and Gardini \(2008\)](#).

⁸ This condition allows countries to be initially asymmetric and have different time t endowments.

⁹ See derivation in Appendix.

¹⁰ Note that since the shock is both country-specific and state-specific, imposing the multiplicative form does not cause any loss of generality.

¹¹ Generalizations have been developed to a production economy ([Cole and Obstfeld, 1991](#); [Backus et al., 1992](#); [Stockman and Tesar, 1995](#)).

¹² Note that the (risk-adjusted) PPP consumption smoothing result is independent of the nature of the shock governing output. For example, should a positive output growth shock cause the real exchange rate to depreciate, consumption growth will rise due to the price effect, thus smoothing (risk-adjusted) PPP consumption growth on the LHS of (3). Alternatively, should a positive output growth shock cause the real exchange rate to appreciate, consumption growth will fall due to the price effect, again smoothing (risk-adjusted) PPP consumption growth.

In this model, therefore, the real exchange rate is not only the unit of account that allows the proper valuation of the national consumption baskets, but it plays the fundamental role of a (further) mechanism to attain international risk sharing.

The diametrically opposite case emerges when the planner cannot shift the consumption goods between countries; in this case, idiosyncratic risk cannot be shared and the trivial solution is for each country j to simply consume its endowment basket Y^j , so that:¹³

$$\log \left(\frac{C_t^j}{C_{t-1}^j} \right) = \log \left(\frac{Y_t^j}{Y_{t-1}^j} \right) \quad (4)$$

2.2. Risk sharing channels

The optimal solution can be decentralized and implemented 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; Engel and Matsumoto, 2009), allows economies to implement the full risk sharing solution through portfolio diversification.¹⁴ In the classical Lucas (1982) model, nations pool output endowments in a mutual fund and each nation is allocated consumption in proportion to total world output.

It has long been recognized, at least since Wilson (1968) and Kenen et al. (1969), that the existence of appropriate supra-national (federal) tax/transfer mechanisms allows insuring, at least partially, those countries whose income has been hit by a negative shock, drawing from country incomes hit by a positive shock. The budgets of international organizations like the IMF, the World Bank or the EU collect from Member States contributions which are at least in part a positive function of their GNI growth, and transfer to their members subsidies which are, at least in part, a negative function of their GNI growth.¹⁵

Risk sharing can also be provided through self-insurance, that is by asset accumulation (saving) and depletion (dissaving) through (domestic or international) lending and borrowing. Following a positive country output shock, national and international financial arrangements allow the country to save (and invest) more, thereby smoothing consumption not only over time but also cross-sectionally. In fact, it can be shown that in a bonds-only economy, where lending and borrowing are the only means to smooth consumption, under certain assumptions the full risk sharing allocation can be attained approximately, or provided that the endowment shocks are all transitory (Baxter and Crucini, 1995; Levine and Zame, 2002).

Furthermore, we consider the risk sharing role of domestic government consumption, which can operate as a buffer, 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.¹⁶ This view of government consumption as a (private) consumption smoothing channel should be distinguished from modeling government consumption as a public good, included in the utility function as a component of δ_t^j . In case public goods are not separable from private consumption in the utility function, government consumption may have a different effect on risk sharing: it may drive a wedge between marginal utilities of consumption across countries, thus altering the optimal risk sharing allocation. For example, after a negative output shock an increase in the provision of public goods may increase a country's marginal utility of private consumption, thus jeopardizing its cross-country equalization. We will control for this and other potential non-separabilities in the utility function in our empirical model, following Cochrane (1991), Canova and Ravn (1996) and many others.¹⁷

In a multi-good framework the optimal risk sharing allocation can be also attained through movements in the real exchange rate, eliciting international wealth transfers. 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.¹⁸ In a more general setting, the literature on the international transmission mechanism has identified parameter configurations (e.g., high elasticity of substitution between domestic and foreign goods and/or temporary nature of the shock) whereby a productivity-driven output shock would be followed by the depreciation of the real exchange rate and the ensuing boost to the domestic consumption basket, and parameter configurations (e.g., low elasticity of substitution between domestic

¹³ Alternative specifications (e.g. Obstfeld, 1993) replace the RHS of (4) either with the growth of current net output (i.e., output minus private investment and government consumption), or with the growth of net output's present value. We prefer not to assume exogeneity of I and G, or impose intertemporal smoothing; instead, we allow I, G and intertemporal smoothing to act as endogenous risk sharing mechanisms. As for the production role of I, we already pointed out in footnote 11 that it can be easily incorporated in our framework, without effect on the implications.

¹⁴ A similar mechanism is at work not only through cross-border capital income flows, but also via transboundary labor income flows (see Juessen (2008) and Nikolov (2016)).

¹⁵ Empirical analyses of risk sharing through international taxes and transfers include Arreaza et al. (1999) and Feyrer and Sacerdote (2013). The risk sharing role of the EU budget has been analyzed by Asdrubali and Kim (2008), and that of centralised public European institutions – i.e. the ESFS, the ESFM and the ESM – by Milano (2017) and Cimadomo et al. (2020).

¹⁶ This mechanism has been documented by Obstfeld (1994) and Asdrubali and Kim (2009).

¹⁷ In case it is assumed that public consumption is a choice variable in the utility function, standard models imply that it will also need to be smoothed (see Cochrane, 1991 or Canova and Ravn, 1996).

¹⁸ See for example Corsetti and Pesenti (2001), Heathcote and Perri (2002), Berka et al. (2012) or Caselli et al. (2020).

and foreign goods and/or permanent nature of the shock, or a shock limited to tradables) whereby a productivity-driven output shock would generate the opposite effect.¹⁹ Note that, in our empirical analysis, we decompose the real exchange rate adjustments into relative price and nominal exchange rate adjustments, in order to infer the separate roles of these two factors. We examine for each a purchasing power effect and a price effect on PPP consumption smoothing. The purchasing power effect of the real exchange rate stems from the change induced in PPP consumption growth directly via the change in the real exchange rate. The price effect of the real exchange rate stems from the change induced in PPP consumption growth via the change in consumption.²⁰

The main idea of the "channels" literature is that there is mileage to be gained in allowing these multiple implementation mechanisms to operate sequentially, and in exploring their individual and joint contributions to risk sharing. To this purpose, we maintain a very general setup by not assuming any specific market or institutional structure for the 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). In fact, although we focus on output shocks, we also analyze the risk sharing dynamics arising from 6 other sources of shocks. In this way, 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.

