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Macro-Financial Interactions in a Changing World

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Abstract
We measure the time-varying strength of macro-financial linkages within and across the US and euro area economies by relying on factor models with drifting parameters, where real and financial cycles are extracted and shocks are identified via sign and exclusion restrictions. The main results show that the euro area is disproportionately more sensitive to shocks in the US macroeconomy and financial sector, resulting in an asymmetric cross-border spillover pattern between the two economies. Moreover, while macro-financial interactions have steadily increased in the euro area since the late 1980s, they have oscillated in the US,, exhibiting very long cycles of macro- financial interdependence.

Resume
Vi måler den varierende styrke af makrofinansielle sammenhænge over tid i og på tværs af den amerikanske økonomi og økonomien i euroområdet. Vi gør det på grundlag af faktormodeller med glidende parametre, hvorfra realøkonomiske og finansielle cyklusser uddrages, og stød identificeres via restriktioner på fortegn og eksklusionsrestriktioner. De vigtigste resultater viser, at euroområdet er uforholdsmæssigt mere følsomt over for stød i den amerikanske makroøkonomi og finansielle sektor, hvilket resulterer i asymmetriske grænseoverskridende effekter mellem de to økonomier. Endvidere ses det, at mens de makrofinansielle interaktioner er steget løbende i euroområdet siden slutningen af 1980’erne, har de i USA været forbundet med udsving i form af meget lange cyklusser med indbyrdes makrofinansiel afhængighed.

Key words
Macro-financial linkages; Dynamic factor models; TVP-VAR.

JEL classification
E44; C32; C55; F44; E32; F41.

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Macro-Financial Interactions in a Changing World*

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Abstract

We measure the time-varying strength of macro-financial linkages within and across the US and euro area economies by relying on factor models with drifting parameters, where real and financial cycles are extracted and shocks are identified via sign and exclusion restrictions. The main results show that the euro area is disproportionately more sensitive to shocks in the US macroeconomy and financial sector, resulting in an asymmetric cross-border spillover pattern between the two economies. Moreover, while macro-financial interactions have steadily increased in the euro area since the late 1980s, they have oscillated in the US,, exhibiting very long cycles of macro-financial interdependence.

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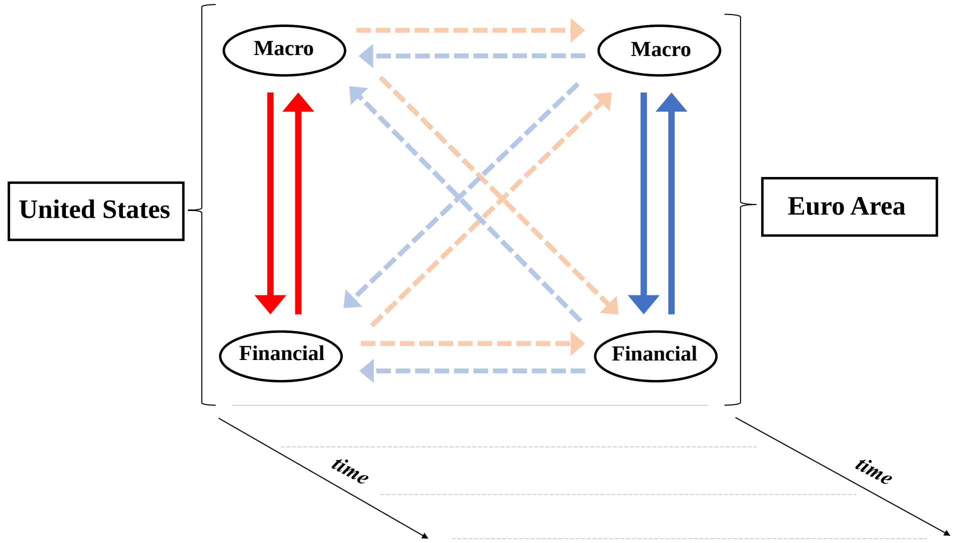
1 Introduction

The eagerness to understand macro-financial linkages has increased at an unpredecented rate in recent years. Much of this has been driven by the desire to comprehend the forces that led to the Great Recession, including the deep and long-lasting consequences of the financial downturn which began in 2007. In particular, recent research on macro-finance has focused on the role of the financial sector as a generator of shocks which are transferred to the overall economy via macro-financial linkages. Less (albeit some) effort has been put into understanding how the macroeconomy can create and transmit shocks to the financial sector. Moreover, very little effort has been invested in grasping the role that linkages themselves may play as amplifier and feedback loop for shocks generated inside the linkages as well as elsewhere. Yet, the prospect for a full recovery seems bleack at present. Despite unprecedented monetary expansion and supportive fiscal policy, per-capita income growth has stagnated in many jurisdictions, including the US and euro area. Therefore, understanding how macro-financial interactions can condition a potential recovery has become crucial for policymakers.

Figure 1 shows a diagram which illustrates the complexities embedded in macro-financial interactions. Each economy in the figure has two sectors, the macroeconomic and the financial. Domestic spillovers between the sectors in the US (euro area) are denoted by red (blue) solid arrows. In parallel, cross-border interactions between the sectors are denoted with dashed arrows. Moreover, all these relationships may be subject to potential fundamental changes over time for a number of reasons, opening an additional dimension to the problem. One outcome from Figure 1 is that the study of international macro-financial dynamic interactions, albeit crucial for policymakers, is challenging due to all the possible ways in which shocks could be transmitted. The aim of this paper is to provide a robust assessment of these interactions by taking all these underlying dimensions into account.

The first part of the problem involves defining what the macroeconomic and financial cycles are. Yet, in the empirical literature there is still a wide debate over the exact definition of a real cycle and how different and more complete it is compared to the standard business cycle. For the financial counterpart, there is even less consensus on what constitutes a financial cycle, its statistical characterisation and how similar it is to the real

Figure 1: International macro-financial dynamic interactions



Note: Solid red (blue) arrows denote the domestic macro-financial interactions for the US (euro area). Dashed red arrows make reference to the spillovers from the US to the euro area. Dashed blue arrows denote the spillovers from the euro area to the US

cycle. The existing definitions usually tend to be narrow (normally incorporating just a few variables in order to capture the multi-faceted nature of the real or financial sectors), exogenously pre-determined (constructed such that they reproduce pre-determined statistical characteristics), or based on short time series samples.[1]

Recognising the above shortcomings, this paper attempts to provide a comprehensive definition of real and financial cycles using dynamic factor models. Unlike previous studies, our empirical framework allows for an endogenous and time-varying selection of variables in the construction of each of the latent cycles, selecting from a large dataset of real activity and financial indicators, for each economy. These variables include information about output, employment, production, consumption, etc., on the real side and information regarding balance sheets, credit, foreign financial activity, etc., on the financial side of the economy. The motivation for including this feature in our modelling strategy is based on the need for flexibility in the determination of the most relevant variables driving the financial cycle over time, given the lack of consensus about its definition.

The second part of the problem consists of measuring the intensity of the evolving macro-

[1]Section 2 provides a detailed review of the literature on the study of macro-financial linkages.

financial interactions. To quantify the degree of time variation and profundity in linkages, the cycles are allowed to endogenously evolve according to a structural VAR model with drifting coefficients. The identification of real and financial structural shocks is based on the use of exclusion, sign and timing restrictions on the impulse response functions, along with alternative schemes for robustness. To the best of our knowledge, this is the first study of macro-financial spillovers between the US and the euro area, each as single economic units, that covers a period starting in the 1980s. In particular, the sample starts in 1981:II for the case of the euro area, which is considerably longer than the sample analyzed in any of the previous studies focusing on macro-financial linkages in this region. Equally, due to good data availability, we can go as far back as 1960:I for the US.

Moreover, we measure the linkages between macroeconomic and financial conditions in a number of ways in order to provide a comprehensive assessment. Besides the qualitative comparison of the real and financial cycles, and the computation of their time-varying correlation, we examine the mutual impact and propagation of structural shocks over time, calculate the time-varying forecast error variance decomposition at different horizons to assess the predictive power that one cycle has on another, and examine the time-varying factor loadings for the real and the financial cycle to measure the strength of common patterns inside each sector.

Lastly, the third part of the problem focuses on quantifying the intensity of cross-border spillovers in the macro-financial sphere. In doing so, we propose a joint (two-economy) model which basically nests the two single-economy models. Considering that US and the euro area top the list of global GDP figures, it is of global relevance to understand their dynamics and the cross-border propagation of shocks. Moreover, the topic is of high policy relevance considering the recent attempts to bring the two economies closer by creating special economic agreements (such as the TTIP), foster deeper financial cross-border flows (global banks, EU passport in banking and market financing in euro area), and enforce regulatory harmonisation (transatlantic mutual recognition of regulation on securities and derivatives, Basel III and FSB).[2]

With longer and smoother financial cycles compared to the macroeconomic cycle, both

[2]= Transatlantic Trade and Investment Partnership

in the euro area and in the US, our results robustly uncover a number of highly policy-relevant features about the evolution of international macro-financial interactions. First, while the euro area has exhibited increasing commonalities in the financial sector since the early 2000s, the strength of commonalities in the US financial sector has remained relatively steady over time. In particular, euro area private sector liabilities have become increasingly determinant for the shape and evolution of financial cycles. Second, while macro-financial interactions have steadily increased in the euro area since the late 1980s, they have oscillated in the US, exhibiting very long cycles of macro-financial interdependence. Moreover, the integration of the financial sector into the overall economy and the increase in the interplay between the two sectors has been more intense in the US, while being more solid and gradual in the euro area. Third, we unveil significant differences in the transmission of mutual shocks. In the euro area, the propagation of shocks has increased in both directions, i.e. from financial to real, and real to financial, but in the US, it has only increased in the first direction, from financial to real. Likewise, the degree of responsiveness of the financial sector to macroeconomic shocks is comparatively higher in the US, suggesting a deeper integration between the two sectors. Fourth, the intensity in the transmission of macro-financial shocks across borders is highly asymmetric, mainly going from US to euro area. In particular, there is a dimension of asymmetry whereby unexpected deteriorations in the US economy are detrimental for euro area financial conditions, while unexpected deteriorations in the euro area economy could be beneficial for the financial conditions in the US These asymmetries increased over time, until the Great Recession.

The rest of the paper is organized as follows: Section 2 provides a brief review of the literature that helps to identify our contributions. Section 3 describes the employed empirical framework. Section 4 analyses domestic macro-financial linkages. Section 5 studies international spillovers. Section 6 provides our conclusions.

2 Literature review

The financial turmoil of 2008 sparked an interest in studying the structural interplay between financial cycles and the broader economy. While the questions raised in those studies were not necessarily new, and build on the arguments laid out in the 1930s and 1970s (Fisher (1933) and Minsky (1977)), the scope of the pre-Great Recession studies were much narrower, focusing either on a few cycles, particular aspect, or a particular segment of the financial sector. For instance, there were studies showing the procyclical nature of the financial system (Borio et al. (2001) and Borio and Lowe (2002)). Others have tried to find long-run regularities in financial crises and the factors leading up to them (Reinhart and Rogoff (2009)).[3]

The recent empirical studies examining the interplay between macroeconomic and financial cycles can generally be divided into two main strands. The first one focuses on the measurement of both cycles, which presents challenges, especially when defining a financial cycle. Conversely, the second strand focuses on assessing changes over time in the relationship between macroeconomic and financial cycles. Next, we proceed to briefly review the two strands of the literature to elucidate the contributions of this paper.

In the first place, studies that have focused on the measurement of the cycles can be grouped into four categories. The first category uses frequency-based filters to extract the cyclical components of macroeconomic and financial variables and to describe their similarities and differences. Most of these studies find that financial cycles have a longer duration and are larger in amplitude than business cycles, but with an increasing synchronisation over time (Drehmann et al. (2012), Aikman et al. (2015), Gerba (2015), Schueler et al. (2017) and Gerba et al. (2017b)). However, since these measures are not based on a given theory or model, the analysis of their interdependence may return spurious results, as shown in Phillips and Jin (2015).[4] This is also the case for the second category, which focuses on extracting cycles in frequency domain (Strohsal et al. (2015) and Schueller et al. (2017)).[5] An important shortcoming of this method is that, since it requires stationarity, it makes it difficult to endogenously account for potential structural breaks, which may result in a lengthening or shortening of the cycles. Third, a less restrictive way of depicting the

[3]In a recent work Jorda et al. (2017) document a set of historical features of macro-financial linkages, pointing to the prominent role that financial factors should have in macroeconomic models.

[4]Moreover, these studies either assume that the frequency between the two types of series is similar, or that financial is *ex ante* longer than the business cycle.

[5]These studies also find that financial cycles, in general, are longer than real cycles, but show evidence for both short- and medium-term cycles in real credit growth

two cycles is by relying on turning point identification by using the Bry-Boschan algorithm (Harding and Pagan (2002), (2006)).[6] The main drawback of this method is that it is excessively agnostic and therefore also has very limited theory to explain the results. Fourth, to overcome some of the drawbacks of non-parametric or agnostic filters, model-based filters have been employed. This method is usually based on unobserved component models used to extract cycles by relying on the Kalman filter (Galati et al. (2016) and Ruenster and Vlekke (2016)).

In parallel, different empirical strategies have been employed to infer potential changes in the relationship between macroeconomic and financial variables. The most employed tool has been the vector autoregressions (VARs) subject to parameter instabilities. Blake (2000) and Calza and Sousa (2006) use Threshold VAR models to measure the effect of credit shocks on real activity for the US and euro area, respectively. Both studies show evidence of a stronger impact occurring under low credit growth regimes. For similar purposes, Davig and Hakkio (2010), Hubrich and Tetlow (2015) and Nason and Tallman (2015) use Markov-switching VAR models to study the relationship between financial stress and US economic activity.[7] All these studies agree in that the propagation of financial shocks to the real economy is different during high financial stress regime in comparison to normal times.[8] Other studies allow for instabilities in the VAR models that are smoother than sudden changes of regimes i.e. by allowing parameters to evolve according to random walks. For example, Prieto et al. (2016) use a time-varying parameter (TVP) VAR model to analyse the contribution of credit spread shocks to the US economy. Gambetti and Musso (2017) follow a similar approach to investigate the effect of credit supply shocks. Ciccarelli et al. (2016) investigate commonalities and spillovers in macro-financial linkages by using a panel VAR model with drifting coefficients.[9] An important drawback of these studies is that the employed measure of financial cycles is based on one or a few financial variables,

[6]As shown in Claessens et al. (2011) and Drehmann et al. (2012) financial cycles are also found to be longer than business cycles, although Cagliarini and Price (2017) don't find sufficient evidence. Moreover, they find that business cycles display a higher degree of synchronisation with credit and house price cycles than with equity prices.

[7]Kaufmann and Valderrama (2010) apply a similar framework to also assess the case of the euro area.

[8]In a recent work, Leiva-Leon et al. (2018) evaluate changes in the propagation of shocks between credit sentiment and the macroeconomy by relying on a multivariate Markov-switching framework.

[9]Also, Abbate et al. (2016) pursue a similar goal, but from an international perspective.

which usually are related to credit activity only. This is because of the computational problems arising in estimating such models using a large number of variables. However, this limitation precludes the estimation of a broad measure of the financial cycle, which is a crucial feature given its complexity and the lack of consensus about its definition.

The two strands of the literature described above have been somehow disconnected. This paper intends to unify them by, first, extracting both macroeconomic and financial cycles from a large set of information using Kalman filtering techniques and second, casting those extracted cycles into a structural VAR model with time-varying parameters to assess changes in the propagation of their shocks. This modelling strategy, which consists of a joint estimation (procedure described in Section 3 and Appendix A), allows us to infer changes in macro-financial linkages from a robust and broader perspective than previous studies. Additionally, we allow for a changing and flexible selection of variables driving both the financial and the real cycle, and we identify real and financial shocks using a strategy that is based on sign, exclusion and timing restrictions on the impulse response functions.

We also incorporate an international dimension to our analysis by looking at cross-border spillovers between the US and the euro area, both within the sectors and across. In this regard, most of the studies have looked at the US outward spillover, finding that US financial and real shocks matter significantly for the rest of the world. Using a structural VAR model for pre-2008 data, Bayami and Thahn Bui (2010) find that international business cycles are largely driven by US financial shocks, with a minor role for shocks from other advanced economies. Miranda-Agrippino and Rey (2018) equally find that there are large financial spillovers from the US to the rest of the world.

Our framework is more extensive than previous studies since it allows us to identify outward as well as inward spillovers in the US and the euro area, both within the sectors as well as across them. Moreover, we allow the degree of spillover effects between the two regions to exhibit potential changes over time. Therefore, we provide a full spectrum of international macro-financial interactions, that is, across regions (US and euro area), across sectors (macroeconomic and financial) and over time. The related literature is relatively limited, and most of the related works assess the degree of financial crisis spillovers across markets, without considering the cross-sectoral aspect (real economy) or the non-crisis times.[10]

3 Empirical framework

This section describes the econometric framework used to jointly (i) extract macroeconomic and financial cycles from large datasets and (ii) assess the evolving interdependence between these cycles. Let F_t be a vector that contains n_f indicators of financial conditions and R_t be a vector containing n_r indicators of real activity for a given economy. Our aim is to provide a framework that allows for a flexible selection of the variables driving both cycles over time and that also accounts for potential changes in the propagation of real and financial shocks.

