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## Changing patterns of risk-sharing channels in the United States and the euro area

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Changing patterns of risk-sharing  
channels in the United States and the  
euro area

No 2849

## Abstract

In this paper, we assess how risk-sharing channels have evolved over time in the United States and the Euro Area, and whether they have operated as ‘complements’ or ‘substitutes’. In particular, we focus on the capital channel (income from cross-border ownership of productive assets), the credit channel (interstate or cross-country bank lending), and the fiscal channel (federal or international fiscal transfers). We offer three main contributions. First, we propose a time-varying parameter panel VAR model, with stochastic volatility, which allows us to formally quantify time variation in risk-sharing channels. Second, we develop a new test of the complementarity vs. substitutability hypothesis of the three risk-sharing channels, based on the correlation between the impulse responses of these channels to idiosyncratic output shocks. Third, for the United States, we explain time variation in the risk-sharing channels based on some key macroeconomic and financial variables.

*JEL* Classification: C11, C33, E21, E32.

Keywords: Risk-sharing channels, time variation, complementarity, substitutability.

## Non-Technical Summary

There are two fundamental and nested dimensions in the debate about how countries in monetary union can counteract macroeconomic shocks affecting locally their economies. The first concerns the mechanisms available at a national level to reduce exposure to risks or to mitigate their effects (e.g., eliminating price and wage rigidities, building fiscal buffers). The second concerns the notion of international risk-sharing, which plays a central role in this debate, given that it relates to the cross-border channels available to insure against idiosyncratic or country-specific output shocks (as opposed to shocks hitting the monetary union as a whole).

This paper focuses on this latter dimension, and analyses how states within the United States (US) and countries in the euro area (EA) have “shared risks” over the last decades. In particular, we focus on how countries and states have insured risks via capital and credit markets, and via fiscal transfers. Indeed, agents in a given country or state hit by a negative idiosyncratic shock may alleviate the effects of such shock by receiving income, such as dividends from financial assets held in other regions not affected by this shock (capital channel), by obtaining bank loans or official financial assistance from other jurisdictions (credit channel), and by benefiting from fiscal transfers from abroad (fiscal channel).

We offer a fresh view in this debate along three different dimensions. First, we assess whether the contribution of these three risk-sharing channels has varied over time, which might be explained by several structural and institutional changes that have occurred in the US and the EA over the last decades. Second, we analyse whether a possible increase (decrease) in the contribution of one channel has been associated with an increase (decrease) in the contribution of the other channels. In other words, we study whether the capital, credit and fiscal channels have operated as ‘complements’ or ‘substitutes’. Third, in the case of the US, we identify potential macroeconomic and financial factors underlying the dynamics of the time-varying risk-sharing channels.

Based on the 1975-2020 sample for the US, and on the 1998-2023 sample for the EA, we find substantial time variation in the risk-sharing mechanism, for both regions. The overall level of shock absorption has increased since the 1970s in the US. This improvement has been mainly driven by private risk-sharing channels (i.e., the capital and credit channels), whereas that the federal tax/transfer system absorbed around 10% of the shock initially, which decreased to below 5% in recent years.

We document that the overall level of risk-sharing in the EA is much lower. Only around 30% of an output shock is smoothed, with a slight improvement towards the end of our sample. The most striking finding is that the capital and credit channels move in opposite directions: the capital channel was dominant until the Great Financial Crisis (GFC) of 2009. After that, it collapsed, probably due to financial market fragmentation and

flight-to-safety. On the contrary, the credit channel significantly increased during the GFC and the subsequent European Sovereign Debt Crisis (ESDC), probably also on the back of ESM-IMF financial assistance programmes implemented for countries under financial stress. The role of international fiscal transfers is negligible, but shows a slight improvement after the ESDC, and in particular during the 2020-2022 Covid-19 crisis.

When looking at the interactions between the three channels, we find strong evidence for substitution between the capital and the credit channels. This result is evident in both regions, although it is statistically significant only for the US. Interestingly, we find that in the US the fiscal and credit channels might have reinforced each other from the 2000s. This result tends to support the hypothesis of [Farhi and Werning \(2017\)](#), who suggested potential complementarity between public and private risk-sharing channels.

Finally, for the US, our results suggest that the federal tax/transfer system and the capital channel provide more smoothing during weak economic conditions. In addition, we find that stronger financial integration lead to better functioning fiscal and credit channels. We also show that a higher government debt-to-GDP ratio is associated with a weaker fiscal and credit channel.

Our results have important implications for the improvement of the European Monetary Union's governance framework. We show that there is substantial room to strengthen the shock-absorption capacity of the EMU. The Capital Market Union and the Credit Market Union could reinforce risk-sharing and improve the resilience of the EA to macroeconomic shocks by contributing to smooth output shocks through the capital channel and the credit channel. However, policymakers should be mindful of substitution effects between these two channels. The US experience also points to positive externalities between the fiscal channel and the private risk-sharing channels. When translating this finding for the EA, this suggests that progress on the Fiscal Union could also have a beneficial effect on private risk-sharing mechanisms in the EMU.

# 1 Introduction

The debate on how to improve the absorption of macroeconomic shocks has gained attention in the aftermath of the Great Financial Crisis (GFC) and, more recently, in the context of the Covid-19 pandemic and the economic crisis which followed Russia’s invasion of Ukraine. Both in the United States (US) and in the Euro Area (EA), the discussion has often developed around the concept of “risk-sharing”, which refers to the idea that states within a federation, or countries in a monetary union, share “risks” to insure their future consumption or income streams against negative shocks to local output, i.e., “idiosyncratic shocks” (see, e.g., [Canova and Ravn, 1996](#)). The literature has generally identified two main categories of risk-sharing channels, broadly defined as “private” and “public” channels. The former category includes the capital channel, which mainly operates via portfolio diversification in the international financial markets, and the credit channel, through which private and public agents borrow from international banks and which also includes smoothing via domestic savings.<sup>1</sup> The second category mainly comprises the fiscal channel, which operates through transfers from the federal government (in the US), from a common budget (in the EA) or via international transfers.

So far, the literature has not provided clear answers on whether the share of smoothed relative to unsmoothed output shocks has varied over time in these two regions, and the role of the three risk-sharing channels in explaining time variation. Indeed, there are historical and economic reasons that would explain why these channels operate in different ways over time. First, risk-sharing via the capital channel may have changed due to varying cross-ownership of productive assets and different degrees in the synchronization of financial cycles, and among other factors. Second, looser financial regulation may have facilitated cross-state bank lending, which in turn may have reinforced inter-state risk-sharing via the credit channel. At the same time, cross-border lending is often pro-cyclical, especially in recessions, therefore financial de-regulation may have amplified shocks in bad times (see, e.g., [Albertazzi and Bottero, 2014](#)). Third, the role of federal fiscal policy as a shock absorber may have also changed, as also reflected in a different policy stance and fiscal activism by subsequent (Republican and Democratic) US governments, or new common initiatives at the European Union (EU) level, such as the “Next Generation EU” (i.e., NGEU).<sup>2</sup>

In addition, it is unclear whether an increase in the effectiveness of one channel could reinforce other channels (complementarity hypothesis), or vice versa would weaken them

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<sup>1</sup>Loans from international institutions such as the International Monetary Fund or the European Stability Mechanism, or bilateral cross-country loans, fall also typically under the credit channel (see, e.g., [Cimadomo et al., 2020](#)).

<sup>2</sup>The NGEU is a fiscal stimulus programme approved in the EU on 19 February 2021 in the context of the Covid-19 pandemic. It was launched to finance reforms and investments in EU Member States and is set to run until 31 December 2026. It has made €723.8 billion available to EU countries in total, of which €385.8 billion in loans and €338 billion in grants.

(substitutability hypothesis). Some authors make the case of complementarity between risk-sharing channels. Notably, [Farhi and Werning \(2017\)](#) strongly argue in favour of fiscal insurance as a necessary complement to private risk-sharing in a currency union. They argue that even when markets are complete, international fiscal transfers are necessary to achieve the desired allocation, because agents do not fully internalise the macroeconomic stabilisation effects of private insurance. On the other hand, other authors support the idea of substitutability. For instance, [Belke and Gros \(2015\)](#) claim that a fully-fledged banking union would reinforce the credit channel and may *de facto* operate as a substitute for a fiscal union, therefore weakening the role of the fiscal channel. In addition, the effects of a stronger credit channel on the effectiveness of the capital channel are unclear. On the one hand, easier access to credit from foreign banks may reduce the scope for portfolio diversification on international financial markets, thus suggesting substitutability between these two channels. On the other hand, the presence of foreign banks and financial intermediaries in a given region may facilitate investment opportunities in foreign financial assets. In this case, we would observe complementarity between the two channels.

Our paper offers three main contributions. First, we extend [Asdrubali and Kim \(2004\)](#) and propose a time-varying parameter panel VAR model, with stochastic volatility, which allows us to estimate how the share of smoothed vs. unsmoothed idiosyncratic output shocks have changed over time in the US and the EA. In this context, we provide evidence on whether the contribution of the different risk-sharing channels have varied over time, or have remained stable. Second, we develop a new test of the complementarity hypothesis which is based on the correlation between the time-varying impulse responses of the various channels to the output shock. Third, for the US, we test if some key macroeconomic and financial variables (e.g., output gap, financial development, interest rates and the public debt-to-GDP ratio) may have contributed to explain the time-varying dynamics of risk-sharing channels estimated in the first stage.<sup>3</sup>

We find substantial time variation in the risk-sharing mechanism. The overall level of shock absorption has increased since the 1970s in the US. This improvement has been mainly driven by private risk-sharing channels. Notably, the capital channel has improved substantially in the 1970s and since then it smooths on average around 40% of an output shock on impact. We also find that credit markets attenuates around 30% of an output shock, and its contribution has tended to increase over the sample. Finally, we show that the federal tax/transfer system absorbs around 10% of the shock. However, its smoothing effect has decreased to around 5% in recent years.

We document that the overall level of risk-sharing in the EA is much lower. Only around 30% of an output shock is smoothed on impact, with a slight improvement over the sample.

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<sup>3</sup>This part of the analysis is not carried out for the EA given the shorter size of the impulse responses estimated in the first stage, i.e., only 25 years.

The credit channel has a predominant and increasing role, while the capital channel turns out to be less important, on average over the sample. Our time-varying analysis allows us to uncover that the capital channel had a sizeable smoothing effect in the leading up to the GFC of 2008-2009 and weakened afterward. At the same time, the importance of credit-market smoothing has gone up after the GFC. Not surprisingly, we find that the role of the fiscal channel is negligible, although it shows a slight improvement after the European Sovereign Debt Crisis (ESDC) of 2010-2012, and in particular during Covid-19 pandemic crisis.

When looking at the interactions between the channels, we find clear evidence of substitution between the capital and the credit channels. This result is evident in both regions, and it has been relatively stable over time. This suggests crowding out between these two channels. This finding can also be interpreted as confirming the the “spare-tire” hypothesis, postulating that stock markets can mitigate the effects of a banking crisis ([Levine et al., 2016](#)). Interestingly, we also find that, in the US, the fiscal and private risk-sharing channels have reinforced each other. This result underpins the theoretical findings of [Farhi and Werning \(2017\)](#), who suggested potential complementarity between public and private risk-sharing channels. In the EA, we find similar qualitative results, although the they are estimated less precisely, also due to a smaller sample size.

Finally, for the US, our results suggest that the federal tax/transfer system and the capital channel provide more smoothing during weak economic conditions. In addition, we find that stronger financial integration lead to better functioning fiscal and credit channels. We also show that a higher government debt-to-GDP ratio is associated with a weaker fiscal and credit channel.

The rest of the paper is structured as follows. Section 2 reviews the related literature on risk-sharing. Section 3 presents the empirical methodology and describes the dataset used in the empirical analysis. Section 4 reports and discusses our empirical results. Finally, Section 5 concludes.<sup>4</sup>

## 2 Related Literature

The literature on consumption and income risk-sharing has soared since the 1990s, focusing on both the US and on European countries.<sup>5</sup> Analyzing US state-level data between 1963 and the early 1990s, the seminar paper by [Asdrubali et al. \(1996\)](#) find that 75% of a local shock to per capita gross product of individual states has been smoothed. Cross-state asset

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<sup>4</sup>Supplementary material containing estimation details, a Monte-Carlo experiment on the estimation of the time-varying panel VAR model, robustness analysis, and additional empirical results are included in the Online Appendix (not for publication).

<sup>5</sup>See [Cimadomo et al. \(2022\)](#) for a review of the literature and a comparison of the effectiveness of risk-sharing channels across countries and regions.



ownership contributed to 39% of smoothing, the federal tax/transfer system smoothed 13%, while 22% was accounted by cross-state lending and borrowing (see also [Del Negro, 1998](#), [Asdrubali and Kim, 2004](#) and [Mélitz and Zumer, 1999](#) for early studies on the US). More recent empirical investigations highlighted an increase in the overall level of risk-sharing in advanced economies (see, e.g., [Nikolov, 2016](#)). Some authors estimate risk-sharing over rolling windows of data. The general finding is that total shock absorption varies between 70-85% and has gone up since the 1960s. Some papers showed that the role of the fiscal channel has been relatively stable, while the capital and the credit channels have increased in importance ([Alcidi et al., 2017](#), [Stempel et al., 2021](#)).

Results for the EA indicate that a much larger share of shocks is not smoothed, i.e., around 70%. As opposed to the US, the role of capital markets is limited, while the majority of the absorption is via credit markets. Smoothing via the fiscal channel is negligible, which is attributable to the small size of the EU common budget ([Asdrubali and Kim, 2004](#), [Afonso and Furceri, 2008](#) and [Furceri and Zdzienicka, 2015](#)). Some studies document a significant drop in risk-sharing during the GFC and the ESDC. During these periods the capital market channel collapsed, and even acted as a shock amplifier ([Kalemli-Ozcan et al., 2014](#) and [Alcidi et al., 2017](#)). More recent studies find some improvement after 2012, with the help of official assistance programs of the ESM and the IMF ([Milano and Reichlin, 2017](#) and [Cimadomo et al., 2020](#)). The latest evidence from the Covid-19 pandemic shows some additional improvement through the credit channel, most likely due to the NGEU and its Recovery and Resilience Facility (RRF) ([Cimadomo et al., 2022](#) and [ECB, 2022](#)).

Overall, these studies suggest that risk-sharing estimates may be heterogeneous across countries and regions and have varied over the years. Nevertheless, to the best of our knowledge, there are no papers analysing how the importance of the three risk-sharing channels evolved over time. Two papers related to ours are [Asdrubali et al. \(2023\)](#) and [Foresti and Napolitano \(2022\)](#). The former paper proposes a heterogeneous panel VAR approach for 21 OECD countries where estimates of risk-sharing channels are allowed to change across countries, but not over time. [Foresti and Napolitano \(2022\)](#) add time variation to a framework which also allows for country heterogeneity. They analyse how the total amount of risk-sharing has changed over time, without disentangling the effects of the single channels. Moreover, they employ a static panel framework, i.e., they can only analyse the contemporaneous response to shocks. Our paper, on the other hand, proposes a fully-fledged dynamic panel VAR model with stochastic volatility. Our approach allows us to estimate shock absorption through the different channels in a time-varying framework, and to trace out how these channels react to the idiosyncratic output shock contemporaneously and up to four years after the shock.