2.3. Empirical model of risk sharing channels

2.3.1. Static specification

For every country j (and for the aggregate), we use the following (per capita) variables: GDP (Gross Domestic Product); GNI (Gross National Income) = $GDP + NFI$, where NFI stands for net factor income²¹; GDI (Gross Disposable Income) = $GNI + NIT$, where NIT stands for net international transfers²²; $C + G$ (Total Consumption, TC) = $GDI - S$, where S stands for national savings²³; C (Private Consumption) = $TC - G$; R_t^j (the real (effective) exchange rate) = $\frac{P_t^j c_t^j}{P_t^i}$.

Following Asdrubali et al. (1996), take the following identity:

$$GDP_t^j = R_t^{j1/\gamma} \times \frac{GDP_t^j}{GNP_t^j} \times \frac{GNP_t^j}{GDI_t^j} \times \frac{GDI_t^j}{(C+G)_t^j} \times \frac{(C+G)_t^j}{C_t^j} \times \frac{C_t^j}{R_t^{j1/\gamma}} \tag{5}$$

or

$$GDP_t^j = \left(\frac{P_t^j}{P_t^i}\right)^{1/\gamma} \times \mathcal{E}_t^{j1/\gamma} \times \frac{GDP_t^j}{GNP_t^j} \times \frac{GNP_t^j}{GDI_t^j} \times \frac{GDI_t^j}{(C+G)_t^j} \times \frac{(C+G)_t^j}{C_t^j} \times \tilde{C}_t^j$$

where P_t is the price of the consumption basket, \mathcal{E}_t the nominal exchange rate and $\tilde{C}_t = \frac{C_t}{R_t^{1/\gamma}}$ the consumption basket evaluated at (risk-adjusted) world prices. After taking logs, applying the $\Delta_k = 1 - L^k$ operator and taking deviations from cross-sectional aggregates, multiplying both sides by $\Delta_k gdp_t^j$ and taking expectations and dividing both sides through by $\text{var}(\Delta_k gdp_t^j)$, we obtain a constrained sum of simple regression coefficients:

$$\begin{aligned} 1 &= \frac{\text{cov}(\Delta_k gdp_t^j, (\Delta_k P_t^j - \Delta_k P_t^i)/\gamma)}{\text{var}(\Delta_k gdp_t^j)} + \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k \mathcal{E}_t^{j1/\gamma})}{\text{var}(\Delta_k gdp_t^j)} \\ &+ \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k gdp_t^j - \Delta_k gni_t^j)}{\text{var}(\Delta_k gdp_t^j)} + \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k gni_t^j - \Delta_k gdi_t^j)}{\text{var}(\Delta_k gdp_t^j)} \\ &+ \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k gdi_t^j - \Delta_k (c+g)_t^j)}{\text{var}(\Delta_k gdp_t^j)} + \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k (c+g)_t^j - \Delta_k c_t^j)}{\text{var}(\Delta_k gdp_t^j)} \\ &+ \frac{\text{cov}(\Delta_k gdp_t^j, \Delta_k \tilde{c}_t^j)}{\text{var}(\Delta_k gdp_t^j)} \end{aligned}$$

or,

$$1 - \beta^j(k) = \beta_p^j(k) + \beta_e^j(k) + \beta_F^j(k) + \beta_T^j(k) + \beta_C^j(k) + \beta_G^j(k). \tag{6}$$

¹⁹ See Corsetti et al. (2008a) and Corsetti et al. (2008b).

²⁰ Note that the effects discussed here – involving an impact of real exchange rate adjustments on consumption – differ from the traditional real exchange adjustments considered in the international economic literature since the 1930s – focusing on the impact of real exchange rate adjustments on the balance of payments and output.

²¹ 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.

²² 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.

²³ National savings include not only private savings (by households and firms), but also public savings by the government.

where lowercase variables are in logs and expressed in deviations from the corresponding (log-difference of the) real world aggregate. For each country j and for each lag k , the overall risk sharing measure $1 - \beta$ is decomposed into 6 regression coefficients. The first coefficient on the RHS – β_p – represents the slope in a regression of $(\Delta_k p_t^* - \Delta_k p_t^j)/\gamma$ on $\Delta_k gdp_t^j$, thus capturing the purchasing power smoothing achieved through relative price adjustments, whereas β_e gauges the degree of purchasing power smoothing achieved through adjustments of the nominal effective exchange rate. These two effects result directly in a different valuation of PPP consumption growth – via changes in the denominators of the PPP consumption terms in (3) – and hence contribute to its (dis-) smoothing. The third 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. By the same token, β_T measures the percentage of the shock to output growth that is further smoothed by international current transfers; β_C the additional smoothing provided by domestic and international credit markets through asset increases/decreases; and β_G the further amount of smoothing provided by government consumption. 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, is to be modelled as a smoothing target, not a smoothing channel; hence, Eqs. (5) and (6) would stop short of the last term. 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 estimation model to the theory (couched in terms of private consumption), while maintaining the comparison with previous work.

2.3.2. A heterogeneous panel VAR

Heterogeneous-parameter equation systems are a natural approach to the estimation of the coefficients in (6). However, static estimators such as in Méhitz (1999) or Sørensen et al. (2007), and single-equation error-correction models allowing for heterogeneity such as in Pierucci and Ventura (2010) and Fuleky et al. (2015) may fall short of capturing the complex dynamics of risk sharing channels introduced by Asdrubali and Kim (2004) or Becker and Hoffmann (2006). An advantage of the VAR is that it provides a complete description of the moments of the data at all leads and lags.²⁴ Hence, the dynamic risk sharing profile is a 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 $k = 1, 2, \dots$, the analytic link between the different β_k 's for $k = 1, 2, \dots$ would remain blurred. 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.

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.²⁵ In our VAR-based approach, to obtain estimates of risk sharing for any horizon k , we will consider, for each country j , the conditional moments of the vector $X_t^j = [\Delta_k gdp_t^j, (\Delta_k p_t^* - \Delta_k p_t^j)/\gamma, \Delta_k e_t^j/\gamma, \Delta_k gdp_t^j - \Delta_k gni_t^j, \Delta_k gni_t^j - \Delta_k gdi_t^j, \Delta_k gdi_t^j - \Delta_k (c + g)_t^j, \Delta_k (c + g)_t^j - \Delta_k c_t^j]'$.²⁶

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

$$\Phi^j(L)X_t^j = \varepsilon_t^j + d^j \tag{7}$$

where $\Phi^j(L) = \Phi_0^j - \Phi_1^j L - \dots - \Phi_p^j L^p$ satisfies the condition that the roots of $\det(\Phi^j(L))$ lie outside the unit circle. Note that we do not contemplate cointegration. 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.

Asdrubali and Kim (2004) for panel VAR models and Becker and Hoffmann (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, 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.