3.1 One-economy model

We rely on a dynamic factor model with drifting loadings and where the factors evolve according to a VAR model with time-varying coefficients. Accordingly, consider the model described in the following equations,

$$\begin{bmatrix} F_t \\ R_t \end{bmatrix} = \begin{bmatrix} \Lambda_{f,t} & 0 \\ 0 & \Lambda_{r,t} \end{bmatrix} \begin{bmatrix} f_t \\ r_t \end{bmatrix} + \begin{bmatrix} v_{f,t} \\ v_{r,t} \end{bmatrix}, \tag{1}$$

$$\begin{bmatrix} f_t \\ r_t \end{bmatrix} = \Phi_{1,t} \begin{bmatrix} f_{t-1} \\ r_{t-1} \end{bmatrix} + \cdots + \Phi_{k,t} \begin{bmatrix} f_{t-k} \\ r_{t-k} \end{bmatrix} + \begin{bmatrix} u_{f,t} \\ u_{r,t} \end{bmatrix}, \tag{2}$$

where f_t and r_t denote the financial conditions and real activity factors, respectively.[11] The idiosyncratic innovations, $\mathbf{v}_t = (v_{f,t}, v_{r,t})'$, are assumed to be orthogonal between them and normally distributed, $\mathbf{v}_t \sim N(0, diag(\mathbf{\Omega}))$. The reduced form innovations from the VAR, $\mathbf{u}_t = (u_{f,t}, u_{r,t})'$, are also assumed to be normally distributed, $\mathbf{u}_t \sim N(0, \mathbf{\Sigma})$. To be able to assess the propagation of real and financial shocks, we let $\mathbf{u}_t = \mathbf{A}^{-1}\boldsymbol{\varepsilon}_\mathbf{t}$, where the

[10] For instance, Gravelle et al. (2006) find evidence of shift-contagion across currency markets, but not bond markets. Dungey et al. (2010) find that the degree of shift-contagion depends on the crisis, with higher levels during subprime US 2007 crises or the 1998 Russian/LTCM crisis.

[11] In the empirical applications, we assume $k = 2$.

vector $\boldsymbol{\varepsilon}_t = (\varepsilon_{f,t}, \varepsilon_{r,t})'$, denotes the underlying structural shocks, such that $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_t^{'}) = I$, and $E(\boldsymbol{\varepsilon}_t \boldsymbol{\varepsilon}_{t-k}^{'}) = 0$, $\forall k$, and $\mathbf{A}$ denotes the impact multiplier matrix.

To allow for changes over time in the information contained in the cycles and in the propagation of shocks between real and financial cycles, we let both the autoregressive coefficients $\boldsymbol{\phi}_t = vec(\Phi_t)$, where $\Phi_t = [\Phi_{1,t}, ..., \Phi_{k,t}]$, and the factor loadings $\boldsymbol{\lambda}_t = vec(\boldsymbol{\Lambda}_t)$, where $\boldsymbol{\Lambda}_t = [\Lambda_{f,t}, \Lambda_{r,t}]'$, to be time-varying by following random walk dynamics,

$$\boldsymbol{\phi}_t = \boldsymbol{\phi}_{t-1} + \boldsymbol{w}_t, \tag{3}$$

$$\boldsymbol{\lambda}_t = \boldsymbol{\lambda}_{t-1} + \boldsymbol{\omega}_t. \tag{4}$$

The innovations $\boldsymbol{w}_t$ and $\boldsymbol{\omega}_t$ are white noise Gaussian processes with zero mean and constant covariances, $\boldsymbol{\Psi}_w$ and $\boldsymbol{\Psi}_\omega$, respectively.

To identify macroeconomic and financial shocks, previous studies have mainly relied on a simple recursive, or Cholesky, identification strategy (Davig and Hakkio (2010), Hubrich and Tetlow (2015), Nason and Tallman (2015), Abbate et al. (2016), Ciccarelli et al. (2016), Prieto et al (2016)), which can be highly controversial. In a recent work, Gambetti and Musso (2017) relied on the use of a large set of sign restrictions to identify loan supply shocks. In this paper, we rely on a recent work by Arias et al. (2018) and use a combination of a few sign, exclusion and timing restrictions to identify macroeconomic and financial shocks. Additionally, we use an alternative identification strategy as a robustness exercise, proposed by Bai and Wang (2015).

Regarding the strategy based on the combination of restrictions, we first assume that real activity and financial conditions are persistent processes by assuming positive signs in the off-diagonal entries of the impact multiplier matrix, A^{-1}. Second, we assume that positive real activity shocks have a positive contemporaneous effect on financial conditions, but that a shock in financial conditions does not have a contemporaneous effect on real activity. As noticed by Prieto et al. (2016) (and in many other studies), this assumption implies that macroeconomic variables react to financial shocks with a delay, possibly because of wealth effects and other effects which involve financial intermediaries that take time to materialise - in contrast to financial variables which may react instantaneously to macroeconomic shocks. Third, consequently, we assume that it would take at least one period for real activity to react to a shock in financial conditions. Therefore, we postulate that a positive unexpected change in the financial cycle positively affects the real cycle with a one period lag. This combination of restrictions is summarized in Table 1.

Table 1: Sign, exclusion and timing restrictions for the one-economy model

	Financial Shock	Real Shock
	h=0	
Financial Cycle	+	+
Real Cycle	0	+
	h=1	
Financial Cycle	$*$	$*$
Real Cycle	+	$*$

Note: The symbol $*$ indicates that no restriction is imposed in the corresponding relationship, and "*h*" denotes the horizon of the impulse response.

Bai and Wang (2015) proposed a way to perform structural analysis in a context of dynamic factor models with factors that are governed by a vector autoregressive structure. This identification strategy simply consists of directly restricting the variance-covariance matrix of the reduced form innovations to be an identity matrix, i.e., $\Sigma = I$. Since the variables in the VAR system are latent and jointly estimated with the rest of the parameters of the model, by imposing this restriction the rest of the elements in the model are adjusted in such a way that the resulting innovations $\mathbf{u}_t$ have a structural interpretation by construction. As a robustness exercise, we alternatively employ this approach to assess the propagation of shocks between macroeconomic and financial cycles. This information corresponds to the solid arrows, red for US and blue for euro area, in Figure 1.

3.2 Two-economy model

The factor model described above is estimated for the two economies, US and euro area, separately in order to provide a deep and accurate understanding of their corresponding macro-financial linkages. However, we are also interested in identifying potential changes in the cross-border spillovers between the two economies. In particular, we are interested in estimating the time-varying effect of (i) financial shocks in the US to the financial cycle in the euro area, (ii) real shocks in the US to the real cycle in the euro area, (iii) financial shocks in the US to the real cycle in the euro area, (iv) real shocks in the US to the financial cycle in the euro area, (v) financial shocks in the euro area to the financial cycle in the US, (vi) real shocks in the euro area to the real cycle in the US, (vii) financial shocks in the euro area to the real cycle in the US, and (viii) real shocks in the euro area to the financial cycle in the US This information corresponds to the dashed arrows in Figure 1, red for spillovers from US to the euro area, and blue for spillovers from euro area to US

In order to address these issues, we propose an extended, or joint, model that nests each of the two models for individual economies. Accordingly, consider the following US-euro area dynamic factor model:

$$\begin{bmatrix} F_t^{US} \\ R_t^{US} \\ F_t^{EA} \\ R_t^{EA} \end{bmatrix} = \begin{bmatrix} \Lambda_{f,t}^{US} & 0 & 0 & 0 \\ 0 & \Lambda_{r,t}^{US} & 0 & 0 \\ 0 & 0 & \Lambda_{f,t}^{EA} & 0 \\ 0 & 0 & 0 & \Lambda_{r,t}^{EA} \end{bmatrix} \begin{bmatrix} f_t^{US} \\ r_t^{US} \\ f_t^{EA} \\ r_t^{EA} \end{bmatrix} + \begin{bmatrix} v_{f,t}^{US} \\ v_{r,t}^{US} \\ v_{f,t}^{EA} \\ v_{r,t}^{EA} \end{bmatrix} \tag{5}$$

$$\begin{bmatrix} f_t^{US} \\ r_t^{US} \\ f_t^{EA} \\ r_t^{EA} \end{bmatrix} = \Psi_{1,t} \begin{bmatrix} f_{t-1}^{US} \\ r_{t-1}^{US} \\ f_{t-1}^{EA} \\ r_{t-1}^{EA} \end{bmatrix} + \cdots + \Psi_{k,t} \begin{bmatrix} f_{t-k}^{US} \\ r_{t-k}^{US} \\ f_{t-k}^{EA} \\ r_{t-k}^{EA} \end{bmatrix} + \begin{bmatrix} u_{r,t}^{US} \\ u_{f,t}^{US} \\ u_{r,t}^{EA} \\ u_{f,t}^{EA} \end{bmatrix} \tag{6}$$

where F_t^{US} and R_t^{US} denote the set of information on financial and real activity, respectively, for the US economy. Similarly, F_t^{EA} and R_t^{EA} denote the same set of information but for the euro area economy. Notice that, consequently, this joint model would extract four latent factors associated to the financial and real cycles for the US (f_t^{US} and r_t^{US}) and for the euro area (f_t^{EA} and r_t^{EA}). The main advantage of this joint model is that we allow for the four latent factor to be endogenously interrelated in a VAR fashion. Moreover, we also allow for time variation in the parameters of the VAR in order to identify changes in the cross-border propagation of macroeconomic and financial shocks. The dynamics of the evolving parameters are assumed to be of the same nature as the ones detailed in the region-specific models, i.e. following independent random walks.

The reduced form innovations, $\mathbf{u}_t^* = (u_{r,t}^{US}, u_{f,t}^{US}, u_{r,t}^{EA}, u_{f,t}^{EA})'$, and structural innovations, $\boldsymbol{\varepsilon}_t^* = (\varepsilon_{r,t}^{US}, \varepsilon_{f,t}^{US}, \varepsilon_{r,t}^{EA}, \varepsilon_{f,t}^{EA})'$, are linked through the impact multiplier matrix, i.e. $\mathbf{u}_t^* = B^{-1}\boldsymbol{\varepsilon}_t^*$. The main challenge associated to the joint model arises when defining the restrictions to identify cross-border spillovers. As noticed by Prieto et al. (2016), structural (DSGE) models are still not available in a form to derive meaningful and widely accepted sign restrictions to disentangle real and financial shocks (see Eickmeier and Ng (2011) for a discussion). However, we take advantage of the fact that the model incorporates two economies instead of only one in order to define a set of restrictions that helps us to identify the underlying structural shocks. In particular, we assume that, within each region, there is a positive and contemporaneous response of real activity and financial conditions to both real and financial shocks. Next, we assume that euro area developments in general have no contemporaneous impact on US developments, with only one exception: We allow for the possibility that the financial conditions in the US and euro area contemporaneously influence each other. Finally, we assume that positive US real shocks are favorable for both real and financial conditions in the euro area. However, a positive financial shock in the US would take at least one period to generate a positive influence on the euro area macroeconomic conditions. This set of restrictions can be summarized in Table 2.

Table 2: Sign and exclusion restrictions for the two-economy model

	Fin. Shock EA	Real Shock EA	Fin. Shock US	Real Shock US
Financial Cycle EA	+	+	∗	+
Real Cycle EA	+	+	0	+
Financial Cycle US	∗	0	+	+
Real Cycle US	0	0	+	+

Note: The symbol ∗ indicates that no restriction is imposed on the corresponding relationship.

For robustness purposes, we additionally estimate the model by assuming an alternative shock identification strategy, which consists of a Cholesky factorization in Table 5 in Appendix A.2. In doing so, we assume the following order of the latent factors. We order first the US real cycle followed by the US financial cycle and by the real cycle of the euro area, leaving at the end the financial cycle of the euro area. Notice that this order implies that (i) financial shocks take at least one period to affect macroeconomic conditions and

(ii) US developments could contemporaneously affect euro area developments, but not vice versa.

For further validation purposes, we re-estimate the model using a mixture of recursive and sign restrictions as outlined in Table 6 of Appendix A.2. This consists of three parts: (i) recursive restrictions within each block; (ii) euro area shocks do not contemporaneously impact the US; (iii) leaving unrestricted the effects that US shocks have on euro area. This is an alternative scheme that is sufficiently broad to incorporate the empirical results contained in the current international macro-financial literature.

The overall output retrieved by the models described in this section provides a comprehensive analysis of macro-financial interactions along the following dimensions: (i) within sectors of a given economy, (ii) across sectors within a given economy, (iii) across sectors and across economies, and (iv) over the time dimension. Moreover, we provide a series of additional exercises for robustness purposes, altering the estimation method of the latent cycles, the identification of structural shocks, and potential changes in the volatility of macroeconomic and financial cycles.

4 Macro-financial linkages

This section provides a comprehensive overview of the time-varying interactions between macroeconomic and financial sectors, for the US and euro area. In doing so, we provide different pieces of information designed to study these interactions from various perspectives, for each economy separately. First, we assess the evolving strength of commonalities within each of the two sectors, i.e. macroeconomic and financial. This is done by jointly characterising the underlying cycles and inferring the segments of the real and financial sectors that are most important for driving those cycles over time. Second, we provide a characterisation of the joint propagation of macroeconomic and financial shocks. This is performed by examining the time-varying correlation between the cycles and analysing information contained in impulse responses and forecast error variance decompositions. We aim to provide a discussion that is comparative in nature; consequently, the description of the results is structured per type of feature, and not per economy. Notice that in the analysis, we use the terms *linkages* and *interactions* intercheangably, treating them as synonyms for deep and dynamically evolving relations between the two sectors. This is in contrast to the commonly used word *nexus* or *link* which we interpret as not profoundly changing over time.

4.1 Data

The description of the variables for the US economy is reported in Table 3 and was retrieved from the St.Louis Fed database. The sample spans from 1960:I until 2017:IV, covering four very distinct episodes in US contemporaneous economic history, including the Golden Age, stagflation and oil shocks, Great Moderation and the Great Recession. The list of variables used in the analysis of the euro area is reported in Table 4. The data spans the period between 1980:I and 2014:IV, covering the pre-Single Market episode, as well as the Single Market and the monetary union era. The data is gathered from the work of Gerba et al. (2018a), in turn collected from a variety of international sources. One set of variables comes from the ECB's Euro Area-Wide Model including variables F1-F3, F9-F11, R1-R5 in Table 4. Variables F4-F7 come from Datastream, while F8 and R6-R7 come from the OECD World Economic Outlook. The remaining variables are retrieved from two BIS sources: F12-F19 and R8 from BIS Market data and F20-F21 from BIS International Financial Statistics database. For the pre-EMU period, the series has been backward extrapolated using weights from euro area-12 and then adjusted as the new members joined the monetary union. Thus, the country weights for the pre-euro area period reflect the relative economic strength of the member states in the union around the time of the introduction of the physical euro coins in 2002.

All variables, except for ratios and spreads, are expressed in growth rates in our model. Financial ratios and spreads are expressed in levels. Our data sample is extensive and wide-ranging enough to encompass many aspects of the financial and real sectors. On the financial side, we have included price as well as quantity variables. Price variables include corporate financing spreads, financial ratios of firms and stock market indices. Quantities include assets and liabilities of banks (including their subcomponents), assets and liabilities of households and firms (along with their subcomponents), credit, monetary system net foreign assets and liabilities, monetary aggregates and velocity of money. On the real side, our sample comprises of aggregate as well as disaggregate macroeconomic measures. Included are GDP and its aggregate demand components, labour market indicators and variables capturing productivity and the supply side of the economy, such as real output per hour, unit labor costs and compensation to employees.

4.2 Strength of commonalities within sectors

The estimated real and financial cycles of the US are plotted in Figure 2. It shows that the financial cycle lasts much longer than the macroeconomic one. While financial activity underwent two major contractions during our sample period (1992 and 2008), macroeconomic activity experienced many more (albeit shorter) downturns. The first corresponds to the global economic downturn in the Western world in the early 1990s, including the US savings and loan crisis and a restrictive monetary policy. The second date corresponds to the onset of the Great Recession. Also, the dynamics of the financial cycle are smoother than those of the real one, experiencing much less of the very short-run variation. Moreover, the financial cycle experienced a profound change in frequency around 1990. While the average length of a financial cycle was 5-7 years in the pre-1990 sample, it increased to 7-10 years in the subsequent period. The macroeconomic cycle, on the other hand, has an average length of 2-5 years throughout the entire sample period.[12]

These attributes also apply to the euro area cycles, as can be seen from Figure 3. Although the frequency of the financial cycle is again lower, there are some differences with respect to the US case. While in the first half of the sample (1980-1996), the financial cycle is largely below the trend, the real cycle had completed a full phase by that time. Also, while the first boom phase in the financial cycle lasted for around 7 years (1996-2003), that of the macroeconomy was 2 years shorter. It is also important to notice that there is a stronger co-movement between both cycles starting from mid-1990s, with boom and bust phases roughly coinciding, although the timing and magnitude are not entirely identical.

On the whole, there are significant differences in the nature of the two cycles. Financial

[12] In line with the Great Moderation literature, documented by McConnell and Perez-Quiros (2000), there has been a decline in the volatility of the real cycle since the mid-1980s.

cycles are longer and smoother, in particular since the 1990s, while real cycles have lower amplitude and are more erratic. Also, it seems that higher and longer build-ups in the financial sector have resulted in higher peaks, while more frequent reversals in the real economy have resulted in deeper troughs for the macroeconomic cycle, relatively speaking. Additionally, there seems to be a significant co-movement between the two cycles, in particular for the euro area. The next section explores this feature in further detail. For robustness purposes, we also compute the underlying cycles using principal components (PC) and plot them in Figures 17 and 18 in the Appendix. Although PC provide a consistent estimation of the factors, this method is not able to endogenously assess potential instabilities in factor loadings. The results show that the factors estimated by PC follow a similar pattern to the factors estimated with Bayesian methods, with the latter exhibiting smoother and more stable dynamics, confirming our inferences about the two cycles.

Compared to alternative composite measures of financial activity, such as the National Financial Conditions Index (NFCI) of Brave and Butters (2012),or the non-financial and credit-to-GDP cycles, we find similarity to the non-financial leverage cycle. The long cycles and the long buil-ups in particular since the 1990s are visible in both. However, the reversals are sharper in our financial cycle, and the flexibility in our framework allows for long-term movement in the trend, in parallel. In addition, like the leverage cycle, our financial cycle is a good lead indicator and can serve as an early warning signal for financial stress and its potential impact on economic growth. The swings in the cycle anticipate those of credit-to-GDP and the business cycle (see Figure 4). In comparison to the adjusted NFCI, the information contained in our financial cycle is more informative on the particular phase of the cycle and the probability and severity of a subsequent reversal. The NFCI, on the other hand, is better suited for risk monitoring and analysis of risk build-up.

We proceed to assess the durability in commonalities within each sector, defined as the contemporaneous relationship between real and financial indicators with its corresponding cycle (or factor). This evolving relationship is measured by the time-varying factor loadings. The information is useful to identify potential changes in the composition of both cycles, and therefore to interpret them in a more accurate manner.