The empirical literature on the interaction between risk-sharing channels is scarce. This literature documents either no interaction or substitution effects between the channels.

Evidence from the US from [Asdrubali and Kim \(2004\)](#) shows crowding-out effects between credit-market and capital-market channels. For EU and OECD countries, some papers also highlight substitution effects between capital markets and fiscal risk-sharing ([Asdrubali and Kim, 2004](#), [Alcidi et al., 2017](#) and [Asdrubali et al., 2023](#)). The possibility of complementarity between the credit and the capital channels is analysed in the context of the literature on the banking union and the capital market union for the EA (see, e.g., [Hoffmann et al., 2018](#)). In this paper, we contribute to the debate by bringing new empirical evidence on complementarity between the fiscal channel and the credit channel, based on a new test.

As a third contribution of the paper, we provide a narrative behind the observed time variation in risk-sharing in the US, based on some macroeconomic and financial determinants motivated by earlier literature. Previous studies identified several factors that could influence the risk-sharing mechanism. In particular, papers have analysed whether risk-sharing has been counter-cyclical, thus providing stronger absorption of local shocks when it is more needed (i.e., during economic downturns), or if it has been instead pro-cyclical, thus amplifying the effects of shocks. Focusing on the period 1963-2005, [Hoffmann and Shcherbakova-Stewen \(2011\)](#) find that inter-state risk-sharing in the US has been pro-cyclical, i.e., increasing in booms and decreasing during downturns. They show that income smoothing through capital income flows tends to be counter-cyclical, whereas the credit-saving channel is strongly pro-cyclical, and this latter effect turns out to dominate. This is confirmed by results from the EA, where a significant drop in risk-sharing has been documented around the GFC, due to the collapse of the capital market channel ([Kalemli-Ozcan et al., 2014](#) and [Alcidi et al., 2017](#)).

Financial deregulation and integration are also found to influence risk-sharing (see, e.g., [Athanasoulis and Wincoop, 2001](#) and [Demyanyk et al., 2007](#)). Furthermore, several empirical studies document that greater financial globalization tends to increase risk-sharing, at least among industrial countries. The underlying intuition is that more internationally diversified investment portfolios generate income flows that are unrelated to fluctuations in domestic income, therefore better isolating agents from idiosyncratic shocks that hit locally their economies (see [Kose et al., 2009](#), [Demyanyk et al., 2008](#), [Pierucci and Ventura, 2010](#) and [Rangvid et al., 2016](#)). Nevertheless, differences in regulation and accounting standards across countries may generate home bias, resulting in sub-optimal shares of foreign assets in domestic portfolios and lower-than-optimal international risk-sharing. Indeed, [Sørensen et al. \(2007\)](#) show that international home bias in debt and equity holdings declined during the period 1993-2003, and this decline was accompanied by an increase in international risk-sharing.

The above findings generally refer to periods of a financial upturn, while the effects of more financial market integration may be reversed during financial market downturns. In addition, if globalization leads to stronger co-movements between international stock

markets, the benefits of cross-border holdings of financial assets might be limited (see, e.g., [Beine et al., 2010](#)). This is sometimes referred to as the “knife-edge” property of the financial markets: financial interconnections work as a shock absorber (i.e., leading to more risk-sharing) in certain states of the world. In others, interconnections tend to generate shock amplification, i.e., risk-spreading (see [Tasca and Battiston, 2014](#); [Balli et al., 2013](#)).

The state of public finances may also have an effect on risk-sharing. A more prudent government and with a larger fiscal space has more capacity to finance regional counter-cyclical policies, therefore reinforcing shock absorption. [Stempel et al. \(2021\)](#) tests this hypothesis at the intra-state US level. He clusters US states based on their risk-sharing profiles. He finds that states differ both in the overall level of risk-sharing and also in the relative importance of each channel. State with stronger fiscal rules are likely to have a better government financial position ([Grembi et al., 2016](#)), and, therefore, more capacity for fiscal smoothing. This is likely to be valid also at the inter-state, i.e., federal level.

Another key determinant of risk-sharing could be monetary policy. A change in the interest rate environment directly affects credit costs and risk premia ([Gertler and Karadi, 2015](#)). This influences the marginal cost of smoothing via credit markets and fiscal policy. If monetary policy affects risk pricing, it could also have an effect on capital market smoothing.<sup>6</sup> Monetary policy is also likely to have strong effects during periods of financial market stress, in particular, if it backstops a financial meltdown, and a freeze of the capital and credit markets. The last section of this paper is devoted to investigate if these variables, in particular the business cycle, indices of financial development, the debt-ratio as measure of the state of public finances, and interest rates as measures of the monetary policy stance, had a role in influencing the effectiveness of the different risk-sharing channels.

### 3 Methodology

Our starting point is the framework proposed by [Asdrubali et al. \(1996\)](#), who quantify risk-sharing based on the cross-sectional variance decomposition of shocks to output. Empirically, this amounts to running regressions of each risk-sharing channel onto changes in output, using National Accounts data (for a brief derivation of this decomposition, see [Online Appendix A](#)). However, this static model does not capture the dynamic behaviour of consumption smoothing or feedback effects among the three channels. [Asdrubali and Kim \(2004\)](#) overcome this by generalizing the framework and estimating risk-sharing in a panel VAR model. They combine output and the smoothing variables in a single system of endogenous variables and apply a recursive identification scheme, motivated by the nature of the National Accounts variables. We follow the same approach in constructing our vector

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<sup>6</sup>In a recent paper, [Hauptmeier et al. \(2022\)](#) analyse the other direction of causality, i.e., they show that risk-sharing can influence the regional transmission of monetary policy.

of endogenous variables  $Y_{it}$ :

$$Y_{it} = \begin{pmatrix} \Delta \log GDP_{it} \\ \Delta \log GDP_{it} - \Delta \log GNP_{it} \\ \Delta \log GNP_{it} - \Delta \log GDI_{it} \\ \Delta \log GDI_{it} - \Delta \log C_{it} \end{pmatrix} \quad (1)$$

where, in the case of the EA,  $GDP_t^i$  is the real per capita gross domestic product of country  $i$  in year  $t$ ,  $GNP_t^i$  is the real per capita gross national product,  $GDI_t^i$  is the real per capita gross disposable income, and  $C_t^i$  is real per capita total consumption (both private and public). For the US, we use the state-level equivalents corresponding to the gross state product, state income, disposable state income, and state consumption. As standard in the literature, we interpret the changes in  $\Delta \log GDP_t^i - \Delta \log GNP_t^i$ ,  $\Delta \log GNP_t^i - \Delta \log GDI_t^i$  and  $\Delta \log GDI_t^i - \Delta \log C_t^i$  in response to orthogonalised shocks to  $\Delta \log GDP_t^i$ , as measures of risk-sharing achieved by capital markets (capital channel), international transfers (fiscal channel), and credit markets (credit channel), respectively. The response to  $GDP$  which is not absorbed by these three channels is labeled as “unsmoothed”. In order to identify the effects of idiosyncratic shocks, all variables are expressed in log-deviations from their respective weighted average values, where the weight of each country (state) in each year is based on the size of the real GDP (GSP in the case of the US) in the previous year.<sup>7</sup>

We extend the framework of [Asdrubali and Kim \(2004\)](#) by adding time-varying parameters and stochastic volatility to the baseline fixed-coefficient panel VAR model. In particular,  $Y_{it}$  denotes the matrix of  $N$  endogenous variables for country  $i$  and  $X_{it}$  collects all the right-hand-side variables  $X_{it} = [Y_{it-1}, \dots, Y_{it-p}, 1]$ .<sup>8</sup> The panel VAR is given by:

$$Y_{it} = X_{it}B_{it} + A_{it}^{-1}H_t^{1/2}e_{it} \quad (2)$$

$$e_{it} \sim N(0, \sigma_i^2)$$

where the intercept is the last column of  $X_{it}$ . The entries of the lower triangular contemporaneous impact matrix  $A_{it}$  have two components. The first component  $a_i$  is idiosyncratic, but fixed over time. The second component  $\alpha_t$  captures time-variation that is common across countries. The coefficient matrix  $B_{it}$  has the same structure. Its first component  $b_i$  is constant, but unit specific, while the second component  $\beta_t$  varies over time, but is common across countries. We focus on this component, as the interest of our analysis is on

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<sup>7</sup>We demean by the weighted averages to account for the different size of the countries/states in the respective region. However, below we show that demeaning by the simple averages (which effectively amounts to introducing time-fixed effects) produces very similar results.

<sup>8</sup>Due to presence of large outliers in the stochastic volatilities of the CRE series for the US, we also include five time dummies in  $X_t$ , namely for the years 1977, 1979, 1984, 1997 and 1999. The inclusion of these dummies does not materially affect the main results, but allows to obtain smoother impulse response functions.

the variation of risk-sharing channels over time.<sup>9</sup>

$$\begin{aligned}
 B_{it} &= b_i + \beta_t & A_{it} &= a_i + a_t \\
 \beta_t &= \beta_{t-1} + \eta_t & a_t &= a_{t-1} + v_t \\
 \eta_t &\sim N(0, Q_B) & v_t &\sim N(0, Q_A)
 \end{aligned}$$

We assume that the time-varying components  $\beta_t$  and  $a_t$  evolve as random walks, with variances  $Q_B$  and  $Q_A$ . The lower triangular form of  $A_{it}$  imposes contemporaneous feedback restrictions, as in [Asdrubali and Kim \(2004\)](#). Variables in the system are contemporaneously exogenous with respect to the variables ordered below it:  $\Delta \log GDP_t^i$  is the most exogenous, as  $GDP$  relates to the value added in production, before tax payments, and financial income or credit flows. And it is important to note that the responses of the three variables (each identifying one of the three risk-sharing channels) to an output shock (ordered first) are invariant to the ordering of these variables (see [Christiano et al., 1999](#)).

The residuals of the model are heteroscedastic with the stochastic volatility given by  $H_t$ , which is a diagonal matrix. The diagonal elements are assumed to evolve as geometric random walks. The volatility can also differ across units.

$$\begin{aligned}
 H_t &= \text{diag}(h_t) \\
 \ln h_t &= \ln h_{t-1} + \varepsilon_t \\
 \varepsilon_t &\sim N(0, g)
 \end{aligned}$$

The model is closely related to the panel VAR proposed in [Canova and Ciccarelli \(2004\)](#). However, the structure of the model is more parsimonious in our setting and the estimation is simpler as a result.<sup>10</sup> Our model generalises the threshold panel VAR used in [Mumtaz and Sunder-Plassmann \(2021\)](#) by allowing for the possibility of changes in coefficients and variances at each point in time. Finally, compared to time-varying VARs proposed in [Cogley and Sargent \(2005\)](#), the cross-sectional dimension of the model can help to obtain more precise estimates of the parameters of the state-transition equation. The model is estimated with a Gibbs sampler, based on the sampler for panel VARs described in [Canova and Ciccarelli \(2004\)](#) and [Jarocinski \(2010\)](#) and the sampler for TVP-VARs with stochastic volatility described in [Cogley and Sargent \(2005\)](#) and [Primiceri \(2005\)](#). The estimation

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<sup>9</sup>The unit-specific component of the coefficients,  $a_i$  and  $b_i$ , allows countries (or states in the US) to have unique risk-sharing profiles. However, as our interest is risk-sharing within a region, when showing our results, we produce them using the weighted average of  $b_i$  and  $a_i$ . Details of the estimation are shown in [Online Appendix B](#).

<sup>10</sup>[Canova and Ciccarelli \(2004\)](#) allow for the possibility of dynamic interdependencies amongst countries. This feature is not needed in our application and a simpler specification can be employed. In contrast to [Canova and Ciccarelli \(2004\)](#), we model time-variation directly in each coefficient and incorporate a stochastic volatility specification for the disturbances.

details are described in Online Appendix B, together with a Monte-Carlo experiment to test the estimation algorithm. The model is estimated with one lag, but below we show that our results are robust to the inclusion of two lags.

The dataset for the US covers the period from 1963 to 2020, all fifty states and it is sourced from the Bureau of Economic Analysis (BEA) and the US Census Bureau. We use the first ten years to train our priors. State income is constructed as state personal income plus federal nonpersonal taxes, contributions, and state and local nonpersonal taxes minus direct transfers to individuals. Disposable state income is state income plus federal grants to state governments, federal transfers to individuals minus federal nonpersonal taxes and contributions, and federal personal taxes. State consumption is PCE-deflated retail sales plus state and local government consumption.<sup>11</sup> The cross-sectional mean and standard deviation of the four series used in the panel VAR are displayed in Figure C1 of the Online Appendix.

The dataset for the EA is from the AMECO database (2022 Spring vintage) and covers the sample 1990-2023. We have decided to include in the analysis also 2022 and 2023, although these years were still preliminary at the time of the analysis, because this allows us to derive some insight into how risk-sharing has evolved during the Covid-19 pandemic and the subsequent economic crisis.<sup>12</sup> The sample includes the EA-19 countries (excluding Ireland<sup>13</sup>): Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, and Spain. We use the first seven years to train our priors. Gross national product is calculated as *GDP* plus net factor income from abroad. Gross disposable income is gross national product plus net transfers from abroad. Total consumption is gross disposable income minus gross national savings. The cross-sectional mean and standard deviation of the four series of the panel VAR for the EA are displayed in Figure C2 of the Online Appendix.

## 4 Results

In this section, we first estimate the evolution of the overall degree of risk-sharing and how the relative importance of the different risk-sharing channels has evolved over time in the US and the EA. We focus on both the risk-sharing achieved on impact, as well as four years after the shock. Then, we move on to explore whether the risk-sharing channels have acted as complements or substitutes over time. In order to do this, we develop a new test of

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<sup>11</sup>The variables definition follows Asdrubali et al. (1996). We, therefore, refer to their paper for a detailed description of how each variable is constructed.

<sup>12</sup>The results for the pre-2022 sample do not change significantly when we drop 2022 and 2023 from the analysis. Note that these years were not available in the US dataset at the time of the analysis.

<sup>13</sup>Ireland is excluded from the analysis owing to unusually large revisions of some of the country's main macroeconomic statistics for 2015 that were undertaken in July 2016. These revisions affected real GDP, some of its components and balance of payments figures.

the complementarity hypothesis based on the correlation between the time-varying impulse responses to the output shock. Finally, exploiting the length of the US sample, we explore potential determinants of each of the three risk-sharing channels.