²⁴ 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.

²⁵ 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.

²⁶ Given the identity in (6), for every country j and period t , the $\Delta_k c_t^j$ 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 to the system but rather induces exact multicollinearity. Hence, we did not include this variable in the VAR.

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) relies on heterogeneous panel VARs (HVAR).²⁷ The HVAR properties provide us with guidance on how the individual IRFs should be aggregated to yield the correct aggregate-level IRF (e.g., we should not use pooled panels). This allows us to discuss risk sharing properties at aggregate level and to properly compare country results with aggregate results. Asdrubali and Kim (2004) compute impulse response functions after a GDP shock hits the system using homogeneous panel VARs. In this paper we follow their approach for normalizing 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, $k = 0, 1, 2, \dots$

The impulse response functions will be given as the coefficients of the moving average representation of the VAR model. Denote by D_k^j the matrices of the moving average representation of the system in terms of the structural shocks and by $D_k^j(r, s)$ the element in row r and column s of the matrix D_k^j , for all countries $j = 1, 2, \dots, J$ and for $k = 1, 2, \dots$. A one-off shock to GDP has a contemporaneous impact on itself given by $D_0^j(1, 1)$. Similarly, it is straightforward to show that the impact after 1 period is given by $D_1^j(1, 1)$ and, in general, after k periods, by $D_k^j(1, 1)$. By summing over all the lags from 0 to ∞ we obtain the total effect or long-run impact of a one-off GDP shock onto GDP, that is, by definition the long run multiplier, $\sum_{k=0}^{\infty} D_k^j(1, 1) \equiv m_{1,1}$. Likewise, the contribution to consumption smoothing of each of the six channels considered in the paper is given by $D_k^j(2, 1), \dots, D_k^j(7, 1)$.

To compute the share of shocks smoothed by each channel after k lags, we can compute the relative change in each channel due to a GDP shock normalized by the long run multiplier $m_{1,1}$. For comparison with the rest of the literature where risk sharing is measured in the same year as the shock takes place, we take $k = 0$ and define total risk sharing on impact RS as the sum of the GDP fractions smoothed through each channel at lag $k = 0$,

$$RS = \frac{\frac{\partial((\Delta p_t^i - \Delta p_t^j)/\gamma)}{\partial c_{t,Y}^j}}{m_{1,1}} + \dots + \frac{\frac{\partial(\Delta(c+g)_t^j - \Delta c_t^j)}{\partial c_{t,Y}^j}}{m_{1,1}}}{m_{1,1}} = \frac{\sum_{r=2}^7 D_0^j(r, 1)}{m_{1,1}}.$$

The unsmoothed fraction of the shock at lag $k = 0$ would be given by:

$$\frac{\frac{\partial \Delta c_t^j}{\partial c_{t,Y}^j}}{m_{1,1}} = \frac{D_0^j(1, 1)}{m_{1,1}} - \frac{\sum_{r=2}^5 D_0^j(r, 1)}{m_{1,1}}.$$

We can also analyze the dynamics of risk sharing by means of the normalized impulse response function after 1, 2, ..., k lags. As an example, denoting total risk sharing after one period by RS_1 , this would be given by:

$$RS_1 = \frac{\frac{\partial((\Delta p_{t-1}^i - \Delta p_{t-1}^j)/\gamma)}{\partial c_{t-1,Y}^j}}{m_{1,1}} + \dots + \frac{\frac{\partial(\Delta(c+g)_{t-1}^j - \Delta c_{t-1}^j)}{\partial c_{t-1,Y}^j}}{m_{1,1}}}{m_{1,1}} = \frac{\sum_{r=2}^7 D_1^j(r, 1)}{m_{1,1}}$$

Then, the HVAR framework and the use of impulse response functions provide a rich description of the risk sharing phenomenon, in terms of channels dynamics and heterogeneity.

2.3.3. 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, given that T is large enough we will estimate the model for each country j . Since we are interested in estimating an average impulse response function for the entire sample, we follow the suggestion by Canova (2007) 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 $j = 1, \dots, J$. Let h_k be the impulse response function evaluated at lag $k = 1, \dots, K$, 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 at every lag k :

$$h(\omega^j) = h(\omega) + v_h^j \tag{8}$$

where v_h^j are iid $(0, \sigma^2)$ and represent the deviation of country j 's effect from the "typical" or average effect. 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:

²⁷ See Canova and Ciccarelli (2013) for a survey on panel VAR models.

$$\hat{h}_{MG} = \frac{1}{N} \sum_{j=1}^N h(\hat{\omega}^j) \tag{9}$$

and its variance–covariance matrix estimated as:

$$\hat{\Sigma}_h = \frac{1}{N(N-1)} \sum_{j=1}^N (\hat{\omega}^j - \hat{h}_{MG}) (\hat{\omega}^j - \hat{h}_{MG})' \tag{10}$$

Notice that we use the cross section to estimate the common or average effects by pooling the estimators of the impulse response functions.

We use annual data from National Accounts and *CPI* for 1960–2018 in our empirical application. The sample of OECD countries included 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 since it provides harmonized statistics.

The nominal aggregates have been transformed in real per-capita terms, dividing nominal values by population and the consumption deflator – the latter taken from the OECD database.

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 the US have a greater share in the “world” *GDP* than smaller countries with higher per capita *GDP*.

We have then computed real effective exchange rates series for country *j* as a geometric mean using import and export weights w_t^i for each time *t* and country *i*, as follows:²⁸

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

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 dollar at time *t*, where all the variables are referred to the set of *J* countries in our OECD sample. Private consumption evaluated at world prices has been computed as $C_t^j / REER_t^{j/7}$.

2.4. Empirical results

We will present the results stemming from the effects of shocks to *GDP* on individual channels and the effects of shocks to individual channels on *GDP* and the other 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 panel regression approach (such as Sørensen and Yosha, 1998 and Asdrubali and Kim, 2004). Columns 2 to 3 show the effect of the real effective exchange rates decomposed into the relative price effect (column 2) and the nominal effective exchange rate effect (column 3). Since we transform the variables and take logs and first differences, what appear in columns 2 and 3 are adjustments through inflation differentials and nominal exchange rate growth, respectively. Columns 4 to 6 present risk sharing through the three traditional channels considered in the previous literature. Column 7 introduces private consumption smoothing through the government consumption channel. Column 9 shows total smoothing achieved, comprising real exchange rate effects, as the sum of all channels. Finally, and for comparison purposes, column 8 shows the sum of smoothing taking place only through the 3 standard traditional channels: the factor market, international transfer and the credit market channels. Our sample runs from 1960 to 2018.²⁹

A first look at the table indicates that the overall degree of risk sharing over the almost 60 years under exam is far from perfect, yet not at all negligible (23% of a shock smoothed on average), and that the credit market channel achieves most of the smoothing. The positive role of the credit market channel is statistically significant for all countries. This does not apply to the remaining channels, where we cannot reject the absence of smoothing in many cases: risk sharing achieved through the factor market channel is 1%, while 0% of smoothing takes place through international transfers. These estimates are consistent with most studies on risk sharing covering OECD countries (or a large subset thereof), especially considering that the

²⁸ Alternatively, we could use arithmetic means to define the REER but the computations using geometric means are easier and, since we take logs afterwards, it preserves the additivity of the logs of the real effective exchange rates as the sum of the logs of nominal exchange rates and logs of price ratios.