For the US case, the dynamic correlation between the indicators (loadings) and cycles is plotted in Figure 12. For the financial loadings, marked with F, and the macroeconomic loadings, marked with R, a couple of features deserve to be mentioned. First, most of the factor loadings associated to financial indicators are sizeable and statistically significant over time, validating the underlying pattern of commonalities across different segments of the financial sector. This is also the case for the loadings associated with real activity. Second, with only a few exceptions, the degree of variability over time in the factor loadings has remained relatively stable for both types of indicators. This result indicates that the composition of US real and financial cycles has, in general, remained relatively unchanged.

The case of the euro area is somewhat different. Figure 13 plots the evolving relationship between indicators (loadings) and the cycle, F for the financial,and R for the macroeconomic (or real). The results indicate a clear change in the composition of the euro area financial cycle. On the one hand, indicators containing information about credit and balance sheet variables have increased their correlation with the financial cycle over time. This includes variables such as loans to non-banks by deposit institutions, loans to non-governmental sector and monetary aggregates, but also others such as net foreign assets and net foreign liabilities. Conversely, other sets of financial indicators have exhibited a decreasing correlation with the financial cycle over time. These variables contain information about the financial position of firms, such as price-earning ratios of non-financial firms or price-book ratios of financial firms. Regarding the real sector, commonalities have remained relatively steady. It is important to notice that the increasing convergence of most of the variables with the financial cycle is significantly larger than the decoupling exhibited by a few other financial variables, pointing to overall increasing commonalities in the financial sector.

These features point to our first main result: Patterns in macro-financial linkages between the two economies are diverging. The euro area has exhibited increasing commonalities in the financial sector since the early 2000s. On the other hand, the strength of the US financial sector has remained relatively steady over time. Despite those divergences, there are also similarities between the two economies. Macroeconomic indicators have exhibited a relatively stable importance in shaping the real cycle. Furthermore, balance sheet (stocks) and credit variables that have become more relevant in shaping the financial cycles can be grouped into the liability side of the non-financial sector. In other words, private sector liabilities have become increasingly determinant for the shape and evolution of financial cycles.

4.3 Depth of linkages across sectors

This section focuses on measuring the evolving interaction between macroeconomic and financial cycles from different perspectives to provide robust assessments. We start by computing the time-varying correlation between the two cycles for each economy.[13] For the case of the US that correlation has varied significantly over time, as shown in Figure 8. In particular, between 1963 and 1992 the correlation consistently declined and reached a record low of 0.4. Yet, this lost ground over 30 years was quickly recovered during the subsequent period, and by 2009 the correlation was at a historical peak of above 0.67.

The growth rate in the correlation during 1990s and 2000s was more than twice as high as the rate of decline in the previous episode. This particular period was characterized by heavy deregulation in the US financial system, both across activities/segments and geographically. Also an intense financial deepening involving many of the known financial innovations occurred during this period. As a result, competition between financial institutions intensified. The US financial system opened up heavily during this period and attracted a lot of foreign capital. That capital fuelled two market bubbles: first in the corporate financing market (dot-com boom) and then in the housing market (subprime). On the real side, during this time inflation was significantly reduced and there was seemingly stable and moderate growth. Apart from a very brief downturn in early 1990s and the early 2000s, the rest of these two decades was characterised by a solid expansion. The increased liquidity in the system also led to increased consumption and investment, and solid employment and productivity figures. These changes potentially explain the rapid increase in correlation between the two cycles over this period.

Next, when one also takes into account that the Great Recession, characterised by a

[13] Since the cycles, proxied by the factors, evolve according to a vector autoregression, we compute the unconditional variance-covariance matrix of the elements in the VAR, i.e. f_t and r_t, and not of its innovations. Next, we compute the corresponding correlation coefficient. Since this measure is only a function of the parameters of the VAR, the same procedure is applied for each period of time to obtain the desired time-varying correlation.

reversal in financial sector activity, outflow of capital, inflation volatility and weak growth, interrupted this trend and led to a decline in the correlation between the two types of cycles (down to 0.5 at the end of 2017).

The corresponding time-varying correlation for the euro area has behaved somewhat differently. Figure 9 indicates that macro-financial interactions have continuously risen, with the exception of the pre-Maastricht Treaty period between 1984-1991. After the Single European Act in 1987, the correlation started to steadily grow, surpassing a historical record of 0.7 by 2011. Notice that the collapse of the European Stability Mechanism in 1992 did not interrupt this long-term trend of macro-financial deepening. In general, since the formal adoption of the euro, the correlation has grown slower compared to the previous growth phase. These results indicate that the establishment of the Economic and Monetary Union (EMU) and the adoption of the currency are associated with long-lasting stronger interactions between the financial sector and the real economy.

Altogether, the correlation between the macroeconomic and financial cycles is high in both economies, albeit with different time patterns. Our second main result shows that, while macro-financial interactions have steadily increased in the euro area since the late 1980s, they have oscillated in the US around a mean of approximately 0.5, exhibiting very long cycles of macro-financial interdependence. Additionally, over the past 25 years, the correlation coefficient has been higher in the euro area, while the rate of change of the correlation has been much larger in the US This implies that the integration of the financial sector into the overall economy and the increase in the interplay between the two have been more intense in the US, while more solid and gradual in the euro area.

We perform two types of robustness exercises associated with the vector autoregression that provide further basis for measurement of macro-financial interactions. First, instead of identifying the structural shocks using the baseline scheme, i.e. by imposing sign, exclusion and timing restrictions on the impulse responses, we directly estimate orthogonal innovations in the VAR, as in Bai and Wang (2015). The time-varying correlation between macroeconomic and financial cycles based on orthogonal innovations is plotted in Figure 19 for the US, and in Figure 20 for the euro area, in Appendix A.3. The results show estimates that are qualitatively similar to the ones obtained with the baseline identification scheme, providing robustness to our assessments. Second, for the case of the US, we also account for the Great Moderation episode by imposing a break in the variance-covariance matrix of the VAR innovations in 1985 in the baseline scheme. Figure 21 plots the time-varying correlation, again showing qualitatively similar dynamics. However, notice that the inclusion of the break in volatility is associated with an overall decline in the strength of macro-financial linkages.

Next, we turn to potential changes over time in the propagation of real and financial shocks for both economies. The top chart of Figure 10 plots the response of real activity to a financial shock in a three-dimensional graph, while the bottom chart plots the response of financial conditions to a real shock for the US economy. The results show a couple of salient asymmetric patterns. First, while the sensitivity of financial conditions to real shocks has remained relatively unchanged over time, the sensitivity of real activity to financial shocks started to increase in the early 2000s. This finding explains the substantial deterioration of the macroeconomy as a result of the financial shocks of the Great Recession between 2007 and 2009. Second, the effects of real shocks on financial conditions lasted significantly longer than the effects of financial shocks on real activity. These patterns are more visible in the two-dimensional graphs of dissected impulse responses, which are reported in Appendix A.3 to conserve space. Figure 22 plots the time-varying cumulated responses at pre-determined horizons, showing that, in general, the effects of real shocks are not only larger, but also more variable over time compared to financial shocks.

The transmission of shocks in the euro area, shown in Figure 11, presents a couple of important differences when comparing it with the case of US First, the effect of financial shocks on real activity has also increased over time. However, the increase started much earlier than in the US, in particular since the early 1990s. Also, notice that around that time financial conditions in the euro area also started to become more sensitive to real shocks. These features are consistent with the sustained increase in synchronisation between macroeconomic and financial euro cycles shown in Figure 9. Second, the sensitivity of real activity to financial shocks in the euro area is small on impact but long-lasting, while in the US that sensitivity is large on impact but short-lasting, in relative terms. These features can be seen in detail in the dissected impulse responses plotted in Figure 23 in Appendix A.3. Also, notice that the response which has exhibited the largest variation over time is the one regarding the effects of real shocks on financial conditions.

Accordingly, our third main finding unveils asymmetric shock propagation patterns in both economies. In the euro area, the interactions have increased in both directions, from financial to real and vice versa, but in the US, they have increased in only one direction, from financial to real. Also, the financial sector of the US shows a sensitivity to macroeconomic shocks which is of higher magnitude and of shorter duration than in the euro area. These asymmetries in macro-financial linkages remain even when we change the identification scheme of structural shocks by directly assuming orthogonality in the innovations of the VAR equation, see Figure 24, for the US and Figure 25, for the euro area in Appendix A.3.

These results persist even when we assume a break in volatility of the US economy in 1985. However, some features deserve commenting. Figure 26 shows that the Great Moderation period is associated with a slight increase in responsiveness of the macroeconomy to financial shocks, but also with a substantial reduction in the sensitivity of the financial sector to real shocks. This implies that when the structural reduction in business cycle fluctuations took place, real shocks not only became smaller but their ability to influence financial conditions also diminished.

Next, we focus on measuring the predictive ability that developments in one sector, i.e. macroeconomic or financial, may have on the other. In doing so, we follow the line of Diebold and Yilmaz (2009) and rely on the notion of the Forecast Error Variance Decomposition (FEVD) obtained from the VAR equation of the model.[14] We report the corresponding results in Appendix A.3 for the sake of space. Figure 27 plots the FEVD over time for the US economy showing that, in general, there have been no significant changes in the contribution of shocks in one sector to future developments of the other, with one important exception. Since the Great Recession, the information contained in financial conditions increased its ability to predict future short-term developments of the macroeconomy, as can be seen in the left plot of chart (b) in Figure 27. For the case of the

[14] A recent literature (Cotter et al (2017) and Korobilis and Yilmaz (2018), among others) focuses on using the network approach proposed in Diebold and Yilmaz (2009) to measure the degree of interconnectedness between international financial market segments (equity, sovereign credit, financial firms). These papers do, however focus on other aspects of interest, such as networks, market monitoring, index performance evaluations and non-structural volatility.

euro area, the situation is rather different. Since the early 1990s, real activity dynamics started to increase their ability to predict future long-term developments in the financial conditions, as shown in chart (c) of Figure 28. Also around that time, euro area financial conditions started to become less predictable based on its own past dynamics.

5 International spillovers

Once we have defined the time-varying macro-financial interactions within an economy, we proceed to examine the intensity of cross-border spillovers between the two economies, both across the sectors and between them. As indicated by the dashed arrows in Figure 1, there are eight possible ways to consider cross-border interactions in macro-finance. These different dimensions of spillovers are measured with the 'global' two-economy model, described in Section 3.2. The estimated factors obtained with the two-economy model follow similar patterns as the ones associated with the one-economy model, as can be seen in Figure 29 in Appendix A.3. This provides additional robustness for our measurement of both types of cycles.

First, we compute the cross-border and cross-sector time-varying correlations and report them in Figure 14. The figure shows clear patterns associated with gradual, but sustained, increases in the correlation between (i) US and euro area financial activity, (ii) US and euro area real activity, and (iii) US financial and euro area real activity. Such an increasing interdependence pattern persisted until the end of the Great Recession, and slightly declined afterwards. The only exception is the correlation between the US real and euro area financial activity, which has remained fairly stable over time.[15]

Although correlation measures are useful to address the overall strength of bilateral cross-border macro-financial relationships, they remain silent about the asymmetric effects between sectors and economies. Therefore, we proceed to evaluate the impulse response functions retrieved from the two-economy model. Figure 15 shows the effect that shocks generated in the US economy have on the euro area, while Figure 16 shows how shocks

[15]Notice that the two-economy model also delivers the time-varying correlations associated with sectors within a given economy. Such estimated correlations are qualitatively similar to the ones obtained with the one-economy model, as can be seen in Figure 30 in Appendix A.3.

generated in the euro area could affect the US economy. The shocks are identified by relying on the combination of sign and exclusion restrictions reported in Table 2. A clear pattern emerges from the estimated joint model. The impact of US shocks is much larger than the one associated with shocks coming from euro area. Real as well as financial shocks originating from the US have a statistically and economically significant impact on euro area macroeconomic and financial cycles, as can be seen in the dissected impulse responses shown in Figure 31 in Appendix A.3.[16] Notice that the largest increase over time is the one of US real activity on E.A. financial conditions. Conversely, shocks from the euro area tend to produce either small or short-lasting effects on the U.S economy (in line with Jensen (2019)). In particular, real euro area shocks have an effect on US real activity that only lasts one quarter. Also, the point estimates responses show that when the financial or real conditions deteriorate (improve) in the euro area, the financial conditions in the US improve (deteriorate). However, as shown in Figure 32 in Appendix A.3, this negative impact is estimated with substantial uncertainty.

It is important to notice that the intensity in the transmission of shocks increases over time, at least until the Great Recession. This is consistent with the increasing correlation pattern between the factor across sectors and regions, shown in Figure 14. Also, there seems to be no evidence of an intensification in the transmission of euro area shocks to the US since the formal introduction of the Euro, at least not as a clearly visible change in pattern since 2000. These results suggest that the hegemony of the US in the international monetary and financial system has been highly dominant (and increasing over time). The introduction of the euro did not manage to alter this (in line with the discussion in Gourinchas et al. (2019)).

There is, however, a subtle but important change in the transmission to euro area financial conditions over 2000s. In particular, after around 2002, the transmission of shocks arriving from the US seems to weaken somewhat, having persistently risen previously. Even if this is not enough evidence to establish a causal relation, it coincides with the full introduction of the euro on 1 January 2002. Hence, although the monetary union may not

[16] This finding is in line with the findings of Berg and Vu (2019) and Kose et al. (2017), who find economically and statistically significant effects on the world economy from US financial volatility. Giorgiadis (2016) finds similar results for US conventional and unconventional monetary policy.

have resulted in an increase in cross-border spillovers of real or financial activity, it seems to have somewhat weakened the transmission of US shocks by creating a tighter net and core, at least in the financial sphere.

Another relevant finding is that, since the Great Recession, the transmission of US shocks has weakened, while the negative transmission of E.A. shocks has also been reduced. This can be interpreted as a small change in the US global role since the financial crisis of 2007-08, whereby the weakening of its economy and the protectionism that followed have reduced its international exposure and role as a producer of cross-border (in)stability. Cuaresma et al. (2019) also find that the transmission of US monetary policy shocks has weakened in the aftermath of the global financial crisis in a global VAR framework.

To assess the validity of the results obtained with our baseline specification, we re-estimate the joint model using two alternative identification schemes described in Tables 5 and 6 in Appendix A.2. Figures 33-34 and 35-36 in Appendix A.3 plot the impulse response patterns associated with the (i) recursive and (ii) alternative sign restrictions identification schemes, respectively. Notice that in both cases the impulse responses are qualitatively similar to the ones obtained using the benchmark identification scheme. The only difference in magnitude we find is that, with these alternative identifications transmission of US financial and euro area real shocks is more intense, while those of US real are of slightly smaller magnitude. Moreover, the negative effects of euro area shocks on US financial conditions are also somewhat stronger in these alternative specifications. One could say that adverse (favourable) shocks in euro area developments could be beneficial (damaging) for the US financial conditions. An explanation for this pattern is that the US may act as a hub that attracts investments and (financial) capital when conditions are adverse in Europe. Since the financial deregulation in the early 1980s and the geographical liberalisation in financial services, the flow of capital to US has continuously increased. However, this positive trend broke with the near financial meltdown in 2008 and the deep contraction in the US financial sector. That could explain why the negative transmission from E.A. to US financial system has debilitated.

Our international analysis reveals a number of important facts regarding the relation between the euro area and the US since the financial liberalization and trade integration in the 1980s. First and most firmly, we find that the transmission of macro and financial shocks across borders is largely asymmetric, going from the US to the euro area. Previous literature hints at this asymmetry, but does not fully model the bidirectional spillovers, or does it for only one policy or aspect. For instance, Jarocinski (2019) shows using a SVAR, that Fed monetary policy has much stronger effects on ECB's monetary policy while euro area's has negligible impact on the US. Second, we find that the intensity of transmissions across borders increased over time. However, since the Great Recession this positive trend has been reversed, and the transmission of US shocks has been weakened. This could be a result from the weakened dominance of the US economy globally, or due to the protectionism that followed the financial crisis of 2007-08. Third, we find a negative relation in the transmission between euro area shocks and US financial conditions. One could say that adverse (favourable) shocks in euro area developments could be beneficial (damaging) for the US financial conditions. However, this pattern has also been weakened following the near financial meltdown in the US in 2008. Previous works (Berg and Vu (2019), Gourinchas et al. (2019), Jarocinski (2019), Giorgiadis (2016)) have advocated for a dominant position of the US in the international financial, monetary or macroeconomic sphere. However, as far as we are aware, this is the first study to formally establish this in a structural empirical model with (i) full bidirectional spillovers between two of the largest global economies, (ii) along macroeconomic and financial dimensions simultaneously and (iii) covering a relatively large time span that allows for long-term interpretations.

6 Conclusions

The relation between the financial sector and the rest of the economy has undergone tremendous changes since the 1990s. The impact of the financial crisis that began in 2007 and its aftermath has spurred an interest in the study of the degree of the linkages, and the extent to which each poses a threat to the stability of the other. Our understanding has significantly improved over the past decade, but there are still many unanswered questions, in particular related to a possible feedback mechanism between the two, both domestically and across borders. This paper attempts to fill this gap by analysing the macro-financial interactions within a structural time-varying framework using a large dataset for two of the largest world economies. Our study includes three dimensions: US, euro area and cross-border spillovers.

Further investigation into the current macro-financial structure, in particular the feedback mechanism between the two, is much needed. Currently, there are significantly more studies which focus on the transmission of financial disturbances, or papers which only investigate one side of the macro-financial linkages. As our findings show, the transmissions go in both directions and are at times asymmetric or uneven. Subsequent studies should take this into account and examine in-depth the feedback mechanism between the two sectors, preferably in structural models. Besides, it would be highly relevant to further explore the relative differences in impact versus persistence in impulse responses between financial and real shocks. One level deeper, we have unveiled how correlations between variables and cycles have changed over time. The correlation of private sector liabilities to financial cycles has significantly increased. Their role in shaping the macro-financial cycles needs to be examined more systematically, including their drift.

We also show that the correlation between euro area macro-financial cycles has been higher than that of the US economy. Structural factors underlying this difference should be examined in further detail, as well as the impact of and potential constraint on future economic growth in both economies. Finally, much more effort will be required to understand the cross-border spillovers of macro-financial linkages. We have established the dominance of US financial developments over euro area. Yet, exactly how and via what channels these are transmitted to the euro area needs to be explored further.