## 4.1 Time variation in risk-sharing channels

We first analyse how the absorption of an output shock via the three channels has evolved over time in the US and the EA. This is represented by the impulse responses to the first shock in model (2). The reaction of the other endogenous variables tells us how a shock to the per capita output of an individual country or state is absorbed by the three risk-sharing channels. The total impact of the shock is normalised at every horizon, such that the reactions of the three channels plus the un-smoothed part add up to one hundred. Figure 1 displays the median impulse responses on impact (in blue), and the cumulative effect four years after the shock (in red) in the US. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentiles of the posterior distribution.<sup>14</sup>

The bottom right panel of the figure shows that the total amount of shock absorption has increased since the 1970s, which is reflected in a declining share of unsmoothed shocks over the sample. At the start of the sample, a drop in a state's output translated into a 35% drop in consumption in the year of the shock. In the mid-2010s, this decreased to around 20%, before picking up again somewhat at the end of the sample. We find less smoothing in the long run. Only 40% of an output shock was smoothed four years after the shock in the mid-1970s, which has increased to around 60% towards the end of our sample. This increase was mostly due to private risk-sharing channels, and, in particular, to the capital channel, which operates through cross-state factor income. On impact, the capital channel shows a sharp increase until the mid-1980s, and large fluctuations around 40% afterward. The last decade of the sample highlights an increase in shock absorption via this channel.

Figure 1 (blue line) also shows that the role of the credit channel has decreased from about 30% to 10% in the mid-1980s, and starts increasing again afterward, although with significant fluctuations. Interestingly, this positive trend, which is even more evident in the long run (red line), seems to accelerate with the Riegle-Neal Interstate Banking and Branching Efficiency Act, signed in 1994 and implemented in 1997, allowing the opening of bank branches across state lines. One explicit goal of the de-regulation was to allow banks to diversify geographic risk. The Act improved bank efficiency and increased state-level per capita growth of personal income and GDP (Jayaratne and Strahan, 1997 and Aguirregabiria et al., 2010). The effectiveness of the credit channel then decreases in the last part of the

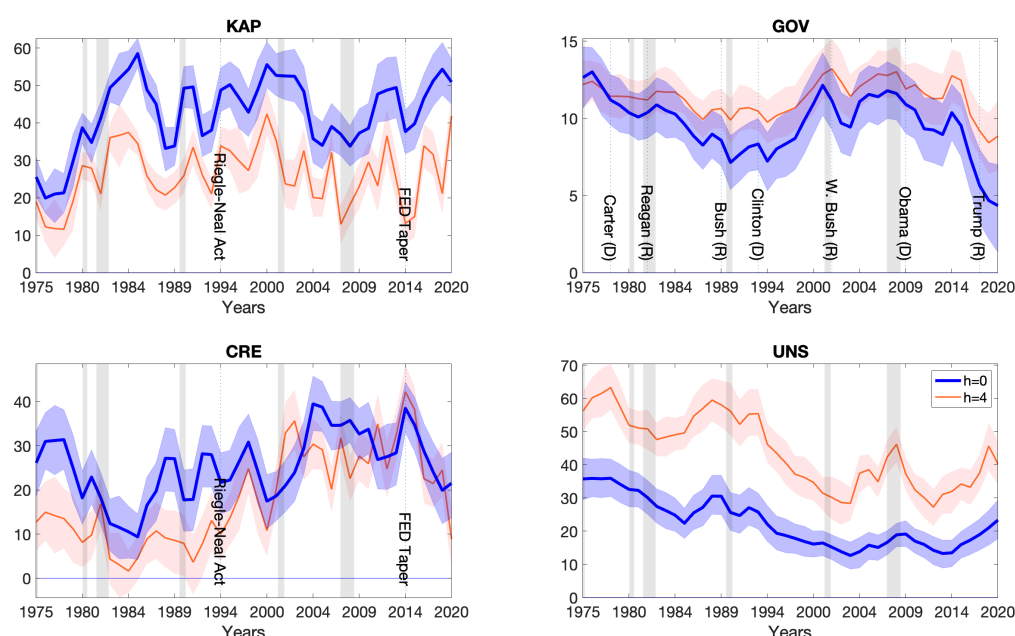
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<sup>14</sup>Figure C3 of the Online Appendix displays the surface plots of the median cumulative impulse responses over time. In this section, we report the normalized responses to facilitate the interpretation of the results, and directly quantify the relative importance of each risk-sharing channel. Figure C5 shows the estimated stochastic volatility series for the US.

sample, coinciding with the Fed’s tapering phase, which is generally considered to start in 2014.

The absorption capacity of the fiscal channel is above 10% in the beginning of the sample and then decreases to around 7% by the mid-1990s. The fiscal channel improves again until the GCF in 2008-2009 and then declines, in particular as of 2015, possibly due to a deterioration of the fiscal space in the US.<sup>15</sup> Finally, it is worth noticing that the overall effectiveness of the three risk-sharing channels is higher on impact relative to the long run, but there are interesting differences. For instance, the capital channel, and, although to a lesser extent, the credit channel, have a larger smoothing role on impact. On the other hand, the fiscal channel tend to have a larger role in the long run, possibly due to lagged and persistent effects of the federal fiscal transfers.

Figure 1: Impulse responses to a state-specific output shock in the US



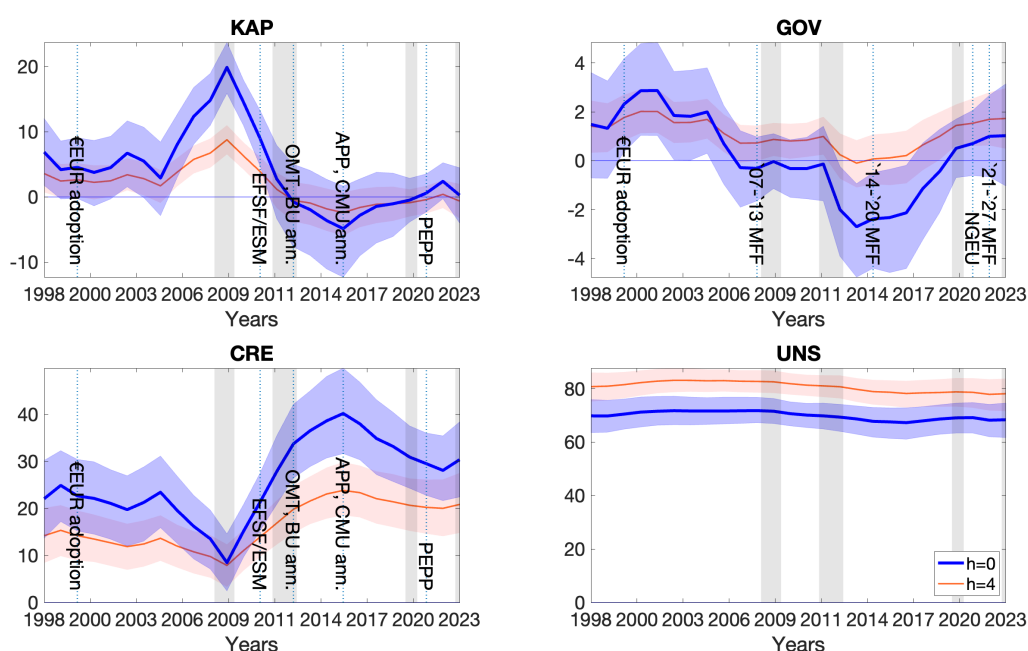
*Notes:* KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands around the median. Vertical shaded (grey) areas indicate NBER recessions, vertical dotted lines indicate the dates of the presidential elections, the start of the FED tapering, and the Riegle–Neal Interstate Banking and Branching Efficiency Act.

<sup>15</sup>In Section 4.3, we explore potential determinants of the risk-sharing channels, and find a negative association between the fiscal channel and the federal debt-to-GDP ratio. This could be related to the fact that a higher debt implies less fiscal space and capacity to finance counter-cyclical transfer policies.



The normalized impulse responses on impact and at the four years horizon for the EA are displayed in Figure 2.<sup>16</sup> First, we observe less risk-sharing among EA countries than among US states (see also ECB, 2022). Around 70% of a country’s output contraction translated into a drop in consumption in the year of the shock, and around 80% four years after the shock. Second, there is evidence of less time variation in the EA than in the US. Some improvement is noticeable, however, since the GFC of 2008-2009, as reflected in a slightly declining share of unsmoothed shocks.

Figure 2: Impulse responses to a country-specific output shock in the EA



*Notes:* KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands around the median. Vertical shaded (grey) areas indicate recessions. Dotted lines indicate the dates of the activation of the EFSF/ESM support programs, the APP and PSPP of the ECB, the NGEU program and the years of the EU multi-annual financial framework (MFF) budget.

The most striking result is in the development of the capital and the credit channels, which evolve in opposite directions. On impact, the capital channel smooths around 5% at the beginning of the sample, and then increases remarkably until the peak of the 2008-2009 GFC, which probably reflects the stronger capital integration among countries following the introduction of the monetary union. This also possibly shows the ex-ante nature of the capital channel, as portfolio allocations are made prior to the realization of a (negative) output shock, and may revert after such a shock. The capital channel then collapses during the

<sup>16</sup>The surface plots of the cumulative impulse responses are provided in Figure C4 of the Online Appendix. Figure C6 shows the stochastic volatility series.

GFC and thereafter declines sharply to even negative (although statistically insignificant) values in mid-2010s. The steady decline after 2009 can be due to flight-to-safety capital flows. Indeed, countries that were hit harder by the crisis (such as EA periphery countries) also experienced capital outflow towards countries that were less affected (such as EA core countries).

The credit channel resembles the mirror image of the capital channel. It accounts for the largest share of smoothing on impact (around 20%) at the beginning of the sample, and, after a drop ending in 2009, it shows a steep increase reaching 40% in 2015 and stabilizing at around 30% towards the end of our sample. The improvement after 2009 could be at least in part attributed to official assistance programs of the International Monetary Fund (IMF) and the ESM (see, also, [Cimadomo et al., 2020](#)). There is some evidence of a strengthening of the credit channel during Covid-19, which could be due to the NGEU funds and its Recovery and Resilience Facility (RRF) programs. The effect of these official programs is reflected in both the credit and the fiscal channels, as they have a loan and as well as a grant component ([Giovannini et al., 2022](#)). The ECB's pandemic emergency purchase programme (PEPP) may have also prevented a freeze in the interbank credit market in this period. The role of the fiscal channel is much smaller. Interestingly, it has dropped to slightly negative values between 2012 and 2017, which is evidence of dis-smoothing. Some improvement is visible from the mid-2010s, which could be attributed to a more fiscally ambitious EU multi-annual financial framework (MFF) for the period 2014-2020, entailing larger fiscal transfers between countries, and to fiscal grants under the EU's RRF. We also find that, similarly to the results for the US, whereas the private risk-sharing channels show the strongest smoothing role on impact, the effects of the fiscal channel are somewhat larger in the long run.

All in all, we uncover significant time variation in the risk-sharing channels and some improvement in smoothing in both regions.<sup>17</sup> These effects are mainly driven by private risk-sharing channels both in the US and the EA. However, while in the US the capital channel is the most important, we find that the credit channel tends to dominate in the EA, especially in the last part of the sample. We also find that the fiscal channel plays a more important role in the US relatively to the EA, but it has lost power in the last half of the 2010s, possibly due to a reduced fiscal space in this country.

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<sup>17</sup>These results are robust to estimating the model with endogenous variables demeaned by their respective simple averages (see Figures C7 and C8 of the Online Appendix), and using two lags instead of one (Figures C9 and C10 of the Online Appendix).

## 4.2 Complementarity vs. substitutability

This section is devoted to study the interaction between the three risk-sharing channels. Uncovering these relationships is important for two main reasons. First, our results show that capital markets can freeze during a financial crisis, which leads to fragmentation and flight-to-safety, seriously impeding risk-sharing. Therefore, it is useful to understand how the other channels respond, when one channel is less operative. Second, the interactions between the risk-sharing channels are specifically important in the context of a monetary union, where the single states or countries lose their monetary independence and exchange rate flexibility to counteract asymmetric shocks. In this context, it is crucial to understand how institutional reinforcing one channel (e.g., introduction of a Fiscal Union in the EA, or expansion of the federal budget in the US) affect the functioning of the other channels.

The hypothesis of complementary vs. substitutability between risk-sharing channels has not been formally tested in the literature, except for [Asdrubali and Kim \(2004\)](#). Using a panel of the US and other OECD countries for the period 1960-1990, they test complementarity by estimating the effect of a shock to one risk-sharing channel on the other channels. Here, we propose an alternative approach. In particular, our approach is based on the correlations between the impulse responses of the three risk-sharing channels to the idiosyncratic output shock. The interpretation is also different from the test proposed by [Asdrubali and Kim \(2004\)](#): in our case, we test how the various channels have co-moved, or diverged, *conditional* on an output shock, instead of looking how a channel responds to a shock to another channel, whose intuition is less clear in our view.

More specifically, we take each unscaled impulse response draw, and calculate the correlations among the three risk-sharing channels.<sup>18</sup> A negative correlation indicates that when one channel improves (deteriorates), the other channel tends to lose (gain) importance. This can be interpreted as evidence of substitution between the two channels. On the other hand, a positive correlation between the two channels is evidence of complementarity: one channel tends to improve when the effectiveness of the other channel(s) also increases. Such a test based on the impulse response correlations is a novelty, which is allowed by our time-varying parameter framework.

Table 1 shows the correlations among the risk-sharing channels in the US. The top panel refers to the full sample, while below we present the results for three sub-samples of 14 years each. The left side of the table reports the correlations of the impulse responses in the year of the shock ( $h = 0$ ), while the right side refers to the cumulative impulse responses four years after the shock ( $h = 4$ ). The correlation between the capital and the credit channels is negative in the full sample both in impact and in the long run. This suggests substitution between the two channels and potential crowding-out effects. An alternative explanation

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<sup>18</sup>The Gibbs sampler allows us to derive a empirical distribution of the impulse responses, therefore also of the correlations among risk sharing channels.

for a negative correlation is the spare-tire hypothesis suggested by [Levine et al. \(2016\)](#), who postulates that stock markets can mitigate the effects of a banking crisis through equity financing. Interestingly, the substitution effect between these two channels seem to be attenuated over time, as it was very strong in the 1976-1990 window, and becomes progressively less strong over the subsequent two windows, ending in 2020.