²⁹ We have also estimated the model using data up to 2014 since the real Irish *GDP* growth rate was above 25% in 2015! The results, not shown for the sake of brevity, remain essentially unaltered for all the countries and are available from the authors upon request.

Table 1

Country-specific impact risk sharing for the years 1960–2018 - HVAR with CRRA coefficient $\gamma = 2$. *, ** and *** denote coefficients that are statistically significant at 10%, 5%, and 1%, respectively.

1960–2018	Rel. price	Exch. rate	Factor markets	Int. transfers	Credit	Govern. cons.	Traditional RS	Total RS
Austria	14***	-33*	0	4**	38***	-9**	42***	14
Belgium	9*	-25	5	-3*	65***	-7	67***	43**
Denmark	13***	1	-2	2	27**	-16*	28***	26
Finland	7	-65***	-2	-1	72***	-12***	69***	-1
France	4	5	-3	-1*	35***	-11**	31***	29
Germany	11***	-33**	2	2*	29***	0	33***	11
Greece	7***	2	1	0	18***	2	19***	30***
Ireland	0	14***	16***	-1	32***	-1	48***	62***
Italy	-6**	-1	2	0	15***	-7**	17***	3
Netherlands	12***	-20*	7	0	34***	-1	40***	32***
Portugal	18***	-12	-6***	6***	15**	3	16**	25*
Spain	10***	-15*	0	1**	12***	-1	12***	7
Sweden	13**	-22	-3	-1	51***	-15**	48***	24
UK	7	2	1	3**	15***	-1	20***	27
Australia	13***	-71***	1	0	46***	-1	46***	-13
Canada	12***	-60***	-2	-1**	54***	-3	51***	-1
Japan	11***	6	-1	1*	30***	-6***	30***	41**
New Zealand	10***	-21	-3	-1	32***	-1	28***	17
Norway	9***	-22**	4*	-2***	72***	-5**	74***	56***
Switzerland	7**	17	10	0	37**	-2	47***	69***
US	8**	-50*	1*	1	19***	-3**	21***	-24
Mean Group	9***	-19***	1	0	36***	-5***	37***	23*

comparable degree of traditional risk sharing – excluding government consumption (dis-) smoothing – amounts to 32%.³⁰ Several new findings emerge, however, in relation to the new channels we introduced. First, government consumption plays on average a dis-smoothing role, amplifying shocks to *GDP* growth by 5%. 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 *consumption* smoothing via 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 consume, given the reduced output growth. Second, there were sound theoretical reasons to expect both a smoothing and a dis-smoothing effect of real exchange rates. Our results show that, after a positive shock to *GDP* growth, the ratio of foreign to domestic price level increases – thus reducing private consumption deflated by relative prices – implying a purchasing power smoothing role of relative price adjustments equal to 9%; however, the nominal exchange rate appreciates to increase private consumption at (risk-adjusted) PPP, implying a purchasing power dis-smoothing effect of nominal exchange rate adjustments of 19% on average.³¹ Overall, the real exchange rate appreciates, thus increasing private consumption at (risk-adjusted) PPP by 10% on average, which suggests a net dis-smoothing purchasing power effect of real exchange rate adjustments. That is, positive shocks to *GDP* appreciate the real exchange rate, which directly increases consumption at (risk-adjusted) world prices through PPP conversion. These results on real exchange rates are consistent with the Balassa-Samuelson hypothesis and Corsetti et al. (2008b), who report real exchange rate appreciations following US technology shocks.³² Moreover, we show that, while relative prices indeed play the smoothing role prescribed by standard theory, their effect is more than offset by the volatility of nominal exchange rates, as suggested by Hess and Shin (2010) and Devereux and Hnatkovska (2020). To deepen our understanding of this result, we tested our model on the OECD subsample belonging to the euro area. Comparing the results (Table 2) with Table 1 above, we confirm that on average total risk sharing is higher, rising from 23% to 36%, basically due to the lack of dis-smoothing on average of the nominal exchange rates for the euro area countries.³³

As for the price effect of real exchange rates through the elasticity of consumption (and saving), it is mainly emerging via the credit market channel. Since its smoothing level (36%) is higher than in a baseline model without real exchange rate effects (31%), we can infer that – as a response to the real exchange rate appreciation which follows positive *GDP* shocks in our sample – total consumption falls, and savings increase by at most 5%, thus slightly helping smooth (risk-adjusted) PPP consumption.³⁴ Our results show that – when conditioned on *GDP* shocks – the negative correlation between private con-

³⁰ For example, Sørensen and Yosha (1998), Balli et al. (2012) or Leibrecht and Scharler (2012).

³¹ Although the magnitude is large in terms of risk sharing, the changes are not too large in terms of the actual percent changes in each variable. For example, if the nominal exchange rate depreciates by 0.2% following a 1% *GDP* increase, our risk sharing measure of the nominal exchange rate channel is 20%.

³² 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-Samuelson hypothesis (see Peltonen and Sager, 2009).

³³ Full results available upon request.

³⁴ In order to estimate the price effect of relative prices and nominal exchange rate on private consumption, we performed a counterfactual exercise in which the relative price and nominal exchange rate are assumed not to change in the seven variable model with alternative orderings of the relative price and nominal exchange rate. From this exercise, we estimated a rather limited impact arising from these second-round effects. The results are not in the paper for the sake of brevity, but are available upon request. As for the results in a baseline model without a real exchange rate, they are also available upon request.

Table 2

Mean Group impact risk sharing for Euro Area countries, for years 1960–2018. *, ** and *** denote coefficients that are statistically significant at 10%, 5%, and 1%, respectively.

1960–2018	Rel. price	Exch. rate	Factor markets	Int. transfers	Credit	Govern. cons.	Traditional RS	Total RS
Mean Group	5*	0	1	0	32***	-2***	33***	36***

Table 3

Mean group impact risk sharing for a model including TFP as additional variable. *, ** and *** denote coefficients that are statistically significant at 10%, 5%, and 1%, respectively.