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Table 3: List of variables for the US

ID	Trans.	Description
F1	2	Non-financial corporate business; net worth, billions of dollars
F2	2	Non-financial corporate business: profits after tax (without IVA and CCAdj), billions of dollars
F3	2	Private residential fixed investment, billions of dollars
F4	2	Households and non-profit organizations; net worth, billions of dollars
F5	2	Non-financial corporate business; credit market instruments; liability, billions of dollars
F6	2	Households and non-profit organizations; credit market instruments; liability, billions of dollars
F7	2	Households and non-profit organizations; home mortgages; liability, billions of dollars
F8	2	All sectors; commercial mortgages; asset, billions of dollars
F9	2	Households and non-profit organizations; total time and savings deposits; asset, level, billions of dollars
F10	2	Households and non-profit organizations; corporate equities; asset, level, billions of dollars
F11	2	Federal government; credit market instruments; liability, level, billions of dollars
F12	2	S&P500
F13	2	M1 money stock, billions of dollars
F14	2	Velocity of M1 money stock, ratio
F15	2	Velocity of M2 money stock, ratio
F16	2	M2-M1 Money stock, billions of dollars
F17	2	Velocity of MZM money stock, ratio
F18	1	AAA-spread
F19	1	BAA-spread
F20	1	Corporate risk spread
F21	1	10-Year Treasury constant maturity rate, percent
F22	2	Total consumer credit owned and securitized, outstanding, billions of dollars
F23	2	Households and non-profit organizations; consumer credit; liability, billions of dollars
R1	2	Real gross domestic product, billions of chained 2009 Dollars
R2	2	Real personal consumption expenditures, billions of chained 2009 Dollars
R3	2	Non-farm business sector: real compensation per hour, index 2009=100
R4	2	Real gross private domestic investment, billions of chained 2009 Dollars
R5	2	Real disposable personal income, billions of chained 2009 Dollars
R6	2	Average weekly hours of production and non-supervisory employees: manufacturing, hours
R7	2	All employees: manufacturing, thousands of persons
R8	2	Non-farm business sector: real output per hour of all persons, index 2009=100
R9	2	Gross fixed capital formation in United States, billions of dollars

Note. The column "Trans." of the table indicates the transformation made to the corresponding variable prior to include it in the model. "Trans.=1" indicates that the variable is expressed in levels. "Trans.=2" indicates that the variable is expressed in growth rates.

Table 4: List of variables for the euro area

ID	Trans.	Description
F1	1	Firm price-book ratio
F2	2	Savings rate households
F3	1	Firm dividend yield
F4	1	Price-earning ratio of non-financial firms EMU
F5	1	Price-earning ratio of financial firms EMU
F6	1	Price-earning ratio of non-financial firms US
F7	1	Price-earning ratio of financial firms US
F8	1	Current account balance
F9	1	Price-book ratio financial firms
F10	1	Price-book ratio non-financials
F11	1	Firms price-cash flow ratio
F12	2	Depository corp. excl. CB, assets, loans to non-banks, M-end
F13	2	OMFI, assets, credit to non fin. corporations, total, M-end
F14	2	Banks (MFI), loans to non-financial corporations (MU), M-end - outstanding amount at end of period
F15	2	Claims of monetary syst. on non-govt. sect., loans (MU11-17), M-end
F16	2	Depository corp. excl. CB, assets, loans to non-banks, M-end
F17	1	Bank liabilities, non-monetary, LT (MU11-17), total, M-end
F18	2	Monetary system net foreign assets, assets (MU11-17), M-end
F19	2	Monetary system net foreign assets, liabilities. (MU11-17), M-end
F20	2	Money stock m2 (MU11-17), M-end
F21	2	Money stock m3 (MU11-17), M-end
R1	2	Real GDP
R2	2	Private consumption
R3	2	Government consumption
R4	2	Gross investment
R5	2	Labour force
R6	2	Total employment
R7	2	Unit labour cost
R8	2	Compensation to employees

Note. The column "Trans." of the table indicates the transformation made to the corresponding variable prior to it being included it in the model. "Trans.=1" indicates that the variable is expressed in levels. "Trans.=2" indicates that the variable is expressed in growth rates.

Figure 2: Estimated factors of the US

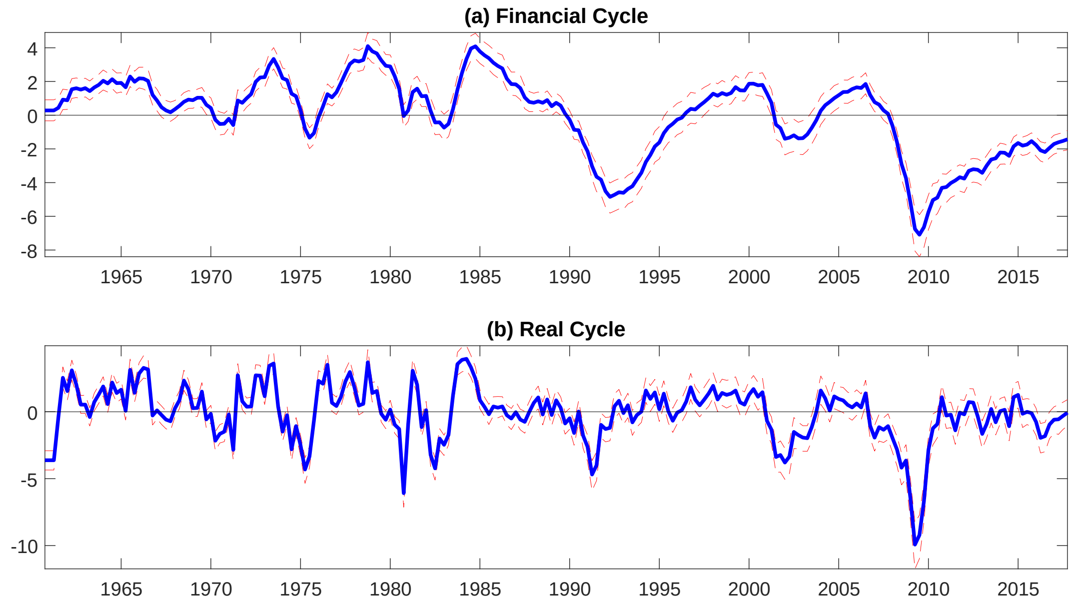
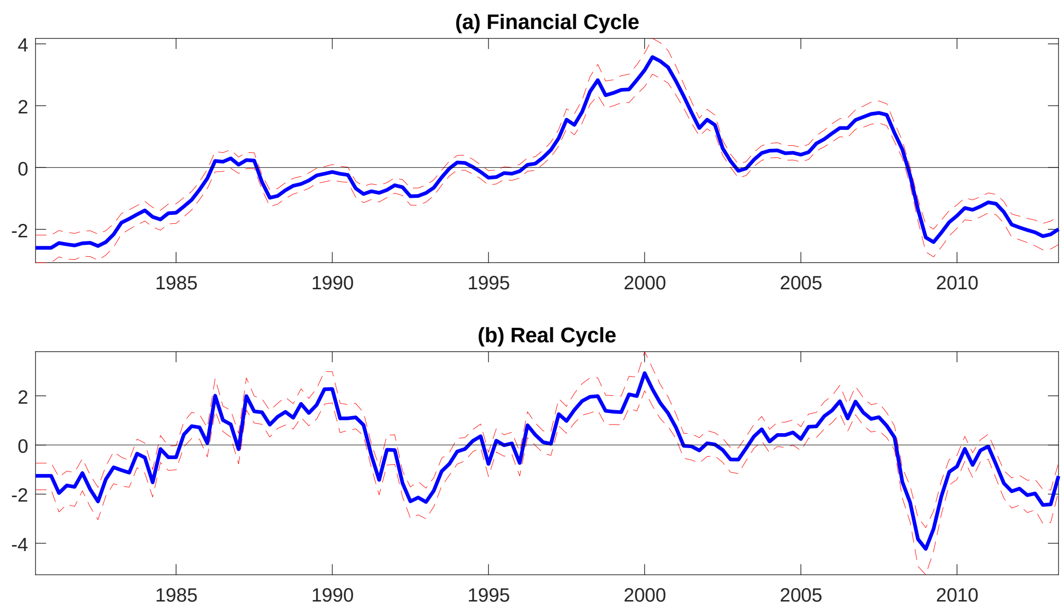


Figure 3: Estimated factors of the euro area



Note: The figures plot the estimated real and financial cycles. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 4: Business cycle with NBER recession dates for the US

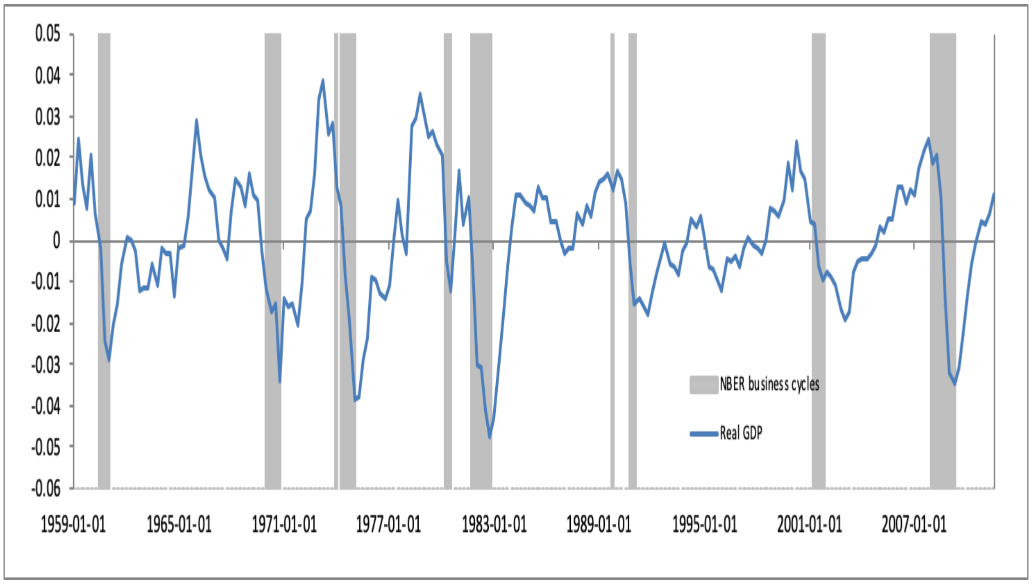
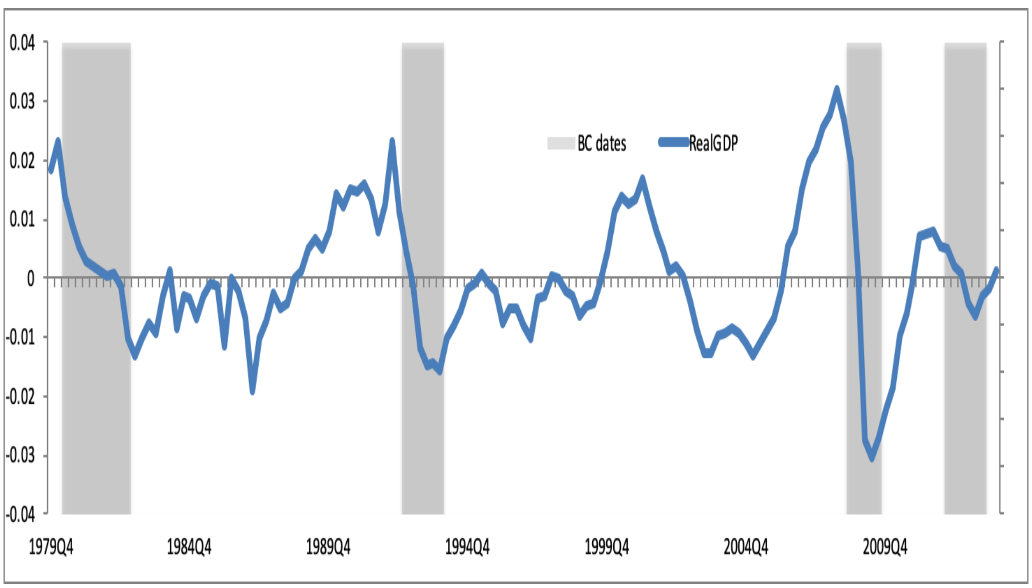


Figure 5: Business cycle with CEPR recession dates for the euro area



Note: The figures show the business cycles in the US and euro area. The cycles have been extracted using an HP filter with lambda = 1600 to extract the quarterly frequency. The recession dates are marked in grey and come from the official sources: NBER for the US and CEPR for the euro area. To facilitate comparison with the macroeconomic cycles estimated in our model, we use the same sample length.

Figure 6: (Adjusted) National Financial Conditions Index for the US

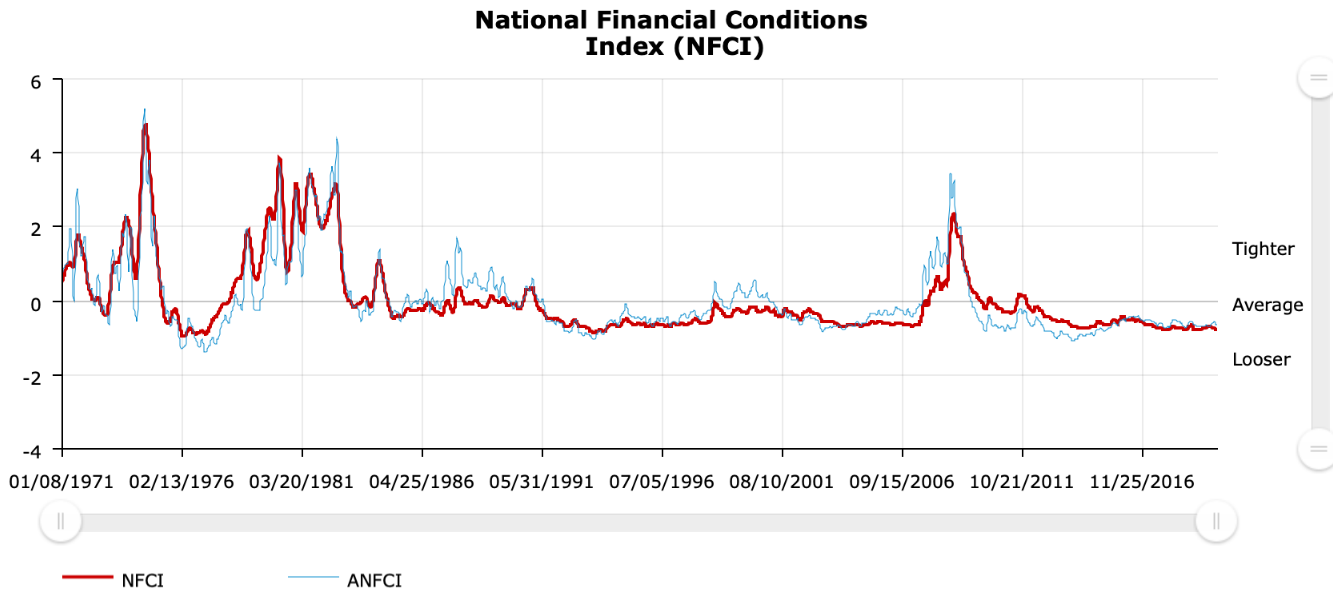
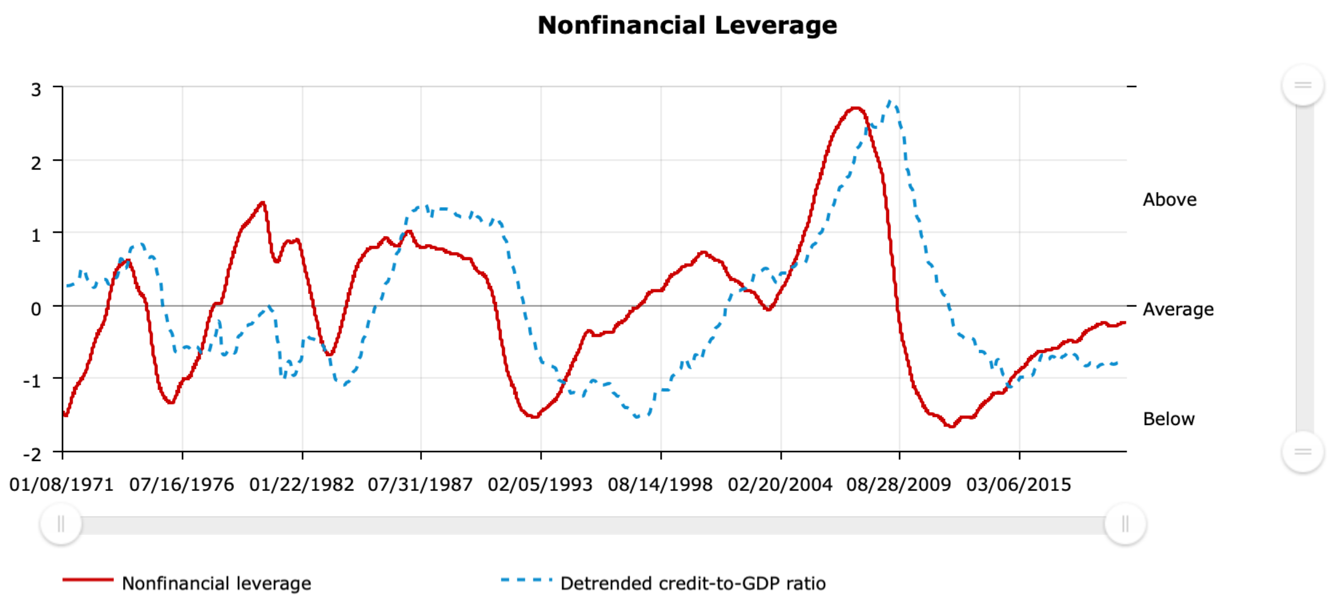


Figure 7: Nonfinancial leverage cycle in the US



Note: Figure 6 depicts the National Financial Conditions Index, as well as its adjusted counterpart. Figure 7 depicts the detrended non-financial leverage cycle, and the detrended credit-to-GDP ratio. These figures are taken from the Federal Reserve Bank of Chicago webpage and have been created by their staff based on the paper by Brave and Butters (2012). Data for credit-to-GDP-ratio comes from Haver Analytics.