Table 1: Correlations among the risk-sharing channels in the United States

Full sample								
On impact ( $h = 0$ )				Long run ( $h = 4$ )				
	KAP	GOV	CRE	KAP	KAP	GOV	CRE	
KAP	1			KAP	1			
GOV	0.23* (0.07, 0.38)	1		GOV	0.34* (0.15, 0.51)	1		
CRE	-0.48* (-0.63, -0.32)	0.40* (0.20, 0.58)	1	CRE	-0.60* (-0.72, -0.44)	0.06 (-0.18, 0.31)	1	
1975 - 1990								
On impact ( $h = 0$ )				Long run ( $h = 4$ )				
	KAP	GOV	CRE	KAP	KAP	GOV	CRE	
KAP	1			KAP	1			
GOV	0.10 (-0.17, 0.38)	1		GOV	0.31* (0.00, 0.56)	1		
CRE	-0.72* (-0.84, -0.54)	0.30 (-0.03, 0.58)	1	CRE	-0.58* (-0.78, -0.27)	0.16 (-0.20, 0.49)	1	
1991 - 2005								
On impact ( $h = 0$ )				Long run ( $h = 4$ )				
	KAP	GOV	CRE	KAP	KAP	GOV	CRE	
KAP	1			KAP	1			
GOV	0.32* (0.01, 0.59)	1		GOV	0.19 (-0.20, 0.51)	1		
CRE	-0.54* (-0.74, -0.25)	0.14 (-0.21, 0.45)	1	CRE	-0.61* (-0.78, -0.36)	0.09 (-0.32, 0.50)	1	
2006 - 2020								
On impact ( $h = 0$ )				Long run ( $h = 4$ )				
	KAP	GOV	CRE	KAP	KAP	GOV	CRE	
KAP	1			KAP	1			
GOV	0.07 (-0.27, 0.40)	1		GOV	0.05 (-0.27, 0.36)	1		
CRE	-0.03 (-0.38, 0.32)	0.87* (0.76, 0.93)	1	CRE	-0.56* (-0.73, -0.31)	0.68* (0.45, 0.83)	1	

*Notes:* The left (right) panel shows the correlations of the unscaled impact (four-year cumulative) impulse responses to a state-specific output shock. For each draw of coefficients, we calculate the time series of the impulse response of each channel to the state-specific output shock, and then calculate the correlation between the three time series. The values reported are the medians, and the 16<sup>th</sup> and 84<sup>th</sup> percentiles (in parenthesis) of these correlations. Star denotes if zero is outside of the 16<sup>th</sup>-84<sup>th</sup> credible interval.

The correlation between the capital and the fiscal channels is found to be positive and statistically significant both on impact and in the long run in the full sample. Interestingly, for the full sample, we also find a positive correlation between the credit and the fiscal channels on impact. This relationship seems to be dominated by the last sub-sample (2006-2020), which shows a statistically significant correlation both on impact and in the long run. To the best of our knowledge, this is the first empirical evidence supporting the complementarity hypothesis between private and public risk-sharing channels outlined by [Farhi and Werning \(2017\)](#), [Buti and Carnot \(2018\)](#) and [Giovannini et al. \(2022\)](#).

The correlations between the risk-sharing channels in the EA are displayed in [Table 2](#). These findings are somewhat less clear-cut than for the US, also due to a smaller sample size,

but some observations are still worth noticing. First, we still find a substitution between the capital and the credit channels, although this relationship is statistically weak. We also document a positive correlation between the credit and the fiscal channels in the long run, although this is statistically significant only in the post-2010 sub-sample. This was the period in which the EFSF/ESM support programs were launched for some EA countries under financial stress, and the 2014-2020 multi-annual financial framework (MFF) budget was approved in the EU. Both programmes had a loan component (which is reflected in the credit channel) and a grant component (which affects the fiscal channel), therefore the two channels appeared to reinforce each other.

Overall, in this section we provide two main findings. Firstly, in the US and, although to a lesser extent, in the EA, the capital and credit risk-sharing channels act as substitutes. Secondly, for the US we also document some complementarity between the private and public risk-sharing channels, a finding which is consistent with [Farhi and Werning \(2017\)](#), [Buti and Carnot \(2018\)](#) and [Giovannini et al. \(2022\)](#).

Table 2: Correlations among the risk-sharing channels in the euro area

Full sample							
On impact ( $h = 0$ )				Long run ( $h = 4$ )			
	KAP	GOV	CRE		KAP	GOV	CRE
KAP	1			KAP	1		
GOV	0.01 (-0.27, 0.29)	1		GOV	0.21 (-0.12, 0.51)	1	
CRE	-0.32 (-0.57, 0.00)	-0.23 (-0.48, 0.06)	1	CRE	-0.15 (-0.47, 0.21)	0.12 (-0.22, 0.45)	1
1998 - 2010							
On impact ( $h = 0$ )				Long run ( $h = 4$ )			
	KAP	GOV	CRE		KAP	GOV	CRE
KAP	1			KAP	1		
GOV	-0.42 (-0.72, 0.00)	1		GOV	0.00 (-0.49, 0.53)	1	
CRE	-0.30 (-0.70, 0.33)	-0.04 (-0.48, 0.41)	1	CRE	0.17 (-0.46, 0.66)	0.10 (-0.36, 0.54)	1
2010 - 2023							
On impact ( $h = 0$ )				Long run ( $h = 4$ )			
	KAP	GOV	CRE		KAP	GOV	CRE
KAP	1			KAP	1		
GOV	0.09 (-0.32, 0.46)	1		GOV	0.26 (-0.16, 0.59)	1	
CRE	-0.11 (-0.43, 0.26)	-0.01 (-0.35, 0.33)	1	CRE	0.03 (-0.33, 0.40)	0.45* (0.08, 0.70)	1

*Notes:* The left (right) panel shows the correlations of the unscaled impact (four-year cumulative) impulse responses to a country-specific output shock. For each draw of coefficients, we calculate the time series of the impulse response of each channel to the country-specific output shock, and then calculate the correlation between the three time series. The values reported are the medians, and the 16<sup>th</sup> and 84<sup>th</sup> percentiles (in parenthesis) of these correlations. Star denotes if zero is outside of the 16<sup>th</sup>-84<sup>th</sup> credible interval.

### 4.3 Determinants of risk-sharing channels

In this final section, we attempt to explain the time variation in the responses of the risk-sharing channels to output shocks with some macroeconomic and financial determinants, motivated by the existing literature. The goal of this exercise is not to provide causal evidence of the drivers of risk-sharing, but rather to help us in building a narrative and to complement, within our time-varying framework, the findings of the existing literature. We focus on the US as this allows us to exploit 45 years of observations, whereas, for the EA, we have only two decades, which limit the feasibility of such an analysis. We investigate the role of some key macroeconomic and financial determinants, described at length in Section 2, in affecting the effectiveness of our three risk-sharing channels based a system of seemingly unrelated regressions (SUR), estimated with Bayesian methods. Our dependent variables are the unscaled median impulse responses of the three risk-sharing channels to the idiosyncratic output shock. Estimating these relationships in a system allows us to account for the correlation among the risk-sharing channels documented in the previous section, and improve the efficiency of the estimates. In order to account for the estimation uncertainty of the dependent variables in the system, we follow [Mumtaz and Sunder-Plassmann \(2021\)](#), and weight the observations with the inverse of the posterior variance of the risk-sharing channels. Intuitively, this amounts to a weighted least squares, that down-weights observations where the estimation uncertainty is large.

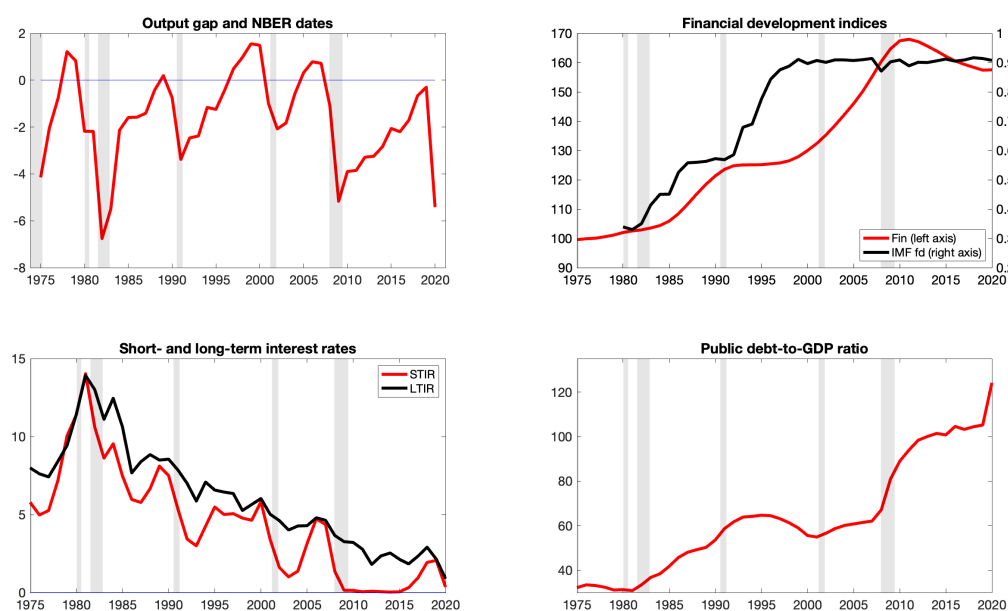
We focus on four main (sets of) explanatory variables, which are displayed in Figure 3: business cycle and financial development indices, short- and long-term interest rates (as proxies for the stance of monetary policy), and the public debt-to-GDP ratio (as a synthetic indicator for the state of public finances). The rationale of using this set of variables has been discussed in Section 2. First, as previous studies find that risk-sharing tends to vary with economic activity ([Hoffmann and Shcherbakova-Stewen, 2011](#) and [Furceri and Zdzienicka, 2015](#)), we take the output gap as a measure of the stance of business cycle. If risk-sharing through a specific channel increases in weak (strong) economic conditions, the coefficient on the output gap variable is expected to be negative (positive). The existing literature also argues that financial integration, deregulation, and innovation are expected to influence the overall level of risk-sharing ([Athanasoulis and Wincoop, 2001](#), [Kose et al., 2009](#), [Demyanyk et al., 2007](#) and [Demyanyk et al., 2008](#)). Therefore, following [Schularick and Taylor \(2012\)](#) who identify financial progress as the main determinant of the long-run trending behaviour of credit in advanced economies, we add the long-run trend of the credit-to-GDP series from the BIS as a proxy of financial development. In Figure 3 we observe that this series is increasing during most of the sample, albeit with a plateau in the early 1990s and a decrease after 2010.<sup>19</sup> In order to capture the stance of monetary policy and to proxy the overall interest-

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<sup>19</sup>We also experimented with an alternative measure for financial innovation, that is the Financial Markets Development composite index of the IMF, which, as Figure 3 shows, is only available as of 1980. These two

rate environment in the US, we use the the 3-month Treasury yield (STIR), and, as an alternative measure, the 10-year Treasury yield (LTIR). A higher interest-rate environment may raise the marginal cost of smoothing a negative shock to a state’s domestic product, as households and firms will need to borrow at higher rates. Similarly, it may also raise the cost of debt-financed fiscal stabilization. Lastly, as a measure of fiscal space, we include the US federal nominal debt-to-GDP ratio (Debt). Fiscal space may affect the capacity of the federal government to finance counter-cyclical policies (Stempel et al., 2021). As a result, we expect that with a lower (higher) debt-to-GDP ratio, the federal government will have more (less) fiscal space to absorb shocks. Figure 3 shows that, with the only exception of the period from 1995 to 2001, the US federal debt-to-GDP ratio steadily increased over the sample, from just above 30% in the mid-1970s to around 120% in 2020.

Figure 3: Time series of the determinants



*Note:* OG: output gap; NBER: annualised NBER recession indicator; Fin: Long-run credit-to-GDP trend obtained from the BIS; IMF fd: IMF financial development index; STIR: 3-month Treasury yield; LTIR: 10-year Treasury yield; Debt-to-GDP ratio: US federal nominal debt-to-GDP ratio. Vertical shaded areas indicate NBER recessions.

Our baseline regression results are displayed in Table 3. To address the potential simultaneity bias between the dependent and the independent variables, we use the lagged values of the predictors, which in practice can be interpreted as the initial conditions before a state-specific output shock hits. The first three columns show the regression results where the dependant variable is the impact ( $h = 0$ ) response of the risk-sharing channels to the output shock, whereas the last three columns display the estimates for the long-run financial innovation measures are highly positively correlated with each other (0.83).

(cumulated) responses four years ( $h = 4$ ) after the shock. We find that the output gap is negatively associated with both the capital and fiscal risk-sharing channels both on impact and after four years. This result is consistent with the capital markets and the federal government providing additional risk-sharing during downturns.<sup>20</sup> We also find that financial integration/innovation seems to have a positive relationship with the the fiscal and the credit channels. Our interpretation is that financial innovation (e.g., securitization of mortgage loans) improves agents' access to credit, which in turn strengthens risk-sharing through credit markets. The stance of the monetary policy does not seem to play a large role, with the only exception of the credit channel in the long run. More specifically, a higher interest-rate environment, which is generally associated with tighter credit conditions, leads to a lower role of the credit channel in the long run. Finally, we find that the debt-to-GDP ratio is negatively associated with the effectiveness of the government and the credit channels, both on impact and in the long run. The negative coefficient of the fiscal channel implies that a higher initial debt level (or less fiscal space) reduces risk-sharing via the federal tax and transfer system. This is consistent with the idea that more fiscal space leads to more capacity to implement counter-cyclical stabilization. A higher debt level also drives up interest rates in the economy, which makes smoothing through credit markets more expensive and results in less risk-sharing via that channel.

Our results are robust to the use of alternative measures of the stance of the business cycle, the interest-rate environment, and the financial development. More specifically, in Table C1 of Online Appendix C we replace the output gap with a dummy based on NBER recession dates. The dummy tracks the number of quarters within the year that are labeled as a recessions, e.g., it takes a value of 1 if the economy was in recession of the full year, 0.75 if the economy was in recession in three out of four quarters in a given year, etc. In Table C2 we use long-term Treasury yield instead of the short-term interest rate, and in Table C3 we test for the Financial Markets Development composite index of the IMF instead of the BIS credit-to-GDP trend. Results are qualitatively similar to what we find in Table 3.

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<sup>20</sup>This finding is also consistent with the empirical literature documenting larger fiscal multipliers during recessions (see e.g. [Auerbach and Gorodnichenko \(2012\)](#) among others).