1960–2018	Rel. price	Exch. rate	Factor markets	Int. transfers	Credit	Govern. cons.	Traditional RS	Total RS
Mean Group	6***	1	-2	-1	36***	-12***	33***	28***

sumption and the real exchange rate (the so-called Backus-Smith puzzle) disappears.³⁵ When coupled with the result above on the smoothing role of relative prices, this evidence points instead to a substantial vindication of the Backus and Smith (1993) risk sharing equation, disrupted only by nominal exchange rate gyrations. To deepen the issue, we reran our model using Total Factor Productivity (TFP) as the exogenous source of shocks, as assumed in part of the literature. The results for the mean group estimators, reported in Table 3, show that the degree of total risk sharing increases from 23% to 28%, essentially due to a stronger role of the nominal exchange rate, driving the average effect of this channel to virtually zero. We can tentatively conclude that GDP growth changes originating in TFP shocks elicit consumption smoothing through the nominal exchange rate.³⁶

Central to our paper, we notice from Table 1 that the degree of risk sharing is strikingly different across countries, which suggests that modeling heterogeneity is crucial. For total risk sharing by the three traditional channels, the country-specific magnitude of risk sharing on impact ranges from 12% to 74%.³⁷ Looking at total risk sharing by all channels (column 9), we notice an equally wide dispersion, with Ireland Norway and Switzerland above 50% and Canada, Australia and US around 0% (or below, if we also consider the non-significant negative values).³⁸

Table 1 also shows heterogeneity across countries in the relative importance of each channel. The credit channel is the more significant to smooth consumption, as it always cushions, to a greater or lesser extent, GDP shocks; however, it also exhibits clear heterogeneity in the amount of smoothing achieved. Credit markets smooth at least 50% of shocks in Belgium, Finland, Sweden, Canada, and Norway, but at most 15% in Italy, Portugal, Spain, and the U.K. We can also see a substantial heterogeneity in the operation of other channels. The smoothing role of the factor market channel is significantly positive in Ireland, but significantly negative in Portugal. The smoothing role of international transfers is significantly positive in Austria, Portugal, Spain and the UK, but significantly negative in Belgium, Canada and Norway. As regards government consumption, it does not help 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 Denmark, Finland, France and Sweden, with an average dis-smoothing above 10% for the sample period analyzed. 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.³⁹ This channel displays a huge dis-smoothing effect in Finland, Australia, Canada and the US, while it has a considerable positive effect in Switzerland (although not statistically significant) and Ireland. 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 Ireland, Japan, and Switzerland), showing a positive risk sharing role. While a full analysis of the factors driving risk sharing channels' effectiveness in each country goes beyond the scope of this paper, we tested whether the amount of foreign investment increases in countries where private markets play a more important role in risk sharing. The correlation between the private component of risk sharing and the amount of foreign direct investment is 0.44, pointing, indeed, to a moderate effect of FDI on the attainment of risk sharing.

To describe the dynamic behavior of risk sharing channels, Fig. 1 shows the estimated impulse response functions.⁴⁰ Its first column of graphs documents the average response to a shock on GDP growth of the various risk sharing channels. The results are normalized by the total effect of a shock cumulated over 5 years as in Asdrubali and Kim (2004). The first graph in the first column is the response of GDP to a GDP shock.⁴¹ The graphs below show the dynamic profile of the different channels. The results document that most of risk sharing is achieved through the credit market channel, which on impact is able to

³⁵ In fact, a large literature has found that the consumption-real exchange rate correlation is close to zero in most samples. Kollmann (2012), in particular, explains this pattern with a model embedding a fraction of hand-to-mouth consumers, in line with the interpretation of the risk sharing regression we provided in footnote 16.

³⁶ Full results available upon request.

³⁷ Full results on individual countries are available upon request.

³⁸ We tested the equality of risk sharing channels across countries using the approach by Canova (2007, Section 8.3.5 Testing for dynamic heterogeneity). We compared 2 estimators: the mean group estimator – that is consistent both under the null and under the alternative – and the pooled estimator – that is only consistent under the null and more efficient in this case. The results, available upon request, confirm that the null of homogeneity can be rejected.

³⁹ Notice that some countries share a common currency, the euro, since 1999, while others do not.

⁴⁰ The dotted lines reported in the plot of the impulse response functions represent 95% confidence intervals computed based on Eq. (10).

⁴¹ We estimated the IRFs to a GDP shock with a different ordering of the variables (other than GDP) and the results remain almost unchanged.