Figure 8: Estimated correlation between factors of the US

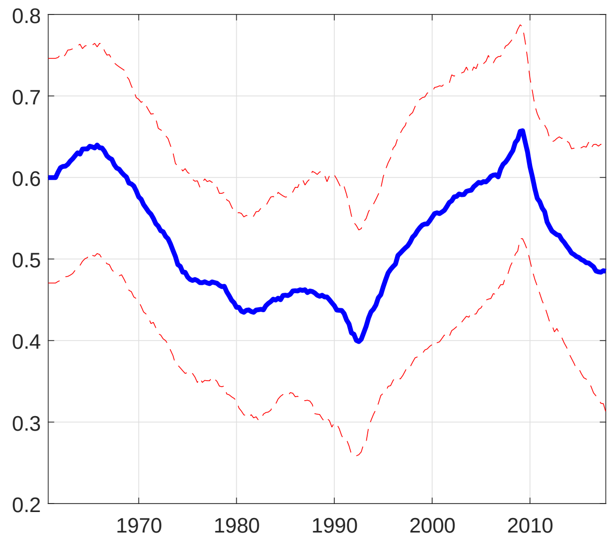
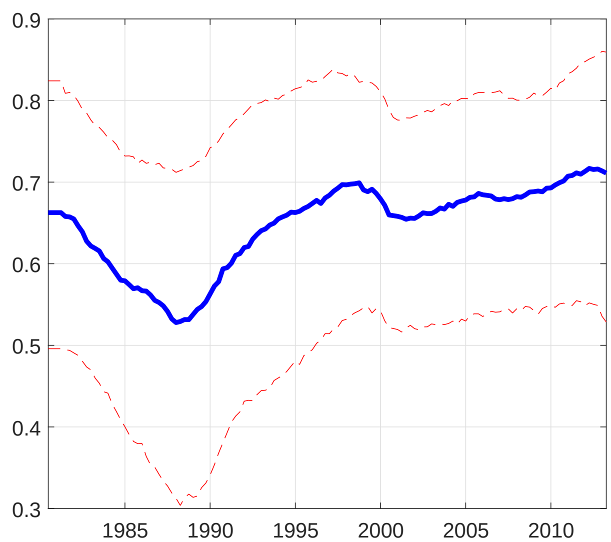
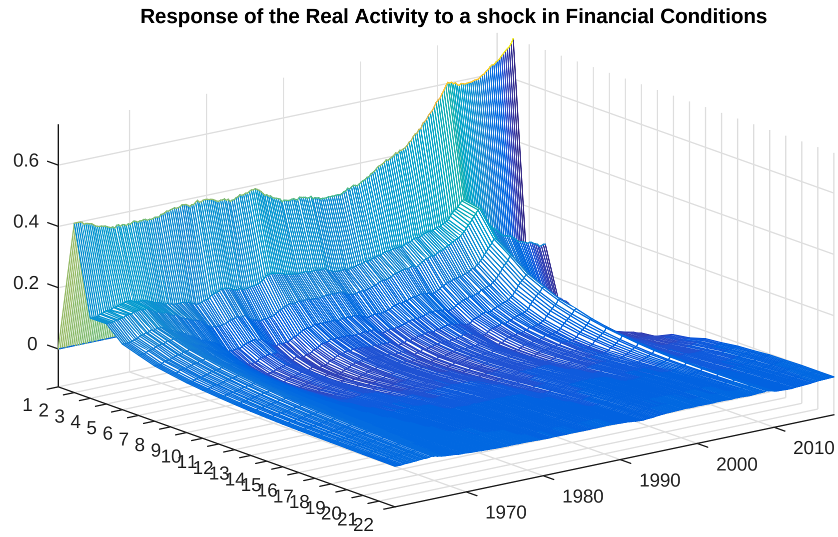


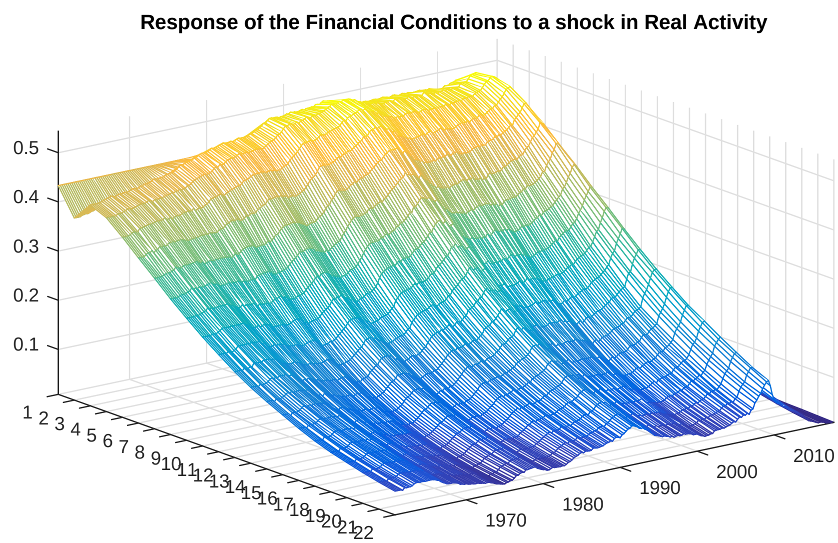
Figure 9: Estimated correlation between factors of the euro area



Note: The figures plot the estimated time-varying correlation between the real and the financial cycle. The solid blue line makes reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

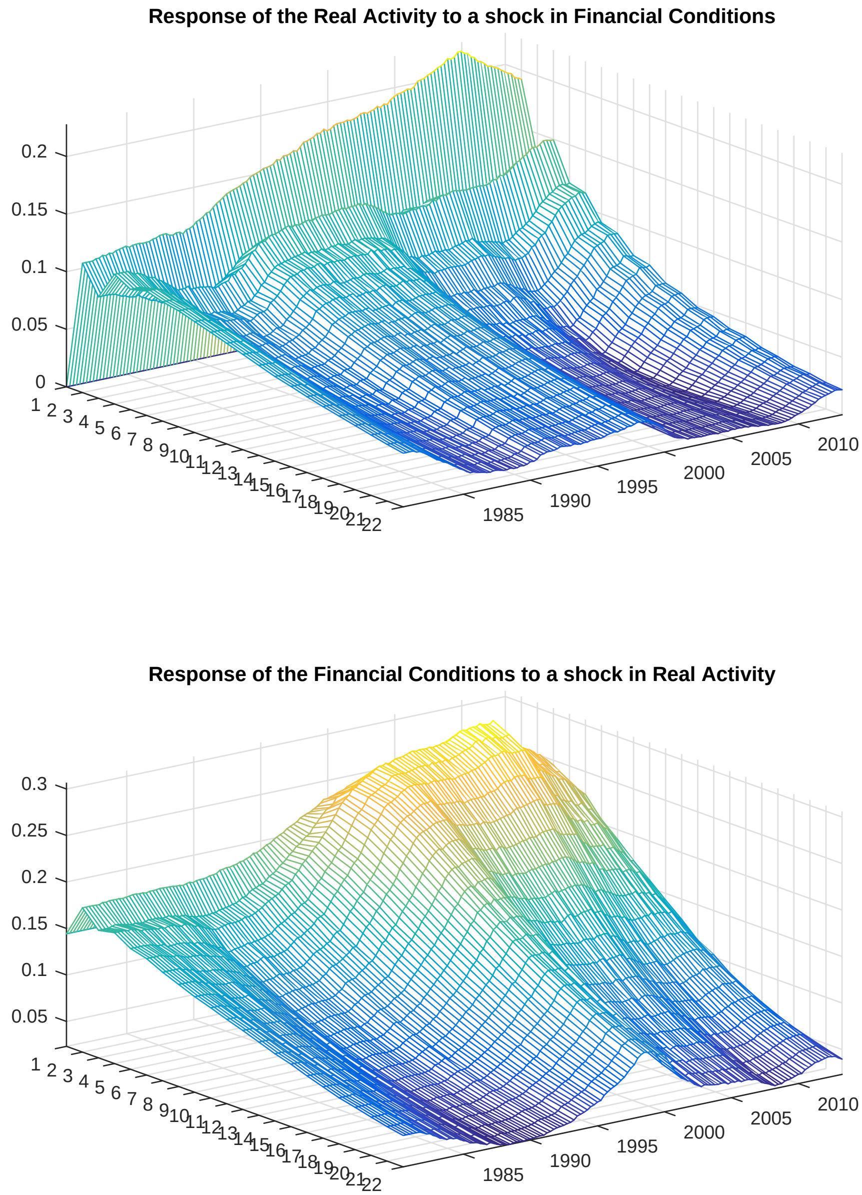
Figure 10: Impulse Responses Between Real and Financial Cycles for US





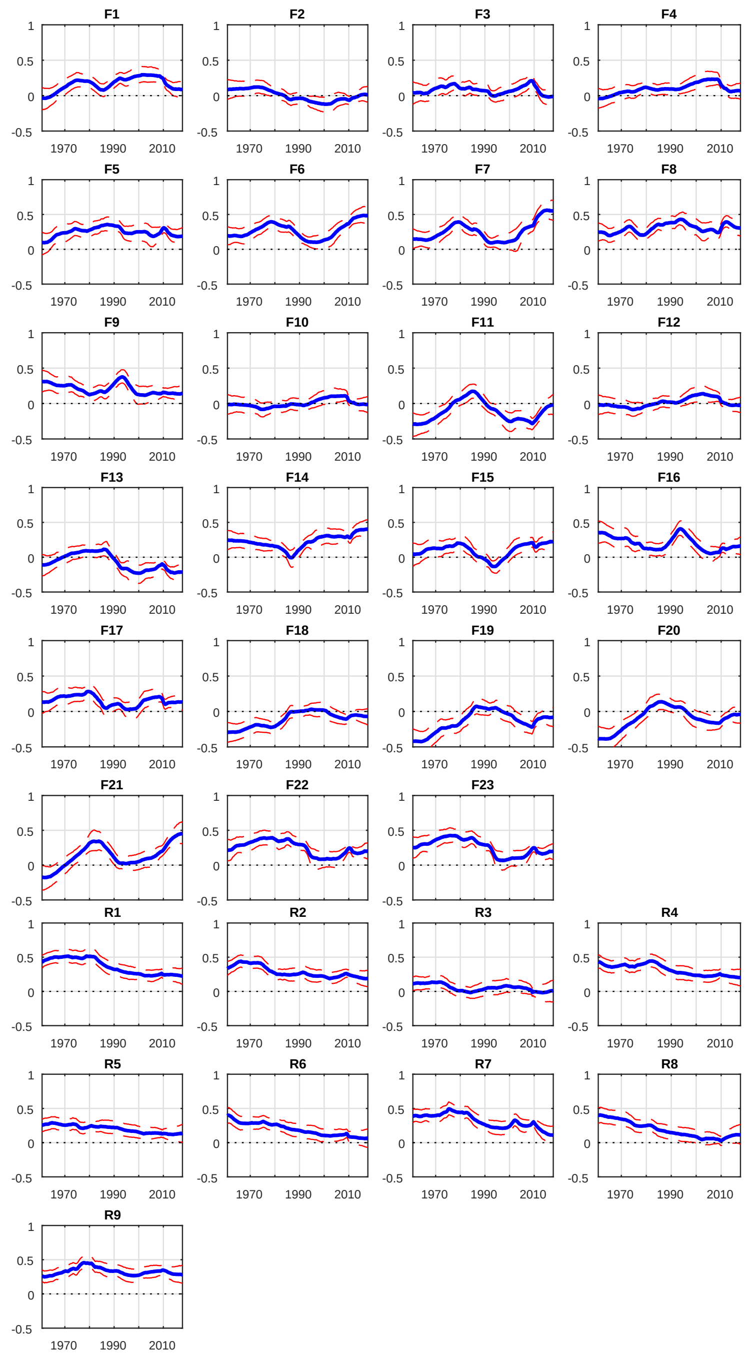
Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution.

Figure 11: Impulse Responses Between Real and Financial Cycles for euro area



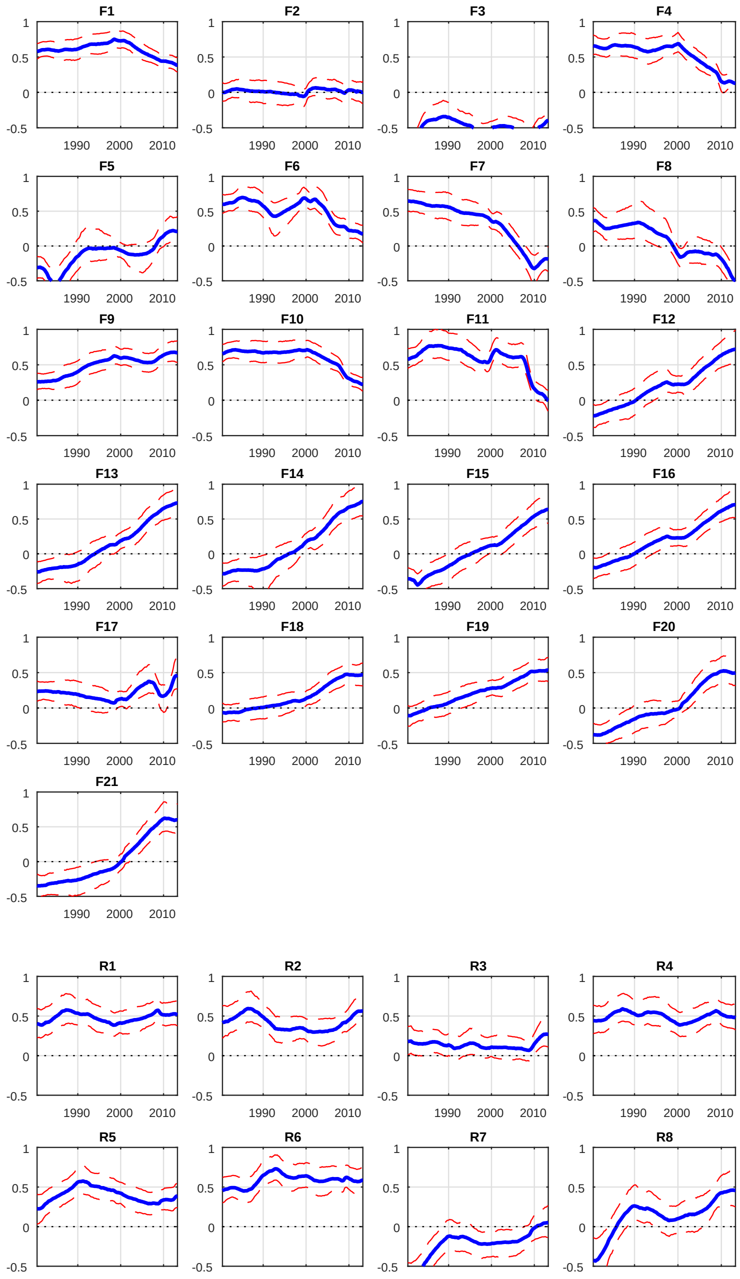
Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution.

Figure 12: Financial (F) and real (R) factor loadings for the US



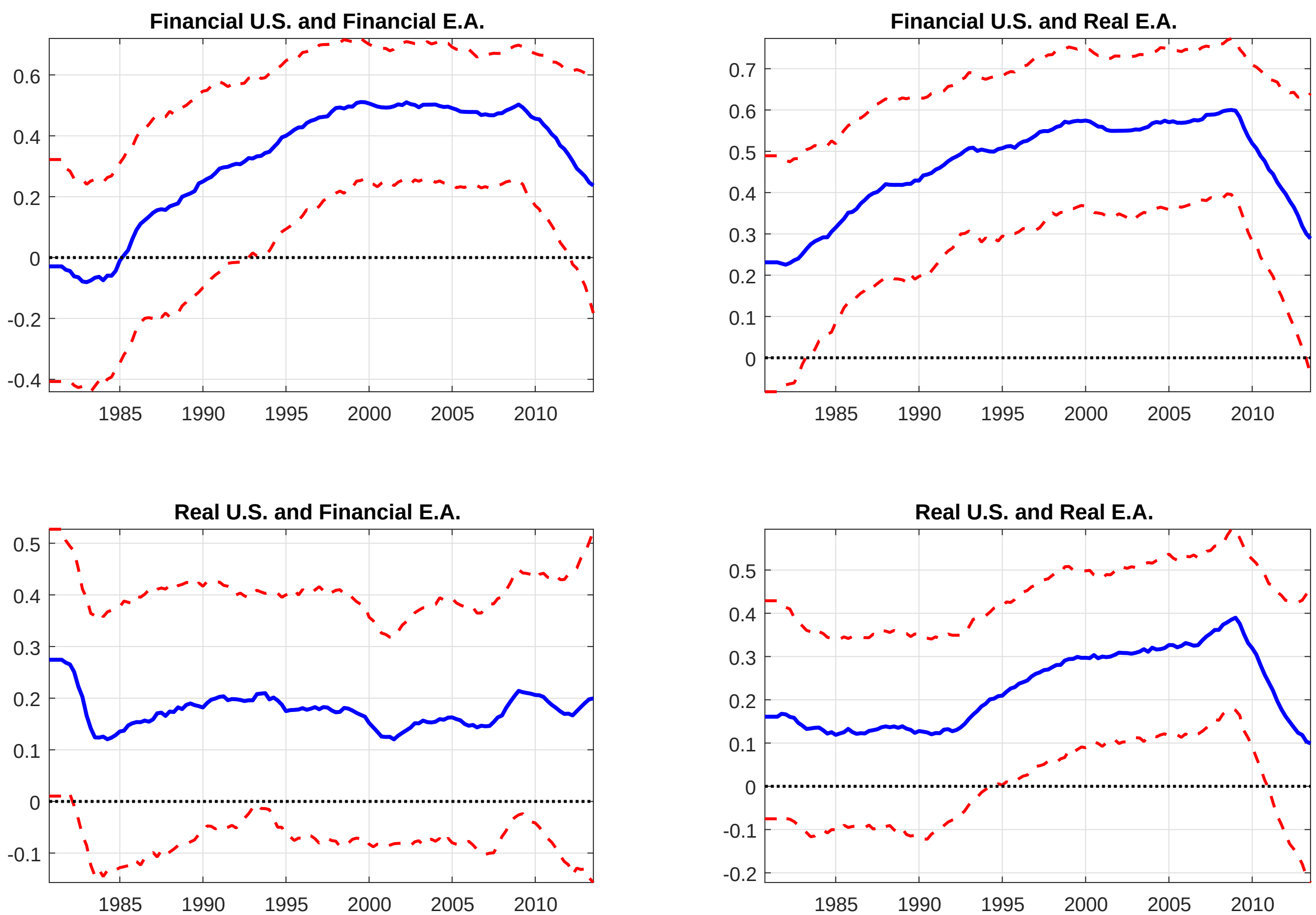
Note: These are the time-varying factor loadings in the financial cycle (above) and the real factor loadings in the macroeconomic cycle (below). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution. For the name of each of the loadings, we refer to Table 3.