Table 3: Determinants of the risk-sharing channels

	Impact ( $h = 0$ )			Long-run ( $h = 4$ )		
	KAP	GOV	CRE	KAP	GOV	CRE
Gap	-0.15*	-0.06*	0.07	-0.28*	-0.11*	-0.09
	(-0.26, -0.05)	(-0.08, -0.04)	(-0.01, 0.15)	(-0.41, -0.16)	(-0.14, -0.07)	(-0.17, 0.01)
Fin	0.01	0.01*	0.03*	0.01	0.01	0.08*
	(-0.00, 0.03)	(0.01, 0.02)	(0.01, 0.05)	(-0.01, 0.03)	(-0.00, 0.01)	(0.07, 0.10)
STIR	0.02	0.02	0.07	0.08	0.02	-0.19*
	(-0.08, 0.13)	(-0.00, 0.04)	(-0.00, 0.16)	(-0.05, 0.22)	(-0.02, 0.06)	(-0.29, -0.10)
Debt	-0.01	-0.02*	-0.04*	-0.01	-0.02*	-0.09*
	(-0.03, -0.00)	(-0.02, -0.01)	(-0.05, -0.02)	(-0.02, 0.01)	(-0.02, -0.01)	(-0.11, -0.08)

*Notes:* Bayesian weighted SUR regression with flat priors, and weights given by the inverse of the posterior variance of the risk-sharing channels. Dependent variables are the unscaled median impulse responses of the risk-sharing channels to the idiosyncratic output shocks, at horizon  $h = 0$  (left panel) or cumulated at horizon  $h = 4$  (right panel). Explanatory variables are the following. Gap: the output gap; Fin: long-run credit-to-GDP trend; STIR: 3-months Treasury yield; Debt: debt-to-GDP ratio. They are lagged at time  $t - 1$ . Constant omitted from the table. Stars denote if posterior median is outside of the 16<sup>th</sup>-84<sup>th</sup> percentile credible interval.

## 5 Conclusions

Focusing on the US and the EA, this paper offers new insights on how idiosyncratic output shocks, i.e., shocks which are not common to all states (US) or countries (EA), are absorbed by private and public risk-sharing channels. In particular, we look at the capital channel (income from cross-ownership of productive assets), the credit channel (cross-state or cross-border lending and borrowing), and the fiscal channel (federal or cross-country transfers). We assess how these three risk-sharing channels have operated over time within each region, using a novel time-varying parameter panel VAR model with stochastic volatility, which generalises [Mumtaz and Sunder-Plassmann \(2021\)](#).

Our analysis allows us to uncover that, over the last decades, the overall level of risk-sharing has clearly increased in the US and also, though to a smaller extent, in the EA. This improvement is mostly due to private risk-sharing channels. However, while in the US the role of the capital channel is the most sizable, we find that in the EA the credit channel dominates. Due to the presence of a larger federal system, we also find that the fiscal channel plays a more important role in the US relatively to the EA. Interestingly, we document that smoothing role of the private risk-sharing channels is larger on impact than in the long run, whereas the opposite is found for the fiscal channel.

In the second part of the paper, we study the degree of substitution and complementarity between the three risk-sharing channels. We find strong substitution effects between capital market smoothing and credit market smoothing in both regions. This can imply

either crowding out between these two channels, or support for the spare-tire hypothesis, postulating that stock markets can mitigate the effects of a banking crisis. In the case of the US, we also find evidence for complementarity between the private (e.g. credit and capital) and the public (e.g. fiscal) channels, which supports the argument of [Farhi and Werning \(2017\)](#).

Finally, for the US, we attempt to explain the time variation in the responses of the risk-sharing channels to output shocks with some macroeconomic and financial determinants. We show that the effectiveness of both the capital and the fiscal risk-sharing channels improves during weak economic conditions. We also find that the fiscal and credit channels work better under stronger financial integration, and when a country is characterised by more fiscal space. At the same time, monetary policy does not seem to be very powerful in influencing the functioning of risk-sharing channels.

Our results have important implications for the improvement of the European Monetary Union's governance framework. We show that there is substantial room to strengthen the shock absorption capacity of the EMU. The Capital Market Union and the Credit Market Union could reinforce risk-sharing and improve the resilience of the EA to macroeconomic shocks by contributing to smooth output shocks through the capital channel and the credit channel. However, policymakers should be mindful of substitution effects between these two channels. The US experience also points to positive externalities between the fiscal channel and the private risk-sharing channels. Looking at this finding from the perspective of the EA, this suggests that progress on the Fiscal Union could also have a beneficial effect on private risk-sharing mechanisms in the EMU.

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# Online Appendix (not for publication)

## A Deriving the risk-sharing coefficients

Our starting point is the methodology of [Asdrubali et al. \(1996\)](#), who decompose the cross-sectional variance of shocks to output. Consider the identity for the EA, that holds for each period  $t$ , suppressing the time index:

$$GDP_i = \frac{GDP_i}{GNP_i} \frac{GNP_i}{GDI_i} \frac{GDI_i}{C_i} C_i$$

where all the variables are in per-capita deviations from their respective regional aggregate values. Taking logs, differencing both sides and taking expectations leads to the cross-sectional decomposition of the variance in  $GDP$ :

$$\begin{aligned} \text{var}\{\Delta \log GDP_i\} &= \text{cov}\{\Delta \log GDP_i - \Delta \log GNP_i, \Delta \log GDP_i\} \\ &\quad + \text{cov}\{\Delta \log GNP_i - \Delta \log GDI_i, \Delta \log GDP_i\} \\ &\quad + \text{cov}\{\Delta \log GDI_i - \Delta \log C_i, \Delta \log GDP_i\} \\ &\quad + \text{cov}\{\Delta \log C_i, \Delta \log GDP_i\} \end{aligned}$$

Then, dividing by  $\text{var}\{\Delta \log GDP_i\}$  yields:

$$1 = \beta_{KAP} + \beta_{GOV} + \beta_{CRE} + \beta_{UNS}$$

where for example

$$\beta_{KAP} = \frac{\text{cov}\{\Delta \log GDP_i - \Delta \log GNP_i, \Delta \log GDP_i\}}{\text{var}\{\Delta \log GDP_i\}}$$

is the cross-sectional OLS slope coefficient in the regression of  $\Delta \log GDP_i - \Delta \log GNP_i$  on  $\Delta \log GDP_i$ . It is interpreted as the percentage of smoothing of an output shock, achieved through international factor income.

## B Estimation

### B.1 Priors and starting values

The following steps describe the setting of the priors and starting values.

1.  $p(b_i | \bar{b}, \lambda)$ . We assume a hierarchical prior for  $b_i$  centered on the weighted cross-section average  $\bar{b}$

$$p(b_i | \bar{b}, \lambda) \sim N(\bar{b}, \lambda \Lambda_i)$$

where  $\Lambda_i$  is set according to the Minnesota procedure. The parameter  $\lambda$  controls the degree of pooling in the model. As  $\lambda \rightarrow 0$  the heterogeneity across states declines. In order to set

the variances  $\Lambda_i$ , we use dummy observations as in [Banbura et al. \(2010\)](#), setting the overall prior tightness parameter to 1.

2.  $p(\lambda)$ . This prior is inverse Gamma:  $p(\lambda) \sim IG(S_0, V_0)$  where  $S_0 = 0$  and  $V_0 = -1$ . As discussed in [Gelman \(2006\)](#), this prior corresponds to a uniform prior on the standard deviation.
3.  $p(Q_B)$ . This prior is inverse Wishart  $IW(Q_0, T_0)$  As common in the literature on time-varying VARs, the scale matrix is set based on a pre-sample of  $T_0$  observations. Let  $Q_{ols}$  denote the average of the OLS estimate of coefficient covariance across countries using the pre-sample. We set  $Q_0 = Q_{ols} \times T_0 \times \kappa$  where  $\kappa = 0.003$ . Let  $\beta_{ols}$  denote the average OLS estimate of the coefficients using the pre-sample. Then the initial state is given as:  $\beta_{0 \setminus 0} \sim N(\beta_{ols}, Q_{ols})$
4.  $p(a_i | \bar{a}, \delta)$ . We set a hierarchical prior:

$$p(a_i | \bar{a}, \delta) \sim N(\bar{a}, \delta \Xi_i)$$

where  $\bar{a}$  are weighted cross-sectional averages and  $\Xi_i$  equals a matrix that reflects the relative scale of the residuals of the model. The degree of pooling is controlled by  $\delta$ .

5.  $p(\delta)$ . As in step 3 the prior is inverse Gamma  $p(\delta) \sim IG(s_0, v_0)$  where  $s_0 = 0$  and  $v_0 = -1$ .
6.  $p(Q_A)$ . This prior is inverse Wishart  $IW(Q_{A,0}, T_{A,0})$ .  $Q_{A,0}$  is set as a block diagonal matrix. Each block corresponds the time-varying elements in each row of  $A_{it}$ . The diagonal elements for each block are set equal to 0.001. The degrees of freedom  $T_{A,0}$  are set equal to the rows of the block plus 1 indicating a non-informative prior. The initial values  $a_{0 \setminus 0}$  are set using OLS estimates as in step 3 above.
7. Starting values for  $H_t$  are obtained as  $(e_t^{ols})^2 + 0.001$  where  $e_t^{ols}$  denote the OLS estimates of the residuals of the panel VAR assuming fixed coefficients. A small scaling factor is added to the squared residuals to remove zeros. The initial conditions are  $\ln h_{0 \setminus 0} \sim N(\bar{\mu}_i, s)$  where  $\bar{\mu}_i$  are the diagonal elements of the VAR error covariance estimated via OLS on the pre-sample explained in step 3.
8.  $p(g_i)$ . The prior is inverse Gamma:  $IG(g_0, d_0)$  where  $g_0 = 0.01$  and  $d_0 = 1$ .
9.  $p(\sigma_i^2)$ . The prior is inverse Gamma:  $IG(\sigma_0, D_0)$  where  $\sigma_0 = 0.01$  and  $D_0 = 1$ .

## B.2 Gibbs sampling algorithm

The Gibbs sampling algorithm involves sampling from the conditional posterior distributions described below. The Gibbs sampler is based on the sampler for panel VARs described in [Canova and Ciccarelli \(2004\)](#) and [Jarocinski \(2010\)](#). In addition, it features elements of the sampler for TVP-VARs with stochastic volatility described in [Cogley and Sargent \(2005\)](#) and [Primiceri \(2005\)](#). Note that  $\Psi$  denotes all remaining parameters.



1.  $H(a_t|\Psi)$ . Given the coefficients  $B_{it}$  and the stochastic volatilities  $H_{it}$ , the model can be written as

$$A_{it}u_{it} = H_{it}^{1/2}\tilde{e}_{it}$$

$$\tilde{e}_{it} \sim N(0, 1)$$

where  $u_{it} = Y_{it} - X_{it}B_{it}$  and  $u_{it} = [u_{1,it}, \dots, u_{N,it}]$ ,  $\tilde{e}_{it} = [\tilde{e}_{1,it}, \dots, \tilde{e}_{N,it}]$ ,  $H_{it} = \text{diag}(h_{it})$  where  $h_{it} = [h_{1,it}, \dots, h_{N,it}] = [\sigma_{1,i}^2 h_{1,t}, \dots, \sigma_{N,i}^2 h_{N,t}]$ . For each cross-sectional unit, this represents a system of equations:

$$u_{1,it} = (h_{1,it})^{1/2} \tilde{e}_{1,it}$$

$$u_{2,it} = -a_{(2,1),it}u_{1,it} + (h_{2,it})^{1/2} \tilde{e}_{2,it}$$

$$u_{3,it} = -a_{(3,1),it}u_{1,it} - a_{(3,2),it}u_{2,it} + (h_{3,it})^{1/2} \tilde{e}_{3,it}$$

$$\cdot$$

$$\cdot$$

$$u_{N,it} = \sum_{j=1}^{N-1} -a_{(N,j),it}u_{j,it} + (h_{4,it})^{1/2} \tilde{e}_{N,it}$$

The first equation is an identity and can be ignored. Note that as we condition on the unit specific coefficients  $a_i$ , this system can be written as:

$$u_{1,it} = (h_{1,it})^{1/2} \tilde{e}_{1,it} \tag{B1}$$

$$u_{2,it} - (-a_{(2,1),i}u_{1,it}) = -a_{(2,1),t}u_{1,it} + (h_{2,it})^{1/2} \tilde{e}_{2,it} \tag{B2}$$

$$u_{3,it} - (-a_{(3,1),i}u_{1,it} - a_{(3,2),i}u_{2,it}) = -a_{(3,1),t}u_{1,it} - a_{(3,2),t}u_{2,it} + (h_{3,it})^{1/2} \tilde{e}_{3,it} \tag{B3}$$

$\cdot$   
 $\cdot$

$$u_{N,it} - \left( \sum_{j=1}^{N-1} -a_{(N,j),i}u_{j,it} \right) = \sum_{j=1}^{N-1} -a_{(N,j),t}u_{j,it} + (h_{4,it})^{1/2} \tilde{e}_{N,it} \tag{B4}$$

That is, unit specific effects can be subtracted out leaving the common time-varying component. Given the assumption that  $Q_A$  is block diagonal, each equation can then be stacked across the cross-sectional units (as the time-varying coefficients are common across units) and has the following state space representation:

$$\tilde{U}_{m,t} = \sum_{j=1}^{m-1} -a_{(m,j),t}U_{j,t} + V_{m,t} \tag{B5}$$

$$a_{m,t} = a_{m,t-1} + v_{m,t}$$

where  $m$  denotes the  $m$ th equation and :  $\tilde{U}_{m,t} = \begin{pmatrix} u_{m,1t} - \left(\sum_{j=1}^{m-1} -a_{(m,j),1}u_{j,1t}\right) \\ \vdots \\ u_{m,Mt} - \left(\sum_{j=1}^{m-1} -a_{(m,j),M}u_{j,Mt}\right) \end{pmatrix}, U_{j,t} =$

$\begin{pmatrix} u_{j,1t} \\ \vdots \\ u_{j,Mt} \end{pmatrix}, V_{m,t} = \begin{pmatrix} (h_{m,1t})^{1/2} \tilde{e}_{m,1t} \\ \vdots \\ (h_{m,Mt})^{1/2} \tilde{e}_{m,Mt} \end{pmatrix}$  and  $a_{m,t} = [a_{(1,j),t}, \dots, a_{(m-1,j),t}]$  is the vector of

coefficients. The variance of  $v_{m,t}$  is the  $m$ th diagonal block of  $Q_A$ . Given the conditionally linear and Gaussian state-space model in equation B5, the Carter and Kohn (1994) algorithm can be used to draw from the conditional posterior of  $a_{m,t}$ . This is repeated for each equation in the system.

2.  $H(Q_A|\Psi)$ . Note that vector  $a_{j,t}$  denotes the time-varying coefficients of the  $j$ th equation. For example  $a_{3,t} = [a_{(3,1),t}, a_{(3,2),t}]$  in equation B3. Given a draw for  $a_{j,t}$ , the  $j$ th diagonal block of  $Q_A$  has an inverse Wishart conditional posterior:

$$IW((a_{j,t} - a_{j,t-1})' (a_{j,t} - a_{j,t-1}) + Q_{j,A,0}, T + T_{A,0})$$

where  $Q_{j,A,0}$  denotes the  $j$ th diagonal block of  $Q_A$ .