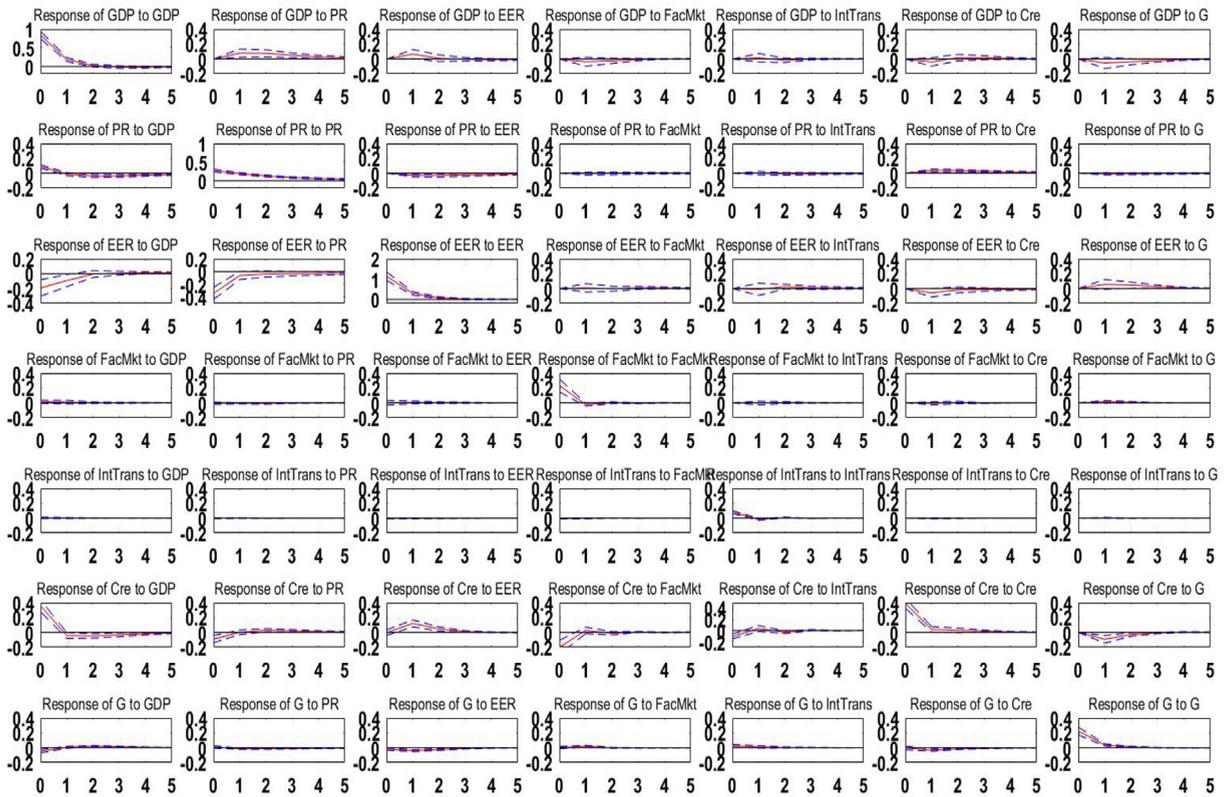


Fig. 1. Mean group impulse response functions (solid line) with 95% confidence intervals (dotted lines) - HVAR with CRRA coefficient $\gamma = 2$.

smooth around 30% of the shock, but plays a slightly negative role afterwards. The short-term response of the credit market channel entails a degree of consumption smoothing that in a 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 component, which could reasonably follow a pattern of intertemporal smoothing different from the overall GDP innovation.

The factor market and international transfer channels do not seem to provide risk sharing at any horizon, although the country-specific analysis below will reveal that while this is true for international transfers, the smoothing dynamics of factor markets is heterogeneous across countries. Also, although government consumption provides dis-smoothing on impact, it plays a positive role in the second and third years after the shock.⁴² We detect a significant and positive contribution – around 10% for a risk aversion coefficient $\gamma = 2$ – of the relative price channel in the first period but a persistent negative role afterwards, which becomes significant in the third to the fifth years. Nominal exchange rate adjustments play a negative role in the first two years.⁴³ The contemporaneous risk sharing responses through purchasing power effects are complemented by the repercussions of the changes in real exchange rate components on next period's output (feedback effect) and thus on next period's consumption smoothing. 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, it may also produce further output increases in successive periods (feedback 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, it may also produce an output decrease in the next periods (feedback effect), thereby mitigating the impact of the shock on the output growth process.

To present a full picture for all the countries and check if heterogeneity is present also in the dynamic behavior of the channels, Fig. 2, bottom panel, shows the individual impulse response functions of the total amount of risk sharing, obtained as the sum of the amounts smoothed through each channel. 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 in each year. We do not plot confidence

⁴² To some extent this may be the consequence of intertemporal government budget constraints.

⁴³ Nominal exchange rate appreciation may lead to domestic price falls in later periods.

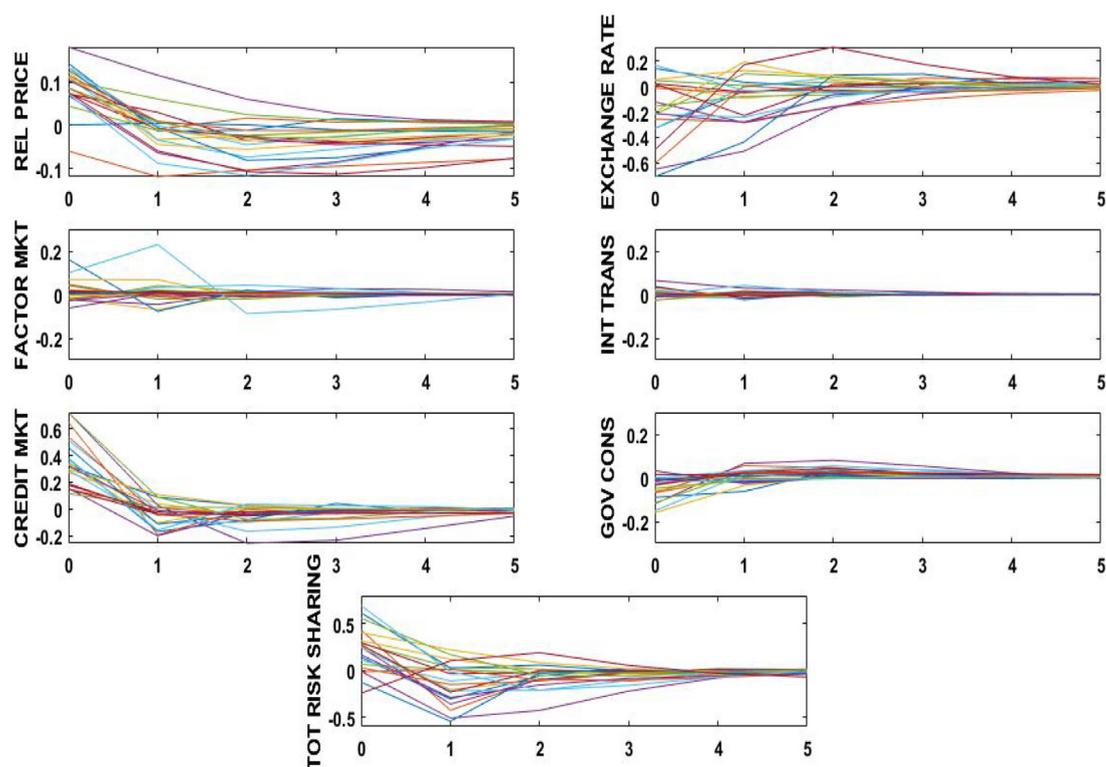


Fig. 2. Country-specific impulse response functions of risk sharing channels - HVAR with CRRA coefficient $\gamma = 2$.

bands to avoid cluttering. The values at impact bring out the heterogeneity that we saw in Table 1, ranging from -20% to over 50% in the amount of total risk sharing achieved contemporaneously. In this graph, heterogeneous responses appear also in later periods. In particular, the heterogeneity in the second period responses is as large as that in the first period.

Fig. 2 also shows impulse response functions for the channels considered; the channels do not behave all alike, with most of the heterogeneity arising through nominal effective exchange rate changes. 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 ranges from smoothing to dis-smoothing depending on the country. The credit market channel always presents a positive behavior on impact but 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 practically do not play a role for any country. Government consumption either provokes dis-smoothing on impact or, alternatively, is ineffective. This means that some governments act counter-cyclically, provoking further dis-smoothing. This channel exhibits adjustment dynamics in later periods, 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 channel, quite high in the relative price and credit channels, and non-negligible also in factor market and government consumption channels. Only international transfers do seem to behave similarly for all countries, practically exerting no smoothing.