Figure 13: Financial (F) and real (R) factor loadings for the euro area



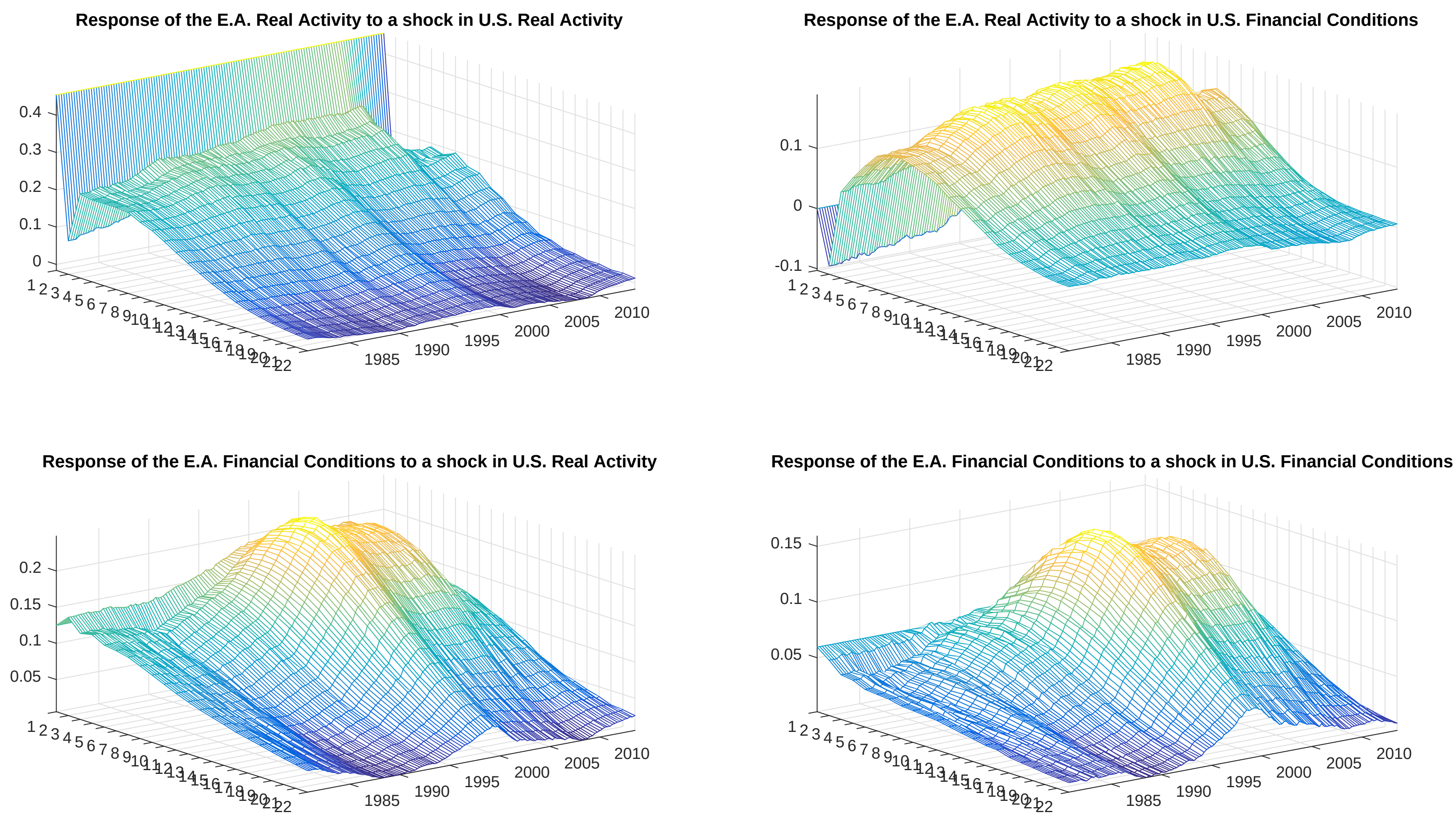
Note: These are the time-varying factor loadings in the financial cycle (above) and the real factor loadings in the macroeconomic cycle (below). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution. For the name of each of the loadings, we refer to Table 4.

Figure 14: Estimated correlation between real and financial factors of US and euro area (Two-economy model)



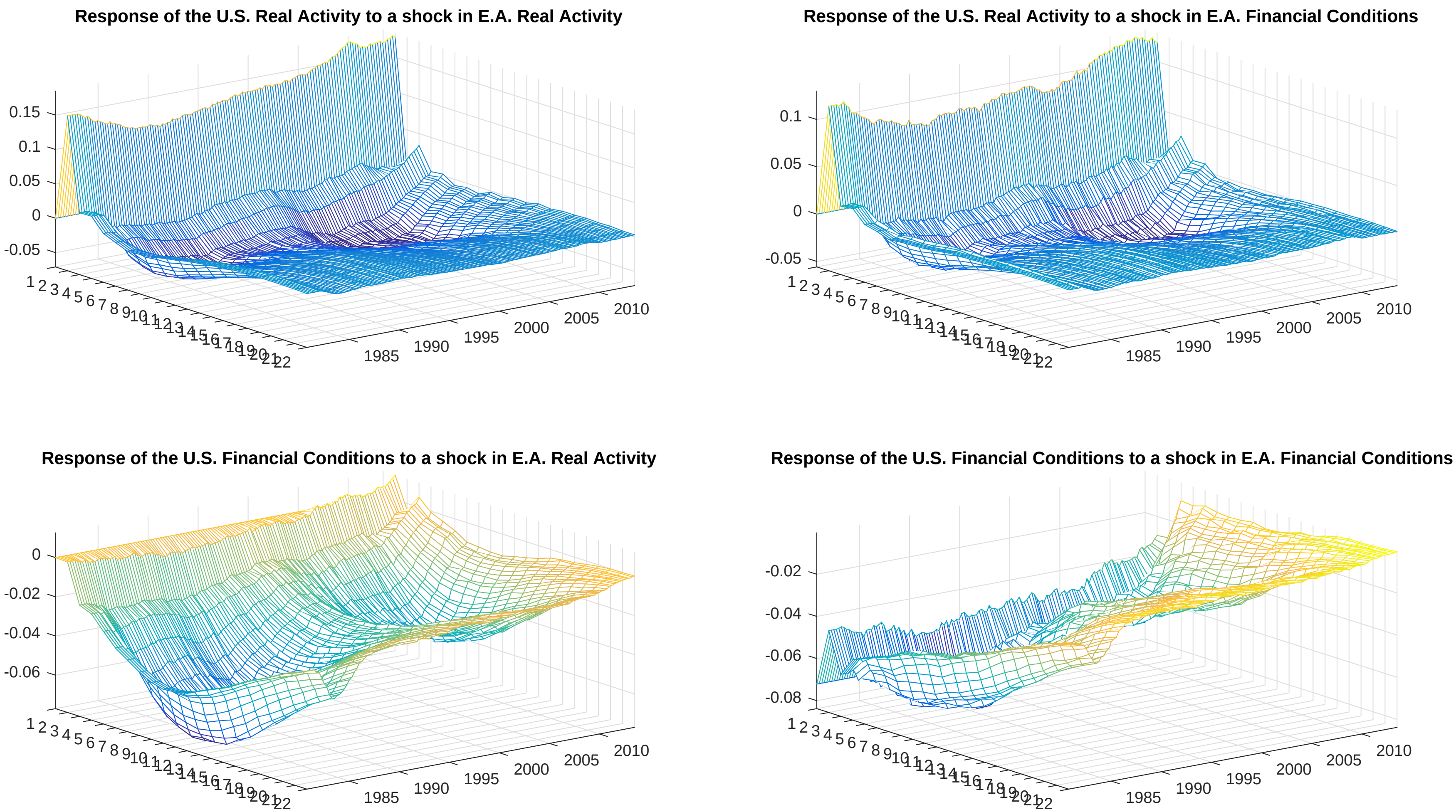
Note: The figures plot the estimated time-varying correlation between the real and financial cycle associated to the US and euro area. The solid blue line makes reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 15: Macro-financial spillovers from the US to the euro area over time (Two-economy model)



Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using sign and exclusion restrictions in the impact multiplier matrix to identify the structural shocks.

Figure 16: Macro-financial spillovers from the euro area to the US over time (Two-economy model)



Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using sign and exclusion restrictions in the impact multiplier matrix to identify the structural shocks.

A Online appendix

A.1 Implications for monetary and financial policy

In light of the tight interaction between the financial sector and the macroeconomy, the feedback loops between the two and the intense cross-border spillovers from the US financial sector to the euro area macroeconomy, the question is how should monetary and financial policies adapt or evolve in order to tackle these challenges. Notably, financial policy has gained a lot of importance since the Great Recession and has captured some of the territory previously entrusted to monetary policy (financial stability). Moreover, it is not clear whether the monetary and financial responses to shocks and frictions should be equivalent in the US and in the euro area, given their asymmetric and distinct nature of spillovers. While we are not attempting to provide a framework for (re)defining policy objectives, targets and instruments, we wish to explore the implications of our findings for monetary and macroprudential stance and provide some groundwork for further investigation.

The current high degree of synchronicity between macroeconomic and financial cycles implies two things. First, disturbances in either sector will be transmitted almost completely to the other sector. Second, it is hard to disentangle the sphere of influence of monetary and macroprudential policy, since their transmissions will be heavily aligned and exert strong spillover effects/externality on the other. Moreover, taking into account that the financial cycle is comparatively longer, it also means that the timing of their phases might have important implications for both policies. While monetary policy impact on shorter frequency, macroprudential policy does so on longer frequency. This means that, it is possible for the economy to experience twin crises resulting in double-dip recessions over a short period of time. Under this scenario, while the economy recovers from the first recession, the financial cycle may start to contract, exerting downward pressures on the macroeconomic cycle and resulting in another recession. And albeit both policies react optimally and according to their individual targets, the total impact might still be inadequate and undesirable since the large overlapping set (or intersection) is overlooked.

Another equally important finding is the potential for financial shock spillover from the US to the real and financial sectors of the euro area. Considering that the transmission is mainly in one direction, the ECB should be very concerned about the developments and fluctuations in the US financial sector. Bearing in mind that the transmission of US financial shocks to euro area real activity is stronger than any other combination of cross-border spillovers, this implies that the monetary policy should be concerned and respond to US financial sector fluctuations to a higher extent than (traditional) financial policy.

The implications for monetary policy from these developments are of significant importance. First, monetary policy will and is forced to respond to developments in the financial sector. Conversely, monetary policy must have a more prominent role to play in financial sector activity compared to the pre-Great Recession optimum. Thus, despite all the effort to insulate monetary policy from financial stability concerns and the realm of financial policy, their influence is stronger than ever before in post-war history. Monetary policy must devote much more efforts to understand, in real time, the particular point that the financial cycle is on, and the potential risks to the monetary system and the macroeconomy. This is particularly relevant to the ECB which must monitor, respond, and target both internal and US financial disturbances. Financial policy, on the other hand, must price in the reaction and targets of monetary policy. There are two ways of achieving this. Either a leader-follower arrangement where monetary policy is the leader, and financial policy the follower. Alternatively, a close interaction between the policies will be necessary at all points in the business cycle, perhaps even explicitly. Also, the monetary stance needs to adjust and incorporate a much broader and deeper map of financial exposures and risks into its map. Lastly, it may well be necessary to expand the monetary policy toolkit to include multiple instruments and (clearly defined) targets. In this new environment, it is hard to conceive how price stability will achieve the broader objective of macroeconomic growth and stability. Only in cooperation with other instruments, possibly those employed during the unconventional monetary policy phase, will that objective be achieved.

A.2 Estimation algorithm

The proposed algorithm relies on Bayesian methods and uses the Gibss sampler to simulate the posterior distribution of parameters and latent variables involved in the time-varying parameter factor model. Define the following vectors containing information on the

$n_f$and $n_r$financial and real activity variables, respectively, $\widetilde{Y}_T = \{F_{1_f,t}, ..., F_{n_f,t}, R_{1_r,t}, ..., R_{n_r,t}\}_{t=1}^{T}$, real activity index, $\widetilde{f}_T = \{f_t\}_{t=1}^{T}$, financial conditions index, $\widetilde{r}_T = \{r_t\}_{t=1}^{T}$, factor loadings, $\widetilde{\Lambda}_{x,T} = \{\Lambda_{x,t}\}_{t=1}^{T}$, where $\Lambda_{x,t} = (\lambda_{1_x,t}, ..., \lambda_{n_x,t})'$, for $x = \{f, r\}$, and autoregressive coefficients, $\widetilde{\Phi}_T = \{vec(\Phi_{1,t}), ..., vec(\Phi_{k,t})\}_{t=1}^{T}$. The algorithm consists of the following steps:

- ***Step 1***: Sample $\widetilde{f}_T$, and $\widetilde{r}_T$ from $P(\widetilde{f}_T, \widetilde{r}_T | \widetilde{\Lambda}_{x,T}, \widetilde{\Phi}_T, \Sigma, \Omega, \Psi_\omega, \Psi_w, \widetilde{Y}_T)$

The model in equations (1)-(2), with $k = 2$, can be cast in a state-space representation with measurement equation given by,

$$\begin{bmatrix} F_{1_f,t} \\ \vdots \\ F_{n_f,t} \\ R_{1_r,t} \\ \vdots \\ R_{n_r,t} \end{bmatrix} = \begin{bmatrix} \lambda_{1_f,t} & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots \\ \lambda_{n_f,t} & 0 & 0 & 0 \\ 0 & \lambda_{1_r,t} & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & \lambda_{n_r,t} & 0 & 0 \end{bmatrix} \begin{bmatrix} f_t \\ r_t \\ f_{t-1} \\ r_{t-1} \end{bmatrix} + \begin{bmatrix} v_{1_f,t} \\ \vdots \\ v_{n_f,t} \\ v_{1_r,t} \\ \vdots \\ v_{n_r,t} \end{bmatrix}, \tag{7}$$

and transition equation defined as,

$$\begin{bmatrix} f_t \\ r_t \\ f_{t-1} \\ r_{t-1} \end{bmatrix} = \begin{bmatrix} \phi^{(1)}_{ff,t} & \phi^{(1)}_{fr,t} & \phi^{(2)}_{ff,t} & \phi^{(2)}_{fr,t} \\ \phi^{(1)}_{rf,t} & \phi^{(1)}_{rr,t} & \phi^{(2)}_{rf,t} & \phi^{(2)}_{rr,t} \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} f_{t-1} \\ r_{t-1} \\ f_{t-2} \\ r_{t-2} \end{bmatrix} + \begin{bmatrix} u_{f,t} \\ u_{r,t} \\ 0 \\ 0 \end{bmatrix}. \tag{8}$$

Conditional on $\widetilde{\Lambda}_{x,T}$ and $\widetilde{\Phi}_T$, equations (7)-(8) constitute a linear and Gaussian state-space model, and the Carter and Kohn simulation smoother is applied to generate inferences of the factors.

- ***Step 2***: Sample Ψ_w from $P(\Psi_w | \widetilde{\Phi}_T, \widetilde{Y}_T)$

To sample the variance of the time-varying autoregressive coefficient innovations, we use an inverse Wishart prior distribution, $IW(\underline{\eta}, \underline{v})$, with $\underline{\eta} = \tau$ and $\underline{v} = \kappa^2 \times \tau \times \Psi_w^{OLS}$, where $\tau = 80$ is the size of the training sample, Ψ_w^{OLS} is the variance of the autoregressive coefficient matrix estimated by OLS based on the training sample, and $\kappa = 0.2$ is a scaling factor. Hence, draws of Ψ_w are generated from the posterior distribution,

$$\Psi_w \sim IW(\bar{\eta}, \bar{v}),$$

where

$$\begin{aligned}
\bar{\eta} &= \underline{\eta} + T \\
\bar{v} &= \underline{v} + (\boldsymbol{\phi}_t - \boldsymbol{\phi}_{t-1})'(\boldsymbol{\phi}_t - \boldsymbol{\phi}_{t-1}).
\end{aligned}$$

- ***Step 3***: Sample $\widetilde{\Phi}_T$ from $P(\widetilde{\Phi}_T|\widetilde{f}_T, \widetilde{r}_T, \Psi_w, \Sigma, \widetilde{Y}_T)$

Conditional on the factors, the time-varying coefficient VAR model that drives the dynamics of the factors can be compactly expressed in the following state-space form,

$$\begin{aligned}
\boldsymbol{y}_t &= \boldsymbol{X}_t'\boldsymbol{\phi}_t + \boldsymbol{v}_t, \quad \boldsymbol{v}_t \sim N(\mathbf{0}, \Sigma) \\
\boldsymbol{\phi}_t &= \boldsymbol{\phi}_{t-1} + \boldsymbol{w}_t, \quad \boldsymbol{w}_t \sim N(\mathbf{0}, \Psi_w)
\end{aligned}$$

where $\boldsymbol{y}_t = (f_t, r_t)'$, $\boldsymbol{X}_t = I_m \otimes [1, \boldsymbol{y}_{t-1}', ..., \boldsymbol{y}_{t-k}']$ are observed, with $m = 2$ being the number of factors, and $\boldsymbol{\phi}_t$ is the latent vector. Therefore, as in Step 1, the Carter and Kohn algorithm is applied to generate draws of $\widetilde{\Phi}_T$. To achieve stability in the system, this step is repeated until it generates a draw of $\boldsymbol{\phi}_t$ that fulfills the stationarity conditions for all time periods in the sample.