3.  $H(\beta_t|\Psi)$ . Given a draw for the elements of  $A$ , the stochastic volatility  $H_{it}$  and the unit specific coefficients  $b_i$ , the panel VAR can be written as:

$$y_{it} = x_{it}\beta_t + \bar{e}_{it}$$

where  $y_{it} = \text{vec}(Y_{it} - X_{it}b_i)$ ,  $x_{it}$  denotes the RHS variables stacked:  $\begin{pmatrix} X_{1,t} \\ \vdots \\ X_{M,t} \end{pmatrix}$  and  $\text{var}(\bar{e}_{it}) =$

$\text{blkdiag}([A_{1t}^{-1}H_{1t}^{1/2}A_{1t}^{-1'}, \dots, A_{Mt}^{-1}H_{Mt}^{1/2}A_{Mt}^{-1'}])$  where  $H_{it} = \text{diag}(h_t\sigma_i^2)$ . Given the transition equation  $\beta_t = \beta_{t-1} + \eta_t$ ,  $\text{var}(\eta_t)$ , this represents a conditionally linear Gaussian state-space system and the Carter and Kohn (1994) algorithm can be used to draw  $\beta_t$ .

4.  $H(Q_B|\Psi)$ . Given a draw for  $\beta_t$ , the conditional posterior for  $Q_B$  is inverse Wishart:

$$IW((\beta_t - \beta_{t-1})' (\beta_t - \beta_{t-1}) + Q_0, T + T_0)$$

5.  $H(b_i|\Psi)$  for  $i = 1, 2, \dots, M$ . Given a draw for the time-varying VAR coefficients  $\beta_t$  and the matrix  $A_{it}$  and the volatility  $H_{it}$ , the model for  $i$ th unit can be written as

$$\bar{Y}_{it} = X_{it}b_{it} + \bar{e}_{it}$$

where  $\bar{Y}_{it} = Y_{it} - X_{it}\beta_t$  and  $var(\bar{e}_{it}) = \Sigma_{it} = A_{it}^{-1}H_{it}A_{it}^{-1'}$ . This is a VAR with heteroscedastic disturbances. After a GLS transformation, the conditional posterior is normal:  $N(M, V)$

$$M = V \left( vec \left( \sum_{t=1}^T (X_{it}\bar{Y}_{it}'\Sigma_{it}^{-1}) \right) + (\lambda\Lambda_i)^{-1}\bar{b} \right)$$

$$V = \left( \sum_{t=1}^T (\Sigma_{it}^{-1} \otimes X_{it}X_{it}') + (\lambda\Lambda_i)^{-1} \right)^{-1}$$

6.  $H(a_i|\Psi)$  for  $i = 1, 2, \dots, M$ . For each unit, the model can be written in terms of the residuals:

$$A_{it}u_{it} = H_{it}^{1/2}\tilde{e}_{it}$$

$$\tilde{e}_{it} \sim N(0, 1)$$

where  $u_{it} = Y_{it} - X_{it}B_{it}$  and  $u_{it} = [u_{1,it}, \dots, u_{N,it}]$ ,  $\tilde{e}_{it} = [\tilde{e}_{1,it}, \dots, \tilde{e}_{N,it}]$ ,  $H_{it} = diag(h_{it})$  where  $h_{it} = [h_{1,it}, \dots, h_{N,it}] = [\sigma_{1,i}^2 h_{1,t}, \dots, \sigma_{N,i}^2 h_{N,t}]$ . As noted above, this is a system of equations:

$$u_{1,it} = h_{1,it}^{1/2}\tilde{e}_{1,it}$$

$$u_{2,it} = -a_{(2,1),it}u_{1,it} + h_{2,it}^{1/2}\tilde{e}_{2,it}$$

$$u_{3,it} = -a_{(3,1),it}u_{1,it} - a_{(3,2),it}u_{2,it} + h_{3,it}^{1/2}\tilde{e}_{3,it}$$

$$\vdots$$

$$\vdots$$

$$u_{N,it} = \sum_{j=1}^{N-1} -a_{(N,j),it}u_{j,it} + h_{N,it}^{1/2}\tilde{e}_{N,it}$$

We can subtract out the impact of the common time-varying coefficients:

$$u_{1,it} = h_{1,it}^{1/2}\tilde{e}_{1,it} \tag{B6}$$

$$u_{2,it} - (-a_{(2,1),t}u_{1,it}) = -a_{(2,1),i}u_{1,it} + h_{2,it}^{1/2}\tilde{e}_{2,it} \tag{B7}$$

$$u_{3,it} - (-a_{(3,1),t}u_{1,it} - a_{(3,2),t}u_{2,it}) = -a_{(3,1),i}u_{1,it} - a_{(3,2),i}u_{2,it} + h_{3,it}^{1/2}\tilde{e}_{3,it} \tag{B8}$$

$\vdots$   
 $\vdots$

$$u_{N,it} - \left( \sum_{j=1}^{N-1} -a_{(N,j),t}u_{j,it} \right) = \sum_{j=1}^{N-1} -a_{(N,j),i}u_{j,it} + h_{N,it}^{1/2}\tilde{e}_{N,it} \tag{B9}$$

The first equation is redundant, while the remaining equations represent linear regressions with heteroscedasticity. For the  $m$ th equation let the dependent variable be denoted by  $\check{y}_m$  and the independent variables by  $\check{x}_m$ , then the regression can be written as

$$\check{y}_m = \check{x}_m\check{b}_m + h_{m,it}^{1/2}\tilde{e}_{m,it}$$

Let  $\check{y}_m^* = \frac{\check{y}_m}{h_{m,it}^{1/2}}$ ,  $\check{x}_m^* = \frac{\check{x}_m}{h_{m,it}^{1/2}}$  and the model can be written in terms of a unit variance error term. The conditional posterior for this linear regression is normal:  $N(m, v)$

$$m = \left( (\delta \Xi_i)^{-1} + \check{x}_m^{*'} \check{x}_m^* \right)^{-1} \left( (\delta \Xi_i)^{-1} \bar{a} + \check{x}_m^{*'} \check{y}_m^* \right)$$

$$v = \left( (\delta \Xi_i)^{-1} + \check{x}_m^{*'} \check{x}_m^* \right)^{-1}$$

7.  $H(\sigma_i^2 | \Psi)$  for  $i = 1, 2, \dots, M$ . For each unit, the model can be written in terms of the orthogonal residuals

$$A_{it} u_{it} = \check{e}_{it}$$

where  $\check{e}_{it} = [\check{e}_{1,it}, \dots, \check{e}_{N,it}]$ . Note that  $\text{var}(\check{e}_{it}) = \text{diag}(h_t \sigma_i^2)$  with  $h_t = [h_{1,t}, \dots, h_{N,t}]$  and  $\sigma_i^2 = [\sigma_{1,i}^2, \dots, \sigma_{N,i}^2]$ . A GLS transformation can remove the influence of  $h_t$

$$\check{e}_{it}^* = \frac{\check{e}_{it}}{h_t^{1/2}}$$

and  $\sigma_{m,i}^2$  can be drawn from the inverse Gamma distribution as :

$$IG(\check{e}_{m,it}^{*'} \check{e}_{m,it}^* + \sigma_0, T + D_0)$$

for  $m = 1, \dots, N$ .

8.  $H(H_t | \Psi)$ . The model for the  $i$ th unit can be written as

$$A_{it} u_{it} = H_t^{1/2} e_{it}$$

where  $e_{it} = [e_{1,it}, \dots, e_{N,it}]$ ,  $H_t = \text{diag}(h_t)$  with  $h_t = [h_{1,t}, \dots, h_{N,t}]$  and  $e_{it} \sim N(0, \sigma_i^2)$  with  $\sigma_i^2 = [\sigma_{1,i}^2, \dots, \sigma_{N,i}^2]$ . Stacking the  $m$ th orthogonal residual across units  $m = 1, \dots, N$ , we get the non-linear state space system:

$$\begin{pmatrix} h_{m,t}^{1/2} e_{m,1t} \\ \vdots \\ h_{m,t}^{1/2} e_{m,Mt} \end{pmatrix}, \text{var} \begin{pmatrix} e_{m,1t} \\ \vdots \\ e_{m,Mt} \end{pmatrix} = \text{diag}(\sigma_i^2)$$

$$\ln h_{m,t} = \ln h_{m,t-1} + \varepsilon_{m,t}, \text{var}(\varepsilon_{m,t}) = g_m$$

Thus each orthogonalised residual features common stochastic volatility. As in [Cogley and Sargent \(2005\)](#), we use the independence Metropolis algorithm of [Jacquier et al. \(2004\)](#) to sample each column of  $h_{m,t}$ .

9.  $H(g | \Psi)$ . Given a draw for  $\ln h_t$ , the variances  $g = [g_1, \dots, g_N]$  can be drawn one by one from the inverse Gamma distribution:

$$IG((\ln h_{m,t} - \ln h_{m,t-1})' (\ln h_{m,t} - \ln h_{m,t-1}) + g_0, T + d_0)$$

10.  $H(\lambda|\Psi)$ . The form of the conditional posterior is inverse Gamma with scale parameter  $\sum_{i=1}^M (b_i - \bar{b}) \Lambda_i^{-1} (b_i - \bar{b})' + S_0$  and degrees of freedom  $(M \times \bar{K}) + V_0$  where  $\bar{K} = N(Np+1)$
11.  $H(\delta|\Psi)$ . The form of the conditional posterior is inverse Gamma with scale parameter  $\sum_{i=1}^M (a_i - \bar{a}) \Xi (a_i - \bar{a})' + s_0$  and degrees of freedom  $(M \times \tilde{K}) + v_0$  where  $\tilde{K} = \frac{N(N-1)}{2}$
12.  $H(\bar{b}|\Psi)$ . By the Bayes Theorem,  $H(\bar{b}|b_i, \lambda) \propto p(b_i|\bar{b}, \lambda) p(\bar{b})$ . This density is normal as  $p(b_i|\bar{b}, \lambda)$  is normal and product of the normal priors for each  $i$ . With a flat prior for  $\bar{b}$  this density is given by  $N(\bar{M}, \bar{V})$  :

$$\bar{V} = \left( \frac{1}{\lambda} \sum_{i=1}^M \Lambda_i^{-1} \right)^{-1}$$

$$\bar{M} = \bar{V} \left( \frac{1}{\lambda} \sum_{i=1}^M \Lambda_i^{-1} b_i \right)$$

13.  $H(\bar{a}|\Psi)$ . As in step 11, this conditional posterior is normal  $N(\bar{m}, \bar{v})$

$$\bar{v} = \left( \frac{1}{\delta} \sum_{i=1}^M \Xi_i^{-1} \right)^{-1}$$

$$\bar{m} = \bar{v} \left( \frac{1}{\delta} \sum_{i=1}^M \Xi_i^{-1} a_i \right)$$

### B.3 Monte-Carlo experiment

To test the algorithm and code, we run a small Monte-Carlo experiment. We generate data from the following panel VAR model:

$$Y_{it} = X_{it} B_{it} + A_{it}^{-1} H_t^{1/2} e_{it}$$

where  $Y_{it}$  contains  $N = 3$  endogenous variables for  $i = 1, 2, \dots, M = 40$  units. The time series is assumed to be  $t = 1, 2, \dots, 160$ . The first 100 observations are discarded to remove the influence of initial conditions leaving a time-series of  $T = 60$ .

The components for the VAR coefficients  $B_{it} = b_i + \beta_t$  are generated as follows.  $b_i$  is assumed

to be  $N(\text{vec}(\bar{b}), \bar{v})$  where  $\bar{b} = \begin{pmatrix} 0.7 & -0.1 & -0.1 \\ 0.1 & 0.7 & 0.1 \\ -0.1 & 0.1 & 0.7 \\ 0 & 0 & 0 \end{pmatrix}$  and  $\bar{v} = 0.01$ .  $\beta_t$  is assumed to follow a

simple process. For the first 30 observations  $\beta_t = \text{vec} \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$  and for the remainder  $\beta_t =$

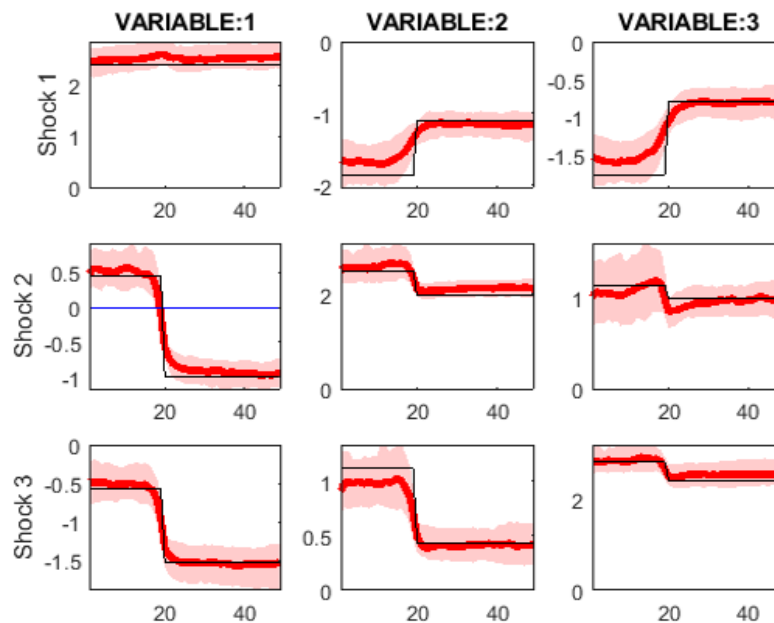
$vec \begin{pmatrix} -0.1 & -0.1 & -0.1 \\ -0.1 & -0.1 & -0.1 \\ -0.1 & -0.1 & -0.1 \\ -0.1 & -0.1 & -0.1 \end{pmatrix}$ . This formulation, thus induces a one-time change in the coefficients.

A similar process is assumed for the elements of  $A_{it} : a_{it} = a_i + a_t$ .  $a_i$  is generated from  $N(\bar{a}, \bar{w})$  where  $\bar{a} = \begin{pmatrix} 0.2 \\ 0.1 \\ -0.2 \end{pmatrix}$ ,  $\bar{w} = 0.01$ .  $a_t = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$  for the first 30 observations and  $a_t = \begin{pmatrix} -0.3 \\ -0.3 \\ -0.3 \end{pmatrix}$  for the remainder.

$\ln h_t$  is assumed to be zero for the first 30 observations and then assumed to increase to one.  $\sigma_i^2$  is drawn from  $U(0, 1)$ .

Given the artificial data, the Gibbs sampling algorithm described above is used to approximate the posterior distribution. We use 10,000 iterations discarding the first 5,000 as burn-in. The saved draws are used to compute the time-varying impulse response to three shocks identified via a recursive scheme. The experiment is repeated 100 times.