Since our sample is quite large and includes different periods, risk sharing might have presumably varied over time. In order to provide a description of the evolutionary pattern of the shock absorption capabilities of risk sharing channels, we computed rolling-window estimates. The first subsample is the pre-euro period, 1960–1998. We add/remove a year at the end/beginning of the subsample and repeat the estimation until we reach 2018. For each subsample, we have computed the mean group impulse response functions. Fig. 3, bottom panel, shows the evolution of total risk sharing using this method. The horizontal axis shows the end year of each subsample.

From Fig. 3, top panel, we observe that risk sharing through the three traditional channels increased slightly through the 1990s, reaching its maximum in 2001; then, it decreased attaining its minimum in 2012 during the European sovereign debt crisis. Risk sharing seems to be slightly recovering in the late 2010s.⁴⁴ We observe a similar pattern – though slightly shifted

⁴⁴ This is consistent with Sørensen et al. (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 et al. (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.

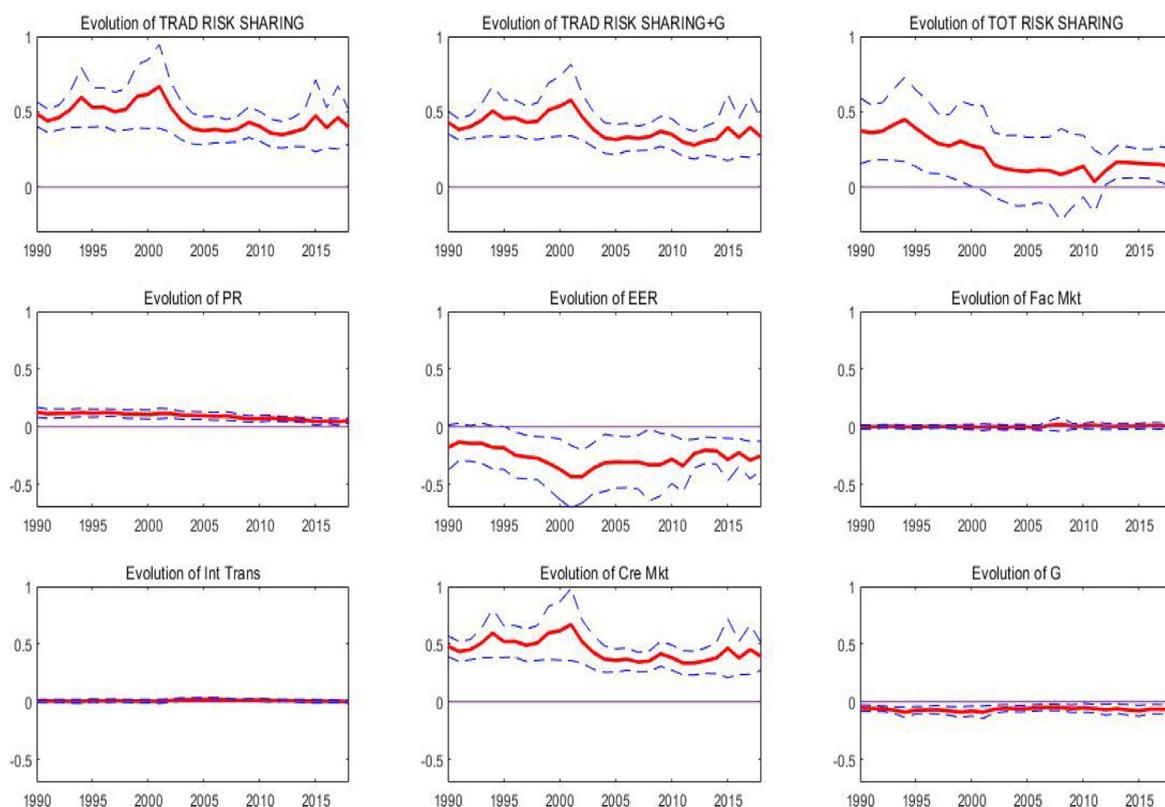


Fig. 3. Evolution of mean group impact risk sharing (solid red line) with 90% confidence bands (dotted blue line) using a rolling window - HVAR with CRRA coefficient $\gamma = 2$.

downwards – when we add government consumption smoothing. When taking into account the real effective exchange rate channels, we record a steeper decrease in the extent of consumption smoothing at international prices. Although point estimates remain positive for all subsamples, they are not statistically significant from 2000 to 2012. In the last years, they have recovered and have become statistically significant again, although the level of total risk sharing is less than one half (for some subsamples close to one third) of what it was in the initial subperiods. To shed some light on the exact mechanisms underlying these patterns, Fig. 3, medium and bottom panels, presents the evolution of risk sharing for the different channels. Note that the three most important risk sharing mechanisms are confirmed to be the credit market, the relative price and the nominal exchange rate channels. In particular, the deterioration of credit market risk sharing underlies the overall decline in traditional risk sharing channels. However, the annihilation of total risk sharing at the start of the century reflects mostly the nominal exchange rate effect. Indeed, in the initial sub-periods, risk sharing via nominal exchange rate adjustments (medium, center) is around -15% . However, it becomes more negative during the turn of the century, recovering to a certain extent in the most recent years. The role of relative price adjustment (medium, left) has always been positive; we notice a constant, if slight, reduction in its effect and in the uncertainty around it, perhaps due to convergence in inflation rates, which have characterized industrial economies in the last 20 years.⁴⁵ The behavior of risk sharing achieved through international transfers (bottom, left) and the factor market channel (medium, right) has been close to zero for most periods. Government consumption (bottom, right) has been relatively stable over time, dis-smoothing around 5% in the last sub-periods. To confirm our conclusions, we traced the risk sharing evolution for the subsample of countries belonging to the euro area. Fig. 4 illustrates vividly that the dis-smoothing effect of the nominal exchange rate (EER) is absent. In fact, we cannot distinguish its effect from 0 for all samples. Additionally, as more data points of the common currency are introduced in the sample, the estimations of risk sharing through the EER get closer to the 0 line, as suggested.

Our set-up also 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 seventh columns of graphs in Fig. 1 show the cross-country average impulse responses to shocks in each channel of risk sharing. Interestingly, the credit market channel

⁴⁵ 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.