- ***Step 4***: Sample Σ from $P(\Sigma|\widetilde{f}_T, \widetilde{r}_T, \widetilde{\Phi}_T, \Psi_w, \widetilde{Y}_T)$

To sample the variance of reduced form innovations, we use an inverse Wishart prior distribution, $IW(\underline{m}, \underline{\nu})$, with $\underline{m} = m + 1$ and $\underline{\nu} = I_m$. Hence, draws of Σ are generated from the posterior distribution,

$$\Sigma \sim IW(\bar{m}, \bar{\nu}),$$

where

$$\begin{aligned}
\bar{m} &= \underline{m} + T \\
\bar{\nu} &= \underline{\nu} + (\boldsymbol{y}_t - \boldsymbol{X}_t'\boldsymbol{\phi}_t)'(\boldsymbol{y}_t - \boldsymbol{X}_t'\boldsymbol{\phi}_t).
\end{aligned}$$

- ***Step 5***: Sample $\widetilde{\Lambda}_{x,T}$ from $P(\widetilde{\Lambda}_{x,T}|\widetilde{f}_T, \widetilde{r}_T, \Omega, \Psi_\omega, \widetilde{Y}_T)$

Given that Ω is assumed to be a diagonal matrix, each time-varying loading can be sampled independently. Accordingly, we use the following state-space representation,

$$\begin{aligned} X_{i_x,t} &= \lambda_{i_x,t} x_t + v_{i_x,t}, \quad v_{i_x,t} \sim N(0, \Omega_{[i_x,i_x]}) \\ \lambda_{i_x,t} &= \lambda_{i_x,t-1} + \omega_{i_x,t}, \quad \omega_{i_x,t} \sim N(0, \Psi_{\omega,[i_x,i_x]}) \end{aligned}$$

for observed variables $X = F, R$, latent factors $x = f, r$, and $i = 1, ..., n$. Next, the Carter and Kohn algorithm is applied to generate draws of the elements in $\widetilde{\Lambda}_{x,T}$.

- ***Step 6***: Sample Ψ_ω from $P(\Psi_\omega|\widetilde{\Lambda}_{x,T}, \widetilde{Y}_T)$

To sample, independently, the variance of the time-varying loading innovations, we use an inverse Gamma prior distribution, $IG(\underline{u}, \underline{z})$, with $\underline{u} = 0.1 \times T$ and $\underline{z} = 0.1^2$. Hence, draws of Ψ_w are generated from the posterior distribution,

$$\Psi_w \sim IG(\bar{u}, \bar{z}),$$

where

$$\begin{aligned} \bar{u} &= \underline{u} + T \\ \bar{z} &= \underline{z} + (\lambda_{i_x,t} - \lambda_{i_x,t-1})'(\lambda_{i_x,t} - \lambda_{i_x,t-1}). \end{aligned}$$

- ***Step 7***: Sample Ω from $P(\Omega|\widetilde{f}_T, \widetilde{r}_T, \widetilde{\Lambda}_{x,T}, \widetilde{Y}_T)$

To sample, independently, the variance of the idiosyncratic terms, we use an inverse Gamma prior distribution, $IG(\underline{l}, \underline{o})$, with $\underline{l} = 0$ and $\underline{o} = 0$. Accordingly, draws of the entries in the diagonal of Ω are generated from the posterior distribution,

$$\Omega_{i_x} \sim IG(\bar{l}, \bar{o}),$$

for $i = 1, ..., n$, $X = F, R$, and $x = f, r$, where

$$\begin{aligned} \bar{l} &= \underline{l} + T \\ \bar{o} &= \underline{o} + (X_{i_x,t} - \lambda_{i_x,t} x_t)'(X_{i_x,t} - \lambda_{i_x,t} x_t). \end{aligned}$$

To approximate the posterior distribution of both the parameters and latent variables involved in the model, each step of the algorithm is recursively repeated $M = 22,000$ times, discarding the first $m = 20,000$ iterations to ensure convergence.

A.3 Alternative Identification Schemes

Table 5: Recursive Identification for the Two-economy model

	Fin. Shock E.A.	Real Shock E.A.	Fin. Shock US	Real Shock US
Financial Cycle E.A.	$*$	$*$	$*$	$*$
Real Cycle E.A.	0	$*$	$*$	$*$
Financial Cycle US	0	0	$*$	$*$
Real Cycle US	0	0	0	$*$

Note: The symbol $*$ indicates that no restriction is imposed in the corresponding relationship.

Table 6: Alternative Sign and Exclusion Restrictions for the Two-economy model

	Fin. Shock E.A.	Real Shock E.A.	Fin. Shock US	Real Shock US
Financial Cycle E.A.	+	+	$*$	$*$
Real Cycle E.A.	0	+	$*$	$*$
Financial Cycle US	0	0	+	+
Real Cycle US	0	0	0	+

Note: The symbol $*$ indicates that no restriction is imposed in the corresponding relationship.

A.4 Additional Figures

Figure 17: Estimated factors of the US - Principal Component

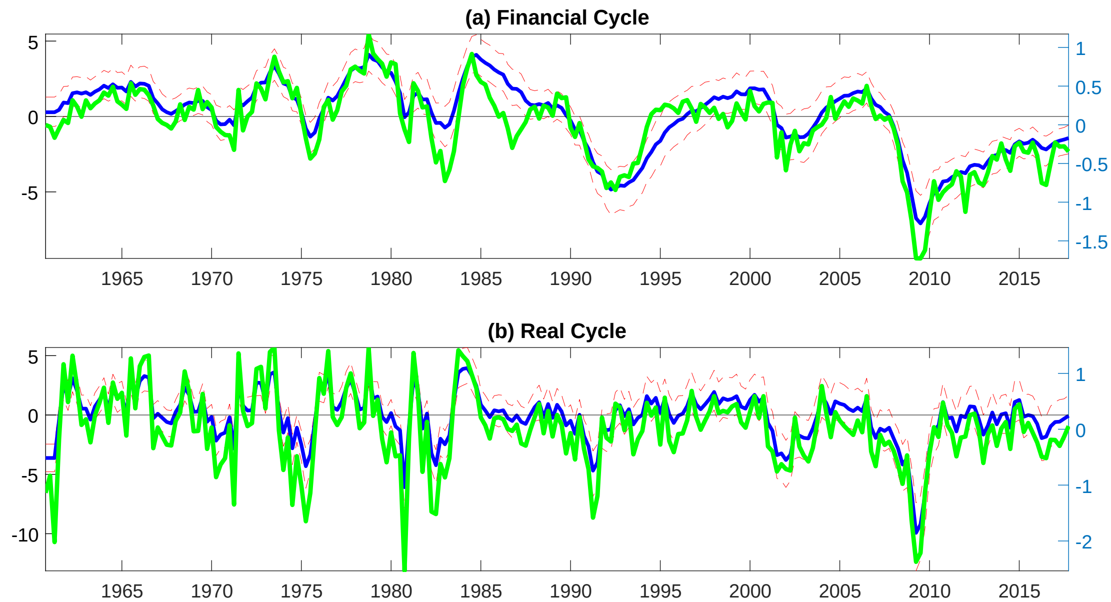
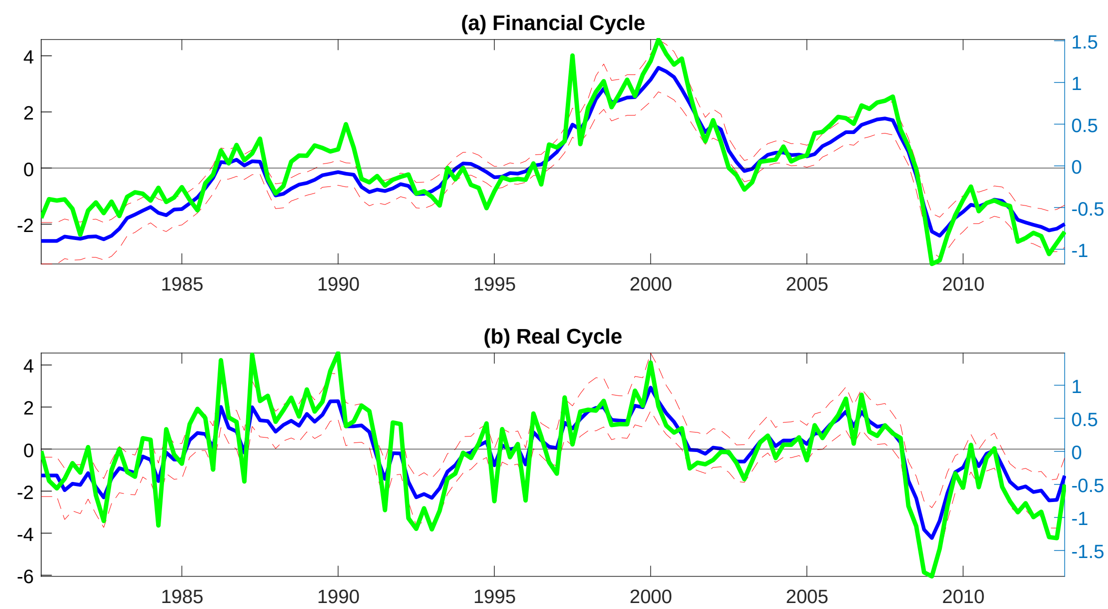


Figure 18: Estimated factors of the euro area - Principal Component



Note: The figures plot the estimated real and financial cycles. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 5 and 95 of the posterior distribution, and the solid green line plots the corresponding factor estimated with principal components, and aligned with the right axis.

Figure 19: Estimated correlation between factors of the US - Orthogonal Innovations

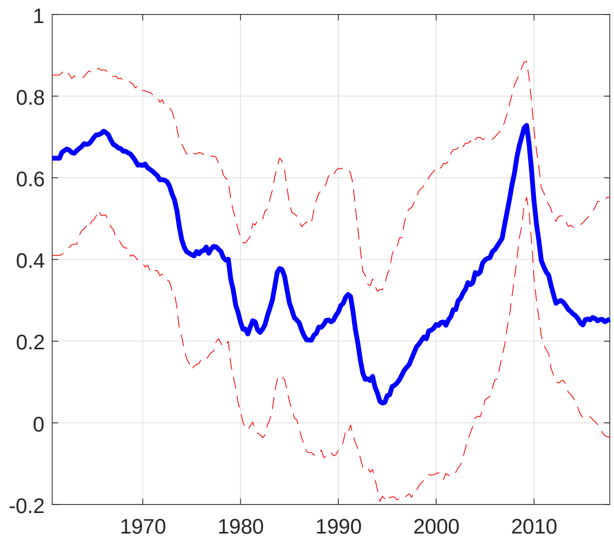
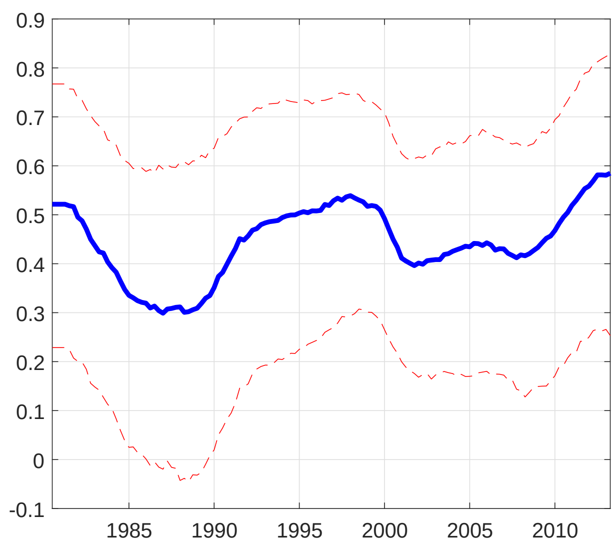
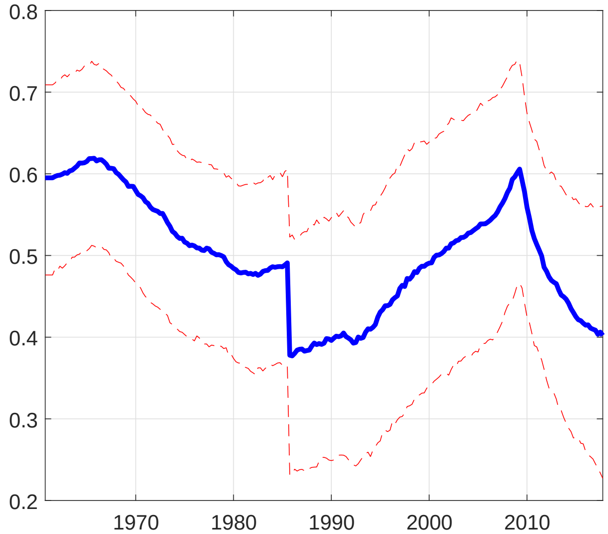


Figure 20: Estimated correlation between factors of the euro area - Orthogonal Innovations



Note: The figures plot the estimated time-varying correlation between the real and financial cycle. The solid blue line makes reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution. The estimates are obtained by assuming orthogonality in the innovations of the factors.

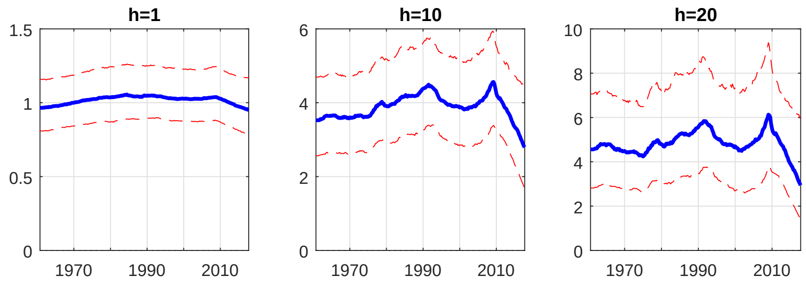
Figure 21: Estimated correlation between factors of the US - Break in Volatility



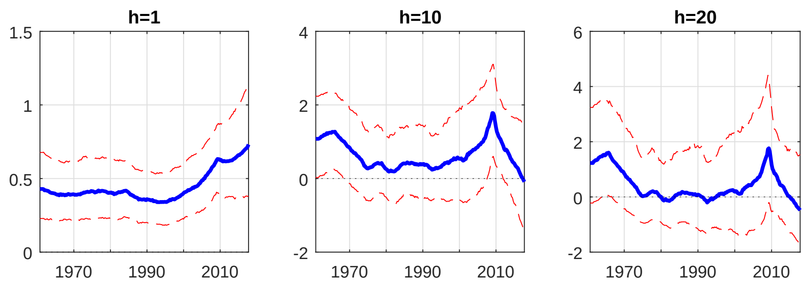
Note: The figure plots the estimated time-varying correlation between the real and financial cycles. The solid blue line makes reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution. The estimates are obtained by assuming a break in the volatility of the factors occurred in 1985.

Figure 22: Cumulated Impulse Response Patterns for US

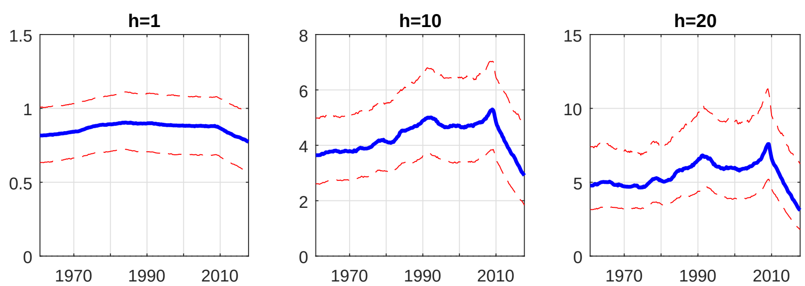
(a) Response of financial conditions to a financial shock



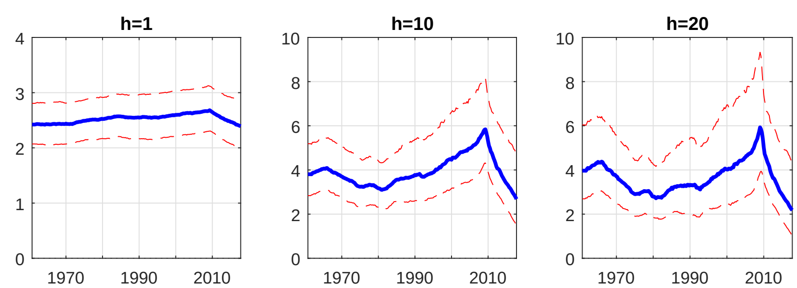
(b) Response of real activity to a financial shock



(c) Response of financial conditions to a real shock



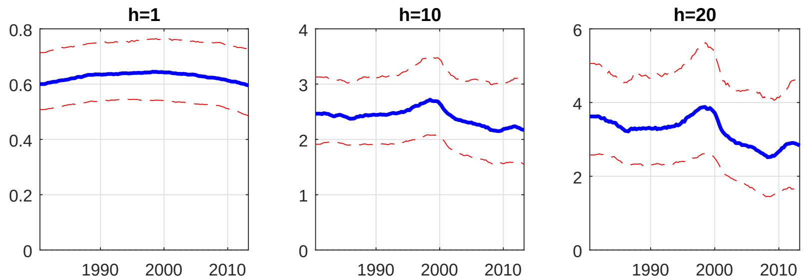
(d) Response of real activity to a real shock



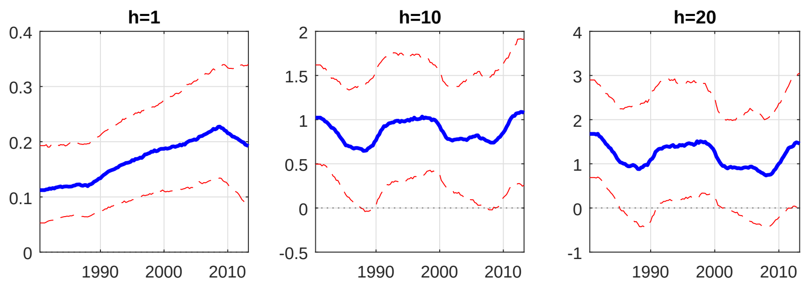
Note: The figure plots the estimated time-varying cumulated impulse responses for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 23: Cumulated Impulse Response Patterns for euro area