Figure B1: Estimated and true cumulative impulse responses



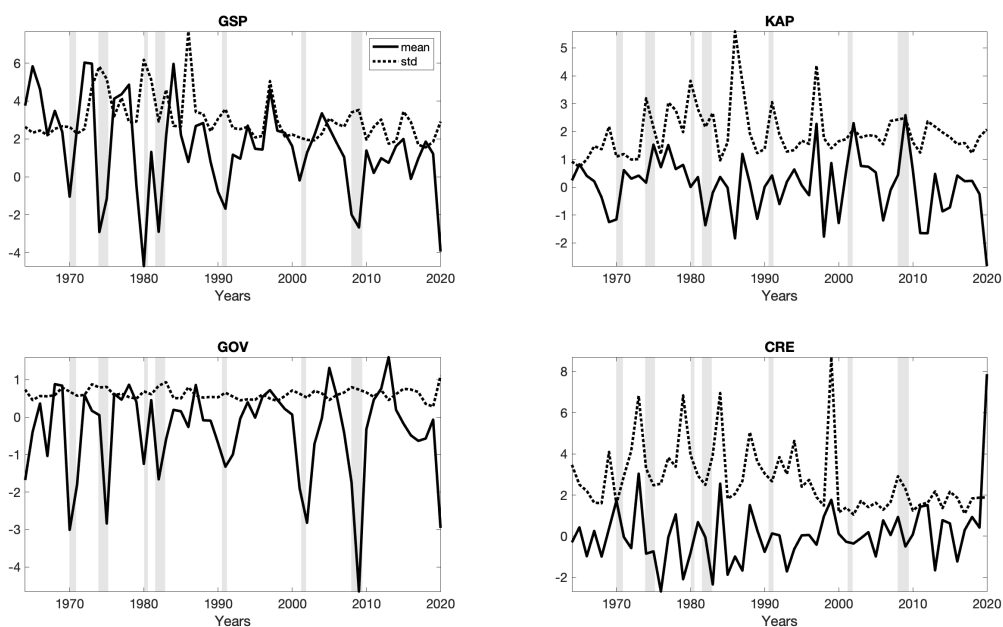
*Note:* The red line and the shaded area show the median estimated response, the 16<sup>th</sup> and the 84<sup>th</sup> bands. The black line shows the true response. The responses are cumulated and the plotted for horizon 40.

Figure B1 shows the estimated cumulated responses at horizon 40 to the three shocks for the average unit (median and 1-standard-error bands across the replications). The black line displays the true responses. The figures show that the estimated responses track the structural change reasonably well.

# C Figures and Tables

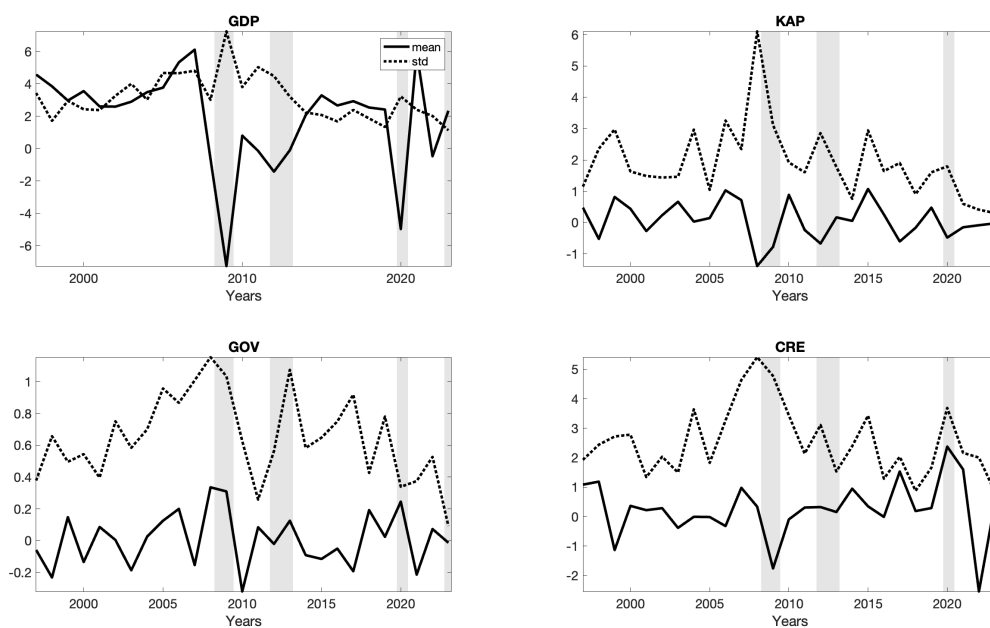
## C.1 Figures

Figure C1: Cross-sectional mean and std. deviation of the series in the US



Notes:  $GSP = \Delta \log GSP_t$ ,  $KAP = \Delta \log GSP_t - \Delta \log SI_t$ ,  $GOV = \Delta \log SI_t - \Delta \log DSI_t$ ,  $CRE = \Delta \log DSI_t - \Delta \log C_t$ . Vertical shaded areas indicate NBER recessions.

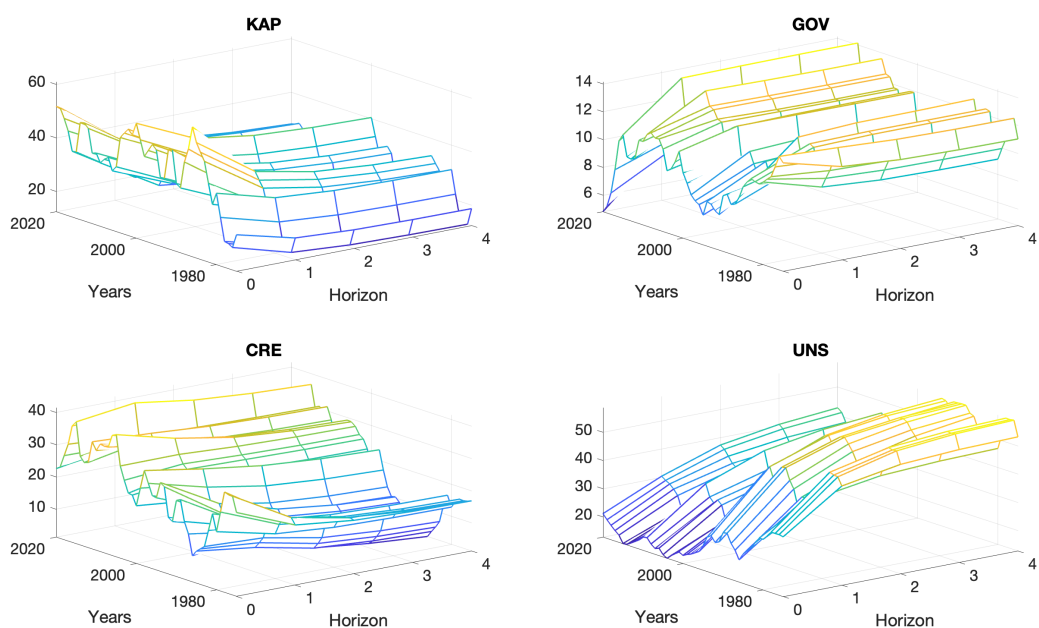
Figure C2: Cross-sectional mean and std. deviation of the series in the EA



Notes:  $GDP = \Delta \log GDP_t$ ,  $KAP = \Delta \log GDP_t - \Delta \log GNP_t$ ,  $GOV = \Delta \log GNP_t - \Delta \log GDI_t$ ,  $CRE = \Delta \log GDI_t - \Delta \log C_t$ . Vertical shaded areas indicate recessions.

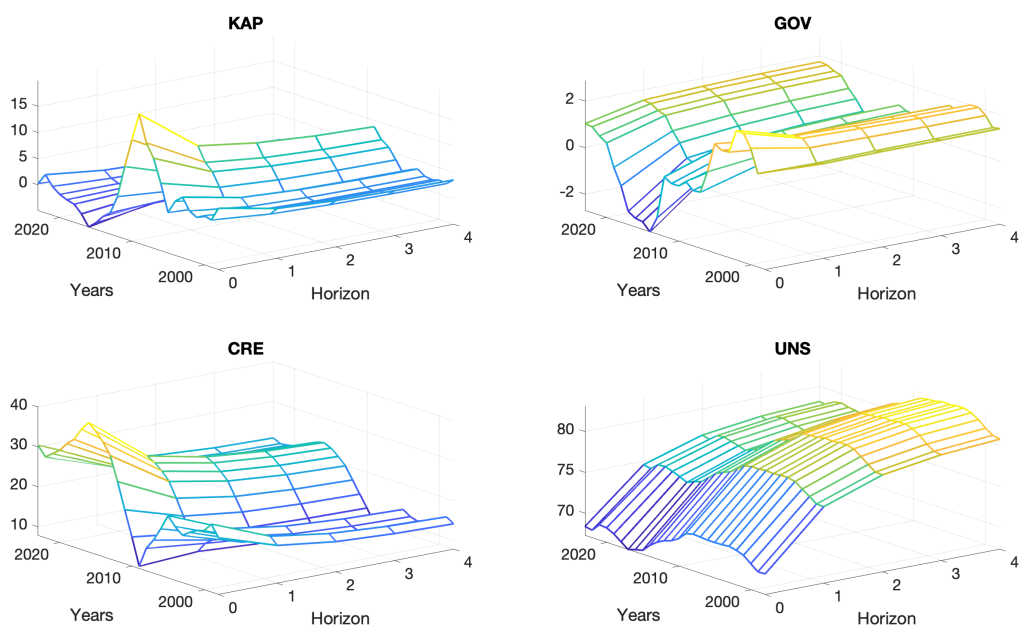


Figure C3: Median cumulative impulse responses to a state-specific output shock in the US



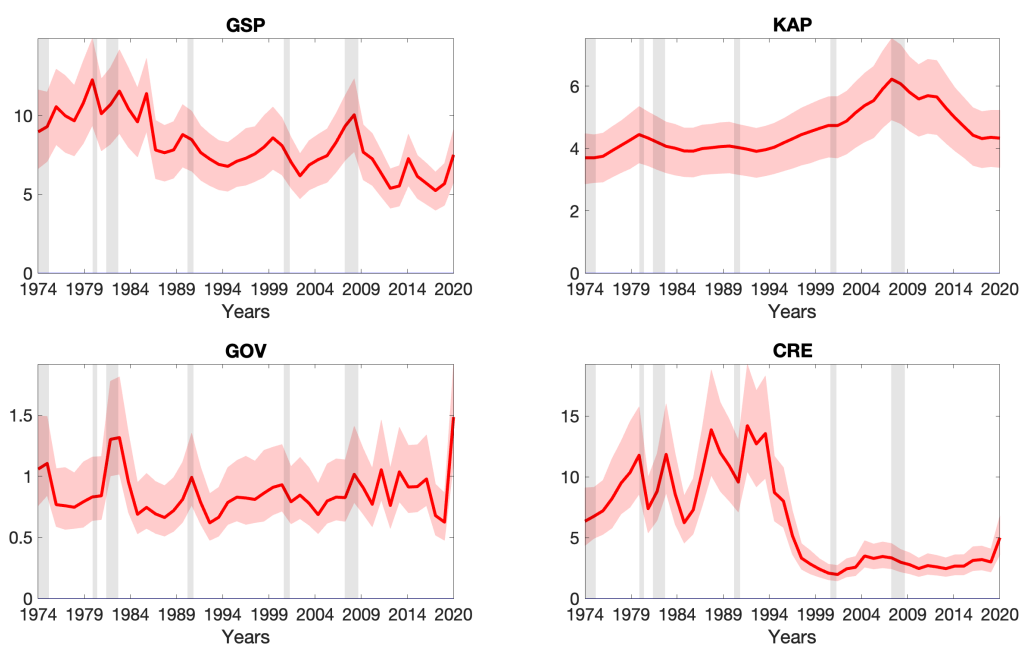
Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. The effects of the shock are normalized to one hundred in each horizon.

Figure C4: Median cumulative impulse responses to a country-specific output shock in the EA



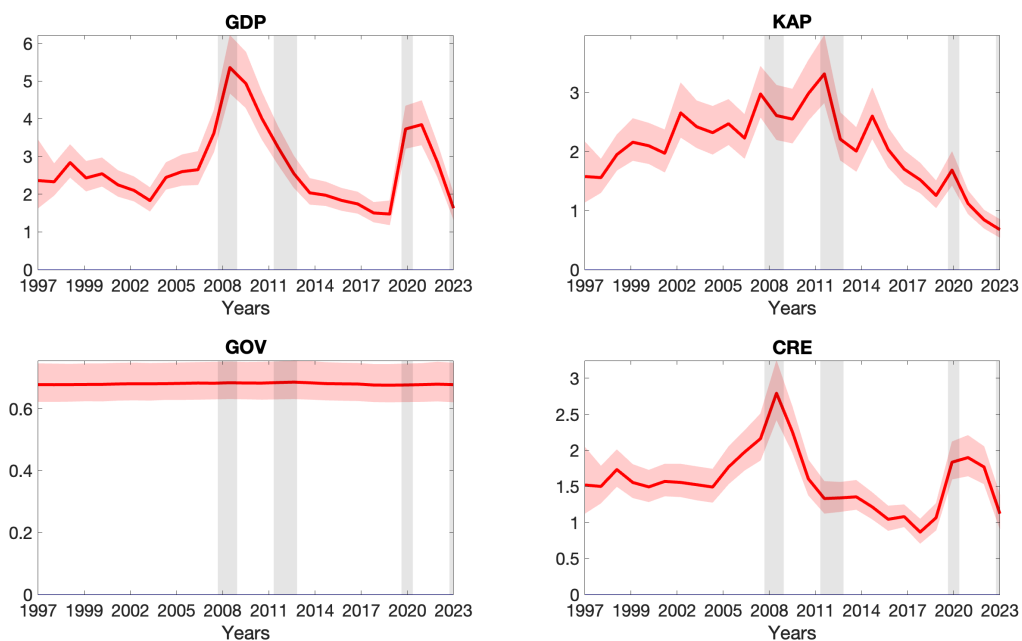
Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. The effects of the shock are normalized to one hundred in each horizon.

Figure C5: Time series of stochastic volatilities in the US



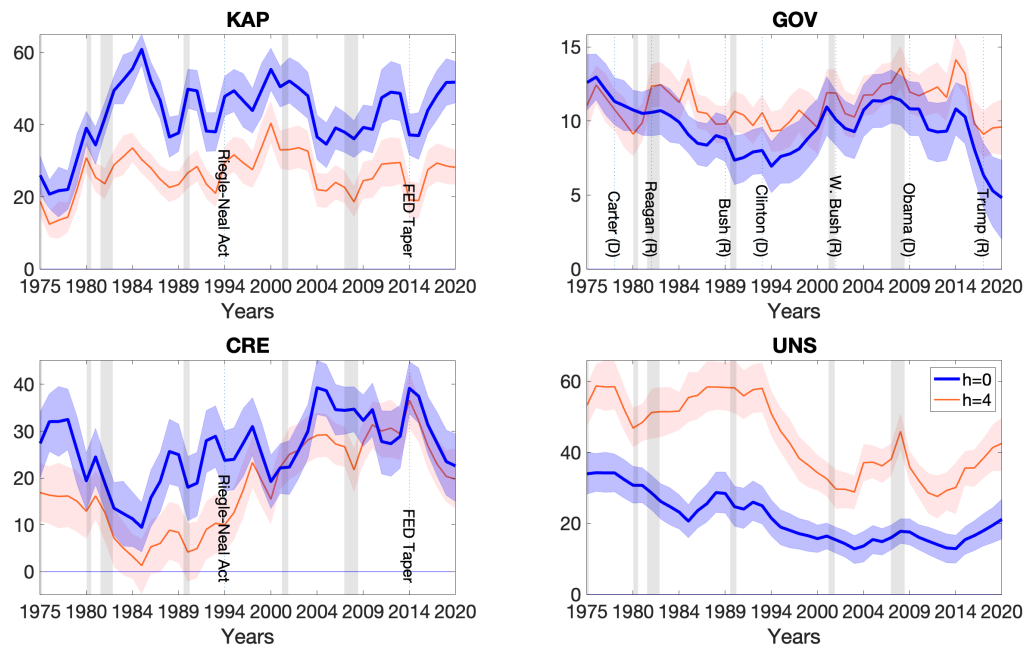
Notes: Vertical shaded areas indicate NBER recessions.