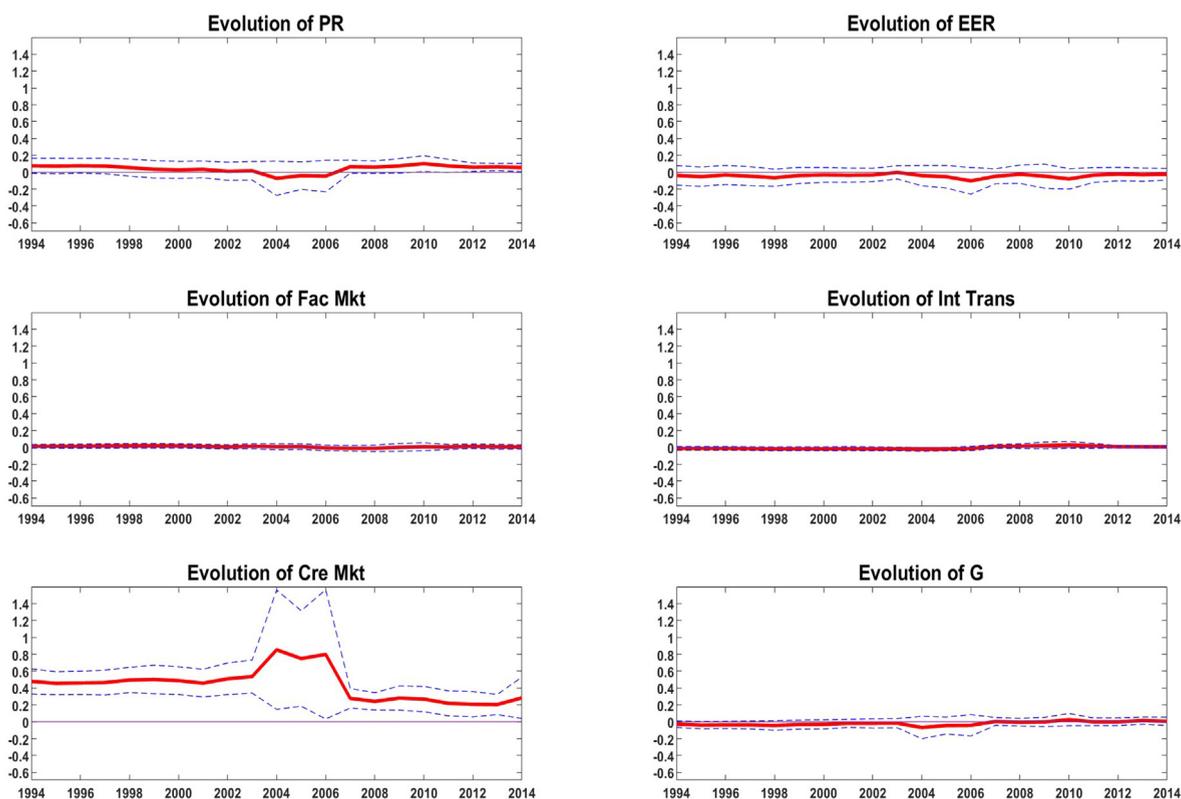


Fig. 4. Evolution of mean group impact risk sharing for Euro Area countries (solid red line) with 90% confidence bands (dotted blue line) using a rolling window - HVAR with CRRA coefficient $\gamma = 2$.

offsets shocks to other risk sharing channels. 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.⁴⁶

The above results are predicated on a calibrated value of the CRRA coefficient $\gamma = 2$, which in many empirical analyses is regarded as a reliable benchmark. Should the value of γ be different, we would have different results. Indeed, there is a precise relation between the value of γ and the risk sharing measure attached to the real exchange rate: the values of relative price risk sharing and nominal exchange rate risk sharing – obtained for $\gamma = 2$ – must be multiplied by $2/\gamma$ for values of $\gamma \neq 2$. For example, when $\gamma = 1$, total risk sharing decreases to 13%, as the dis-smoothing role of the real exchange rate becomes bigger. When γ takes the value of 3, the (dis-) smoothing achieved through the last 2 channels is multiplied by $2/3$ and total risk sharing rises up to 26%. Of course, the higher the value of γ , the higher the degree of total risk sharing. Obviously, the relation is not linear as the CRRA coefficient γ only affects the relative price and nominal exchange rate channels.

3. Concluding remarks

We have estimated the degree of risk sharing among industrialized OECD countries using a heterogeneous panel VAR model that improves upon the treatment of endogeneity of output and appropriately takes into account dynamics and feedback among the channels and between 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. Indeed, as pointed out by some authors, such as [Kalemli-Ozcan et al. \(2014\)](#), risk sharing was not homogeneous across major EU countries during the recent recession and subsequent sovereign debt crisis. Then, the heterogeneous panel VAR model is more suited to estimate risk sharing among this set of countries.

We have added an additional channel for consumption smoothing that works internally to each country. Government consumption accounted for 5% of dis-smoothing on average during the sample period. In our multi-good world, we were able to study the risk sharing behavior of the real exchange rate. Our results show that the real exchange rate provides dis-

⁴⁶ These results are qualitatively the same when changing the ordering of the variables.

smoothing, to a degree that is a function of the risk aversion coefficient. Interestingly, the two components of the real exchange rate react differently to the same output shock: while relative prices do provide risk sharing as implied by theory, nominal exchange rate adjustments more than offset such price response, delivering a net dis-smoothing effect. This role of the real exchange rate represents a novelty: while a substantial strand of the empirical literature has analyzed the shock-absorption properties of the real exchange rate with respect to output,⁴⁸ very few studies have investigated this role with respect to consumption.⁴⁹ In fact, we could distinguish three separate roles for the real exchange rate risk sharing: i) a purchasing power effect, which captures the change in consumption's purchasing power generated by the real exchange rate variation ii) a price effect, which captures the effect induced by real exchange rate changes on aggregate expenditures via demand elasticity, and on cross-border flows via valuation effects; and iii) a feedback effect, which represents the changes onto next period's output caused by the real exchange rate changes via the price effect.

We also studied the evolution of risk sharing channels over time, and documented the role played by the deterioration of credit market smoothing for the long-run decline in risk sharing started at the beginning of the century. However, the annihilation of total risk sharing at the start of the century reflects mostly the nominal exchange rate effect. Relative price adjustment has always been positive, but has been declining since the late 90s, perhaps due to convergence in inflation rates. After a trough in 2012 during the European sovereign debt crisis, overall risk sharing has been slightly recovering in the late 2010s.

This article is essentially an exercise to establish 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 particular, from a theoretical viewpoint, it would be interesting to disentangle the role of country-specific preference parameters – embedded in our full risk sharing model as expressed in Eq. (3) – from the role of other factors, not yet encompassed in the standard model. 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 supranational level.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at <https://doi.org/10.1016/j.jimonfin.2023.102804>.

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⁴⁸ Starting from Obstfeld (1985).

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