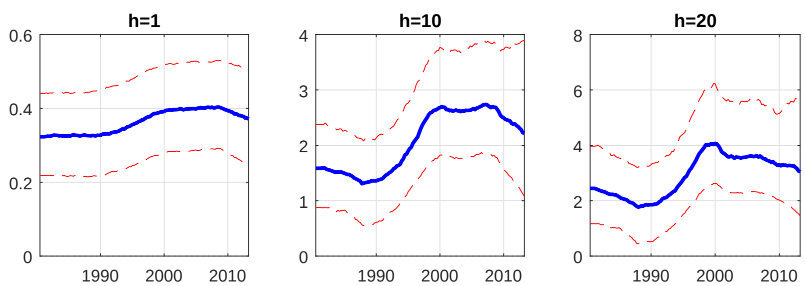
(a) Response of financial conditions to a financial shock



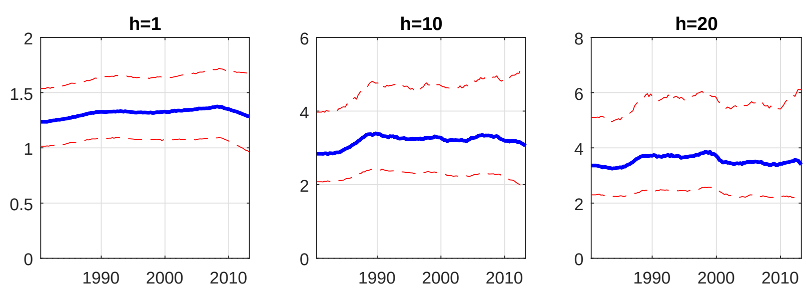
(b) Response of real activity to a financial shock



(c) Response of financial conditions to a real shock

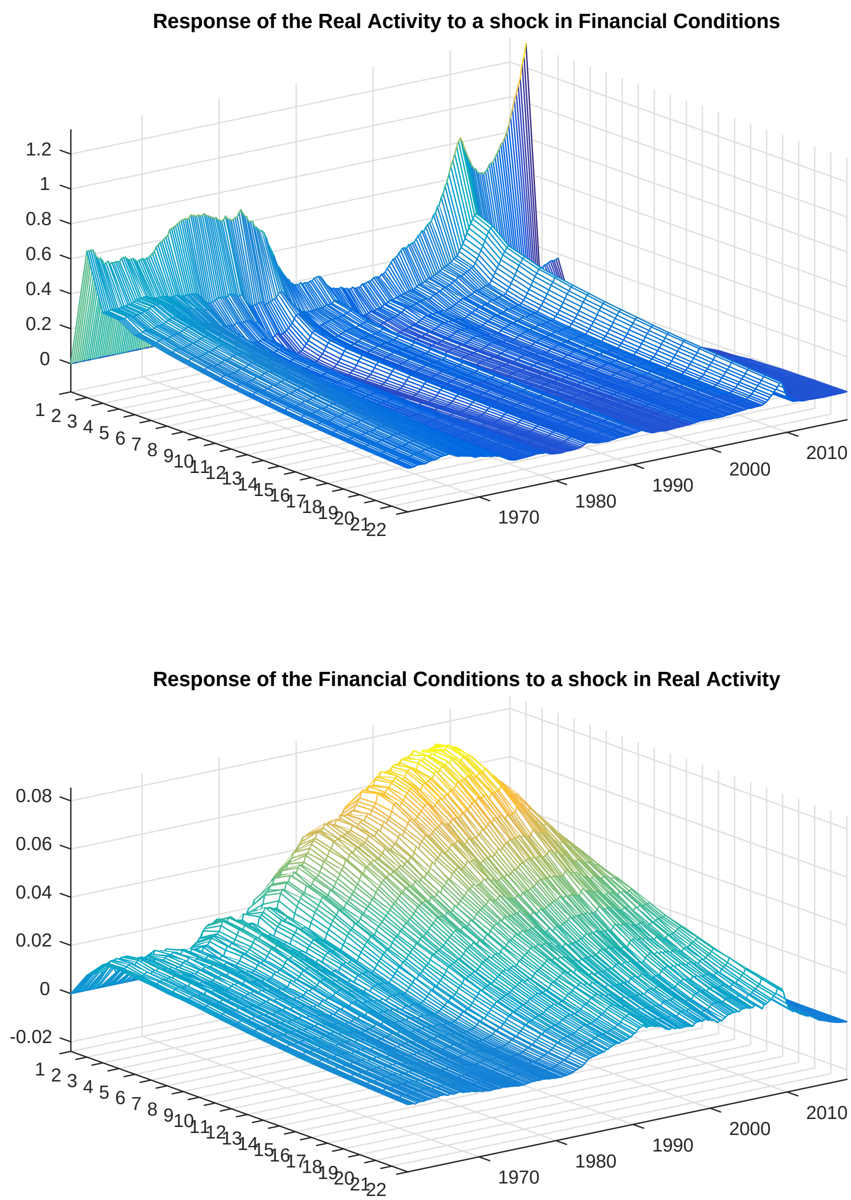


(d) Response of real activity to a real shock



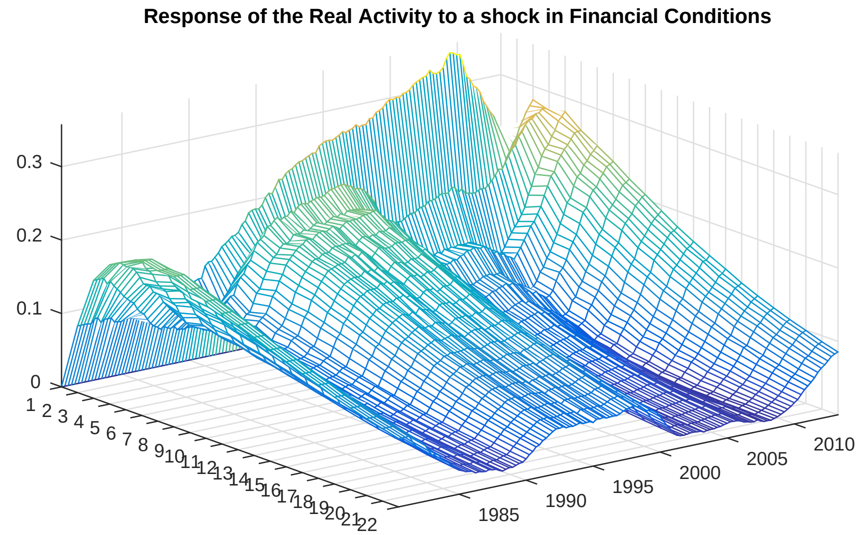
Note: The figure plots the estimated time-varying cumulated impulse responses for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

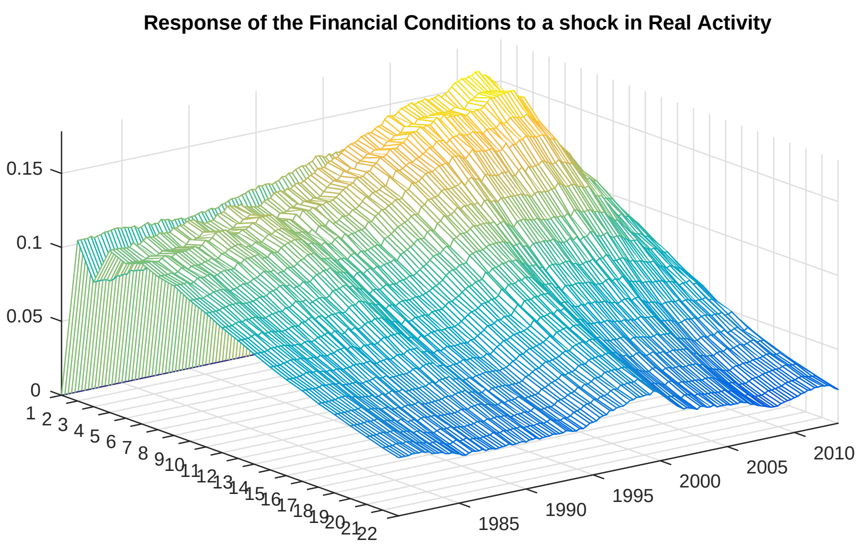
Figure 24: Impulse Responses Between Real and Financial Cycles for US - Orthogonal Innovations



Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by assuming orthogonality in the innovations of the factors.

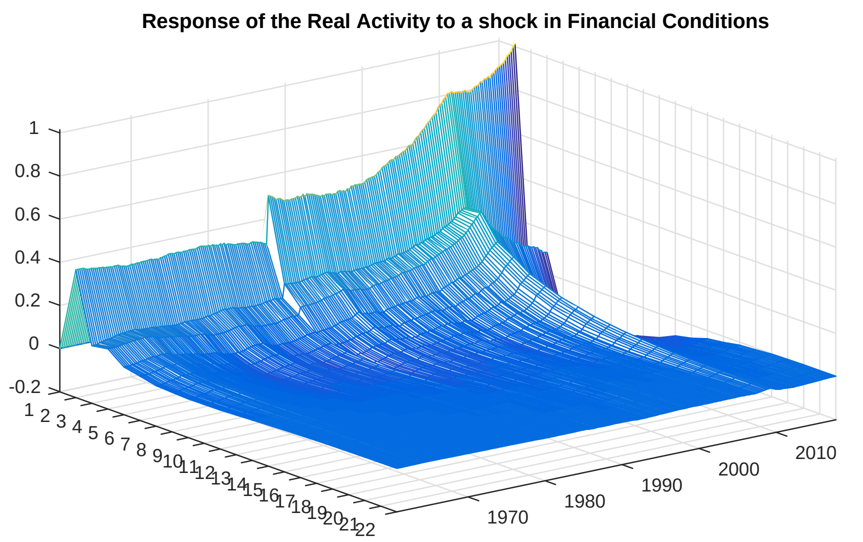
Figure 25: Impulse Responses Between Real and Financial Cycles for euro area - Orthogonal Innovations

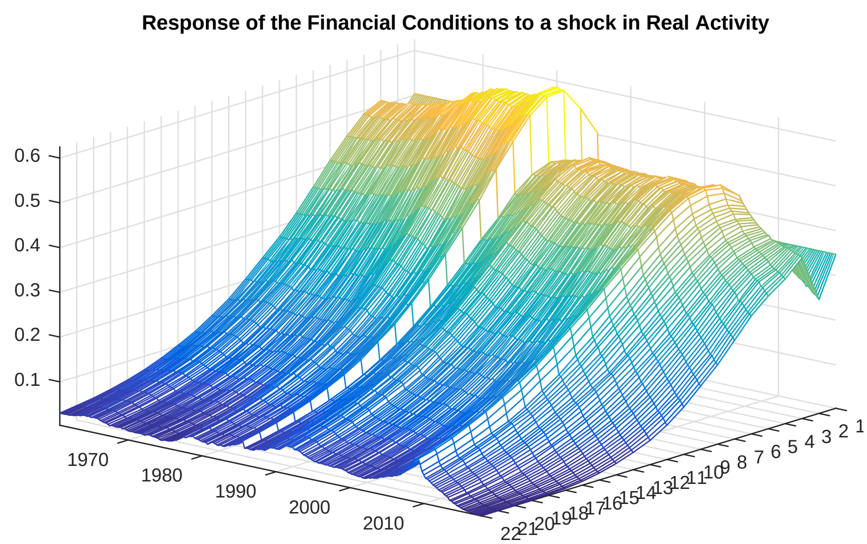




Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by assuming orthogonality in the innovations of the factors.

Figure 26: Impulse Responses Between Real and Financial Cycles for US - Break in Volatility

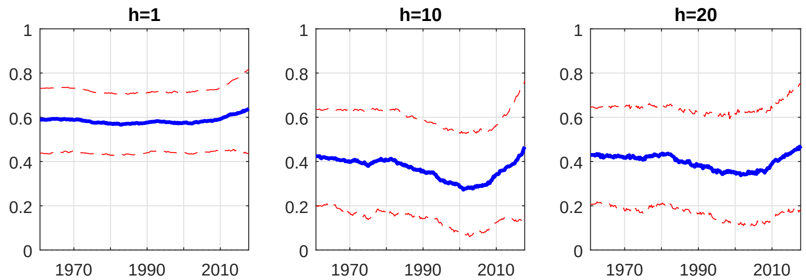




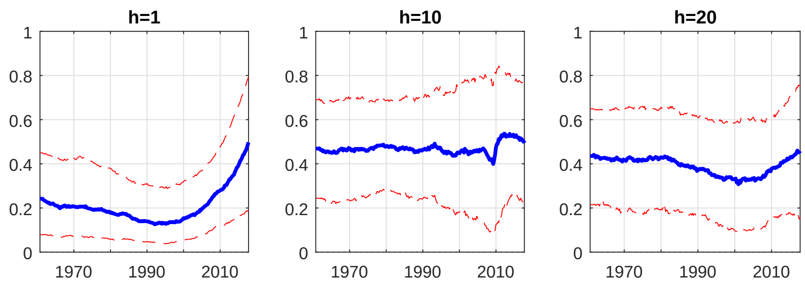
Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by assuming a break in the volatility of the factors occurred in 1985.

Figure 27: Forecast Error Variance Decomposition for US

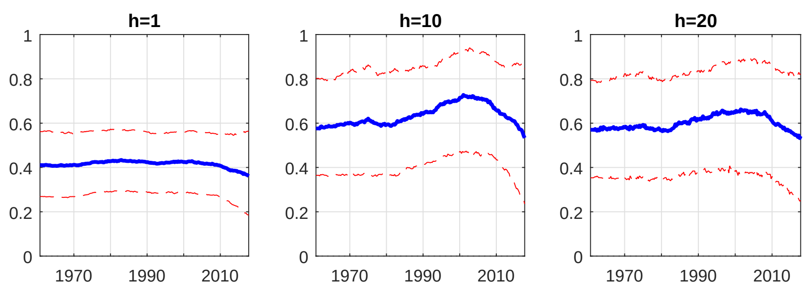
(a) Contribution of financial shocks to financial conditions



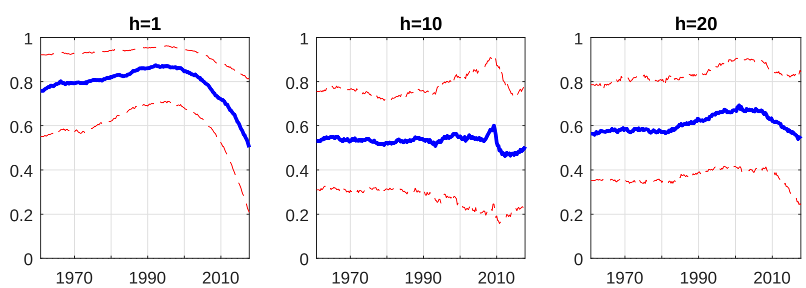
(b) Contribution of financial shocks to real activity



(c) Contribution of real shocks to financial conditions



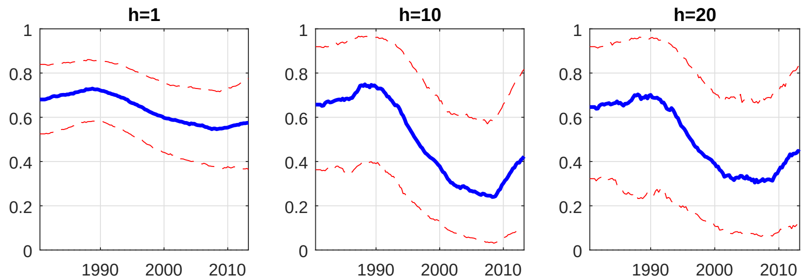
(d) Contribution of real shocks to real activity



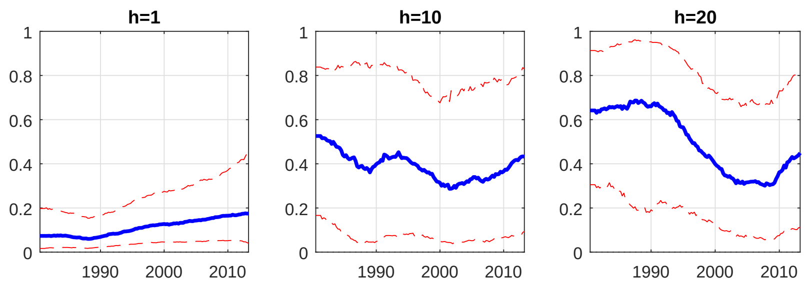
Note: The figure plots the estimated time-varying forecast error variance decomposition for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 28: Forecast Error Variance Decomposition for euro area

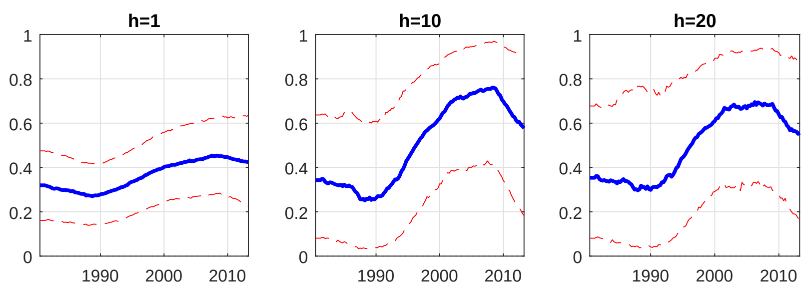
(a) Contribution of financial shocks to financial conditions



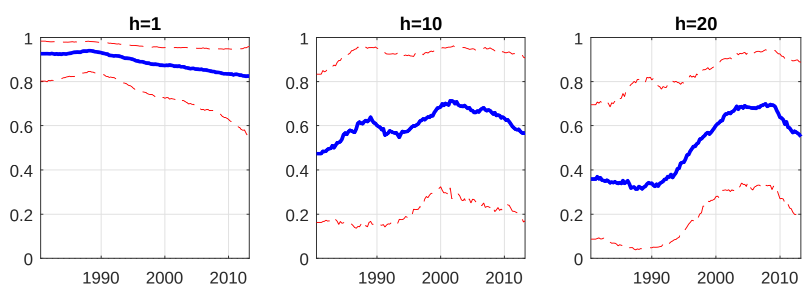
(b) Contribution of financial shocks to real activity



(c) Contribution of real shocks to financial conditions