Figure C6: Time series of stochastic volatilities in the EA



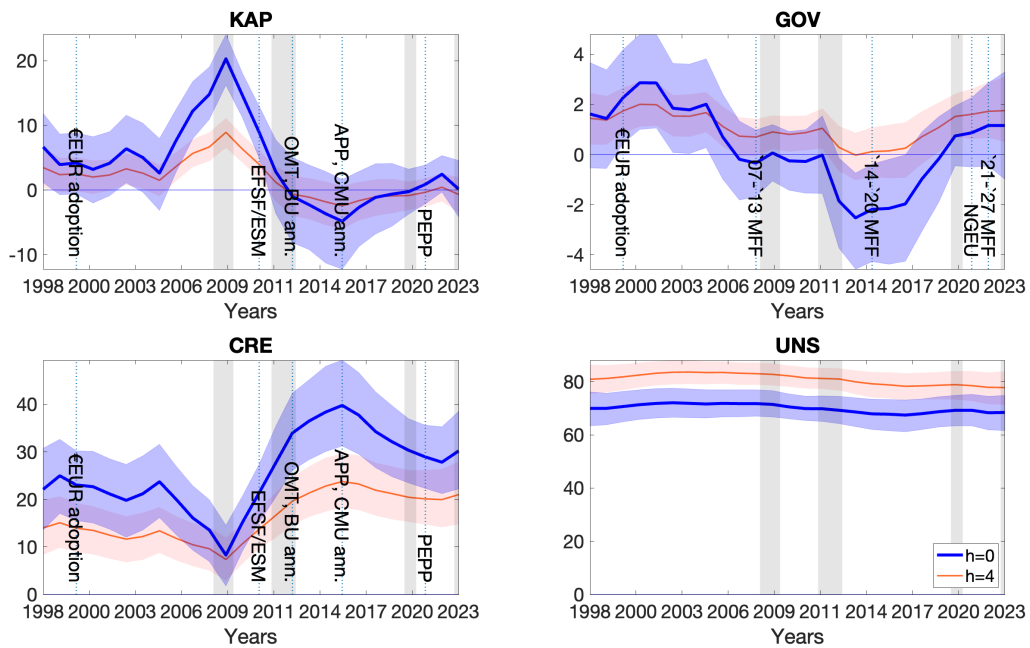
Notes: Vertical shaded areas indicate recessions.

Figure C7: Impulse responses to a state-specific output shock in the US - simple demeaning



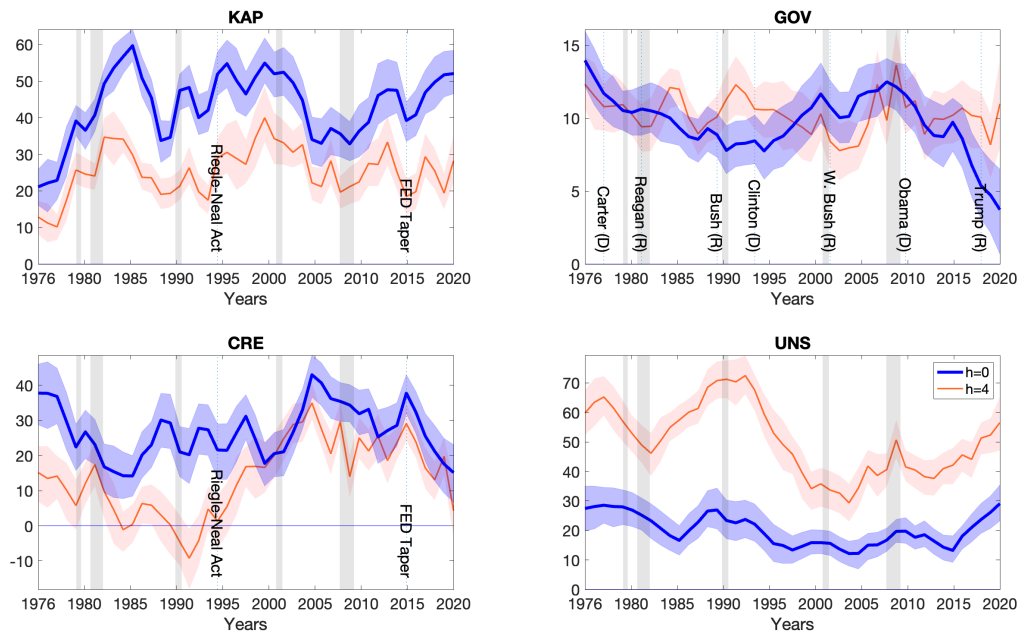
Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands. Vertical shaded (grey) areas indicate NBER recessions, lines indicate the dates of the presidential elections (black), and the Riegle–Neal Interstate Banking and Branching Efficiency Act. Series are demeaned by the simple averages, instead of weighted averages.

Figure C8: Impulse responses to a state-specific output shock in the EA - simple demeaning



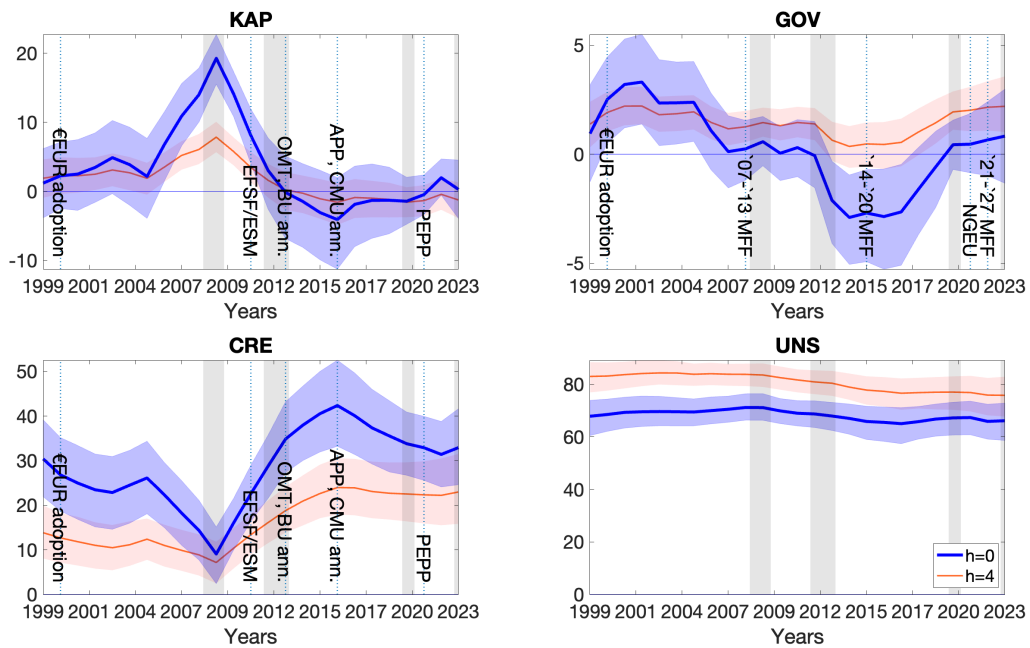
Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands. Series are demeaned by the simple averages, instead of weighted averages. Vertical shaded (grey) areas indicate recessions. Dotted lines indicate the dates of the activation of the EFSF/ESM support programs, the APP and PSPP of the ECB, the NGEU program and the years of the EU multi-annual financial framework (MFF) budget.

Figure C9: Impulse responses to a state-specific output shock in the US - VAR(2)



Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands. Vertical shaded (grey) areas indicate NBER recessions, lines indicate the dates of the presidential elections (black), and the Riegle–Neal Interstate Banking and Branching Efficiency Act.

Figure C10: Impulse responses to a state-specific output shock in the EA - VAR(2)



Notes: KAP: capital channel, GOV: fiscal channel, CRE: credit channel, and UNS: unsmoothed part. Blue line: impact ( $h = 0$ ) effect. Red line: cumulative effect four years ( $h = 4$ ) after the shock. The effects of the shock are normalized to one hundred in each horizon. Shaded areas are the 16<sup>th</sup> and 84<sup>th</sup> percentile posterior bands. Vertical shaded (grey) areas indicate recessions. Dotted lines indicate the dates of the activation of the EFSF/ESM support programs, the APP and PSPP of the ECB, the NGEU program and the years of the EU multi-annual financial framework (MFF) budget.

## C.2 Determinants of the time variation in the US

Table C1: Determinants of the risk-sharing channels - NBER dates

	Impact ( $h = 0$ )			Long-run ( $h = 4$ )		
	KAP	GOV	CRE	KAP	GOV	CRE
NBER	1.01*	0.39*	-0.59	0.32	0.61*	0.36
	(0.06, 2.00)	(0.18, 0.61)	(-1.29, 0.17)	(-0.61, 1.41)	(0.22, 1.04)	(-0.52, 1.31)
Fin	-0.01	0.01	0.03*	-0.01	0.00	0.06*
	(-0.03, 0.01)	(-0.00, 0.01)	(0.01, 0.05)	(-0.03, 0.01)	(-0.01, 0.01)	(0.04, 0.08)
STIR	-0.01	-0.02	0.19*	-0.08	-0.03	-0.17*
	(-0.11, 0.09)	(-0.04, 0.01)	(0.10, 0.29)	(-0.21, 0.06)	(-0.08, 0.02)	(-0.27, -0.07)
Debt	0.01	-0.02*	-0.03*	0.00	-0.02*	-0.07*
	(-0.01, 0.03)	(-0.02, -0.01)	(-0.04, -0.01)	(-0.01, 0.02)	(-0.02, -0.01)	(-0.09, -0.06)

*Notes:* Bayesian weighted SUR regression with flat priors, and weights given by the inverse of the posterior variance of the risk-sharing channels. Dependent variables are the median risk-sharing channels. Explanatory variables are lagged. NBER: NBER recession dates; Fin: long-run credit-to-GDP trend; STIR: 3-months Treasury yield; Debt: debt-to-GDP ratio. Left panel: on impact ( $h = 0$ ). Right panel: four years after the shock ( $h = 4$ ). Constant omitted from the table. Star denotes if posterior median is outside of the 16<sup>th</sup>-84<sup>th</sup> percentile credible interval.

Table C2: Determinants of the risk-sharing channels - Long-term interest rates

	Impact ( $h = 0$ )			Long-run ( $h = 4$ )		
	KAP	GOV	CRE	KAP	GOV	CRE
Gap	-0.17*	-0.05*	0.06	-0.24*	-0.11*	-0.16*
	(-0.27, -0.06)	(-0.07, -0.03)	(-0.02, 0.15)	(-0.35, -0.11)	(-0.14, -0.07)	(-0.26, -0.06)
Fin	0.02	0.01*	0.02	0.02	0.00	0.09*
	(-0.00, 0.04)	(0.01, 0.02)	(-0.00, 0.05)	(-0.00, 0.04)	(-0.01, 0.01)	(0.07, 0.12)
LTIR	0.06	0.01	0.05	0.18	-0.02	-0.15
	(-0.08, 0.23)	(-0.02, 0.04)	(-0.07, 0.18)	(-0.00, 0.38)	(-0.08, 0.04)	(-0.29, -0.00)
Debt	-0.02	-0.02*	-0.03*	-0.01	-0.02*	-0.1*
	(-0.03, -0.00)	(-0.02, -0.01)	(-0.04, -0.02)	(-0.02, 0.01)	(-0.02, -0.01)	(-0.11, -0.08)

*Notes:* Bayesian weighted SUR regression with flat priors, and weights given by the inverse of the posterior variance of the risk-sharing channels. Dependent variables are the median risk-sharing channels. Explanatory variables are lagged. Gap: the output gap; Fin: long-run credit-to-GDP trend; LTIR: 10-year Treasury yield; Debt: debt-to-GDP ratio. Left panel: on impact ( $h = 0$ ). Right panel: four years after the shock ( $h = 4$ ). Constant omitted from the table. Star denotes if posterior median is outside of the 16<sup>th</sup>-84<sup>th</sup> percentile credible interval.

Table C3: Determinants of the risk-sharing channels - IMF financial development index

	Impact ( $h = 0$ )			Long-run ( $h = 4$ )		
	KAP	GOV	CRE	KAP	GOV	CRE
Gap	-0.46*	-0.08*	0.00	-0.39*	-0.07*	-0.31*
	(-0.78, -0.13)	(-0.11, -0.05)	(-0.16, 0.17)	(-0.58, -0.19)	(-0.13, -0.01)	(-0.46, -0.15)
FinIMF	10.08*	0.45*	2.28	0.60	-0.74	5.21*
	(5.24, 15.63)	(0.04, 0.94)	(-0.29, 4.83)	(-2.22, 3.98)	(-1.62, 0.19)	(3.20, 7.42)
STIR	0.28	0.00	0.09	0.00	-0.04	-0.23*
	(-0.01, 0.62)	(-0.02, 0.03)	(-0.07, 0.26)	(-0.18, 0.20)	(-0.09, 0.02)	(-0.36, -0.10)
Debt	-0.05*	-0.01*	-0.02*	-0.02*	-0.01*	-0.06*
	(-0.07, -0.02)	(-0.01, -0.01)	(-0.03, -0.01)	(-0.04, -0.01)	(-0.02, -0.01)	(-0.07, -0.05)

*Notes:* Bayesian weighted SUR regression with flat priors, and weights given by the inverse of the posterior variance of the risk-sharing channels. Dependent variables are the median risk-sharing channels. Explanatory variables are lagged. Gap: the output gap; FinIMF: IMF financial development index; STIR: 3-month Treasury yield; Debt: debt-to-GDP ratio. Left panel: on impact ( $h = 0$ ). Right panel: four years after the shock ( $h = 4$ ). Constant omitted from the table. Star denotes if posterior median is outside of the 16<sup>th</sup>-84<sup>th</sup> percentile credible interval. Estimation sample starts in 1980.



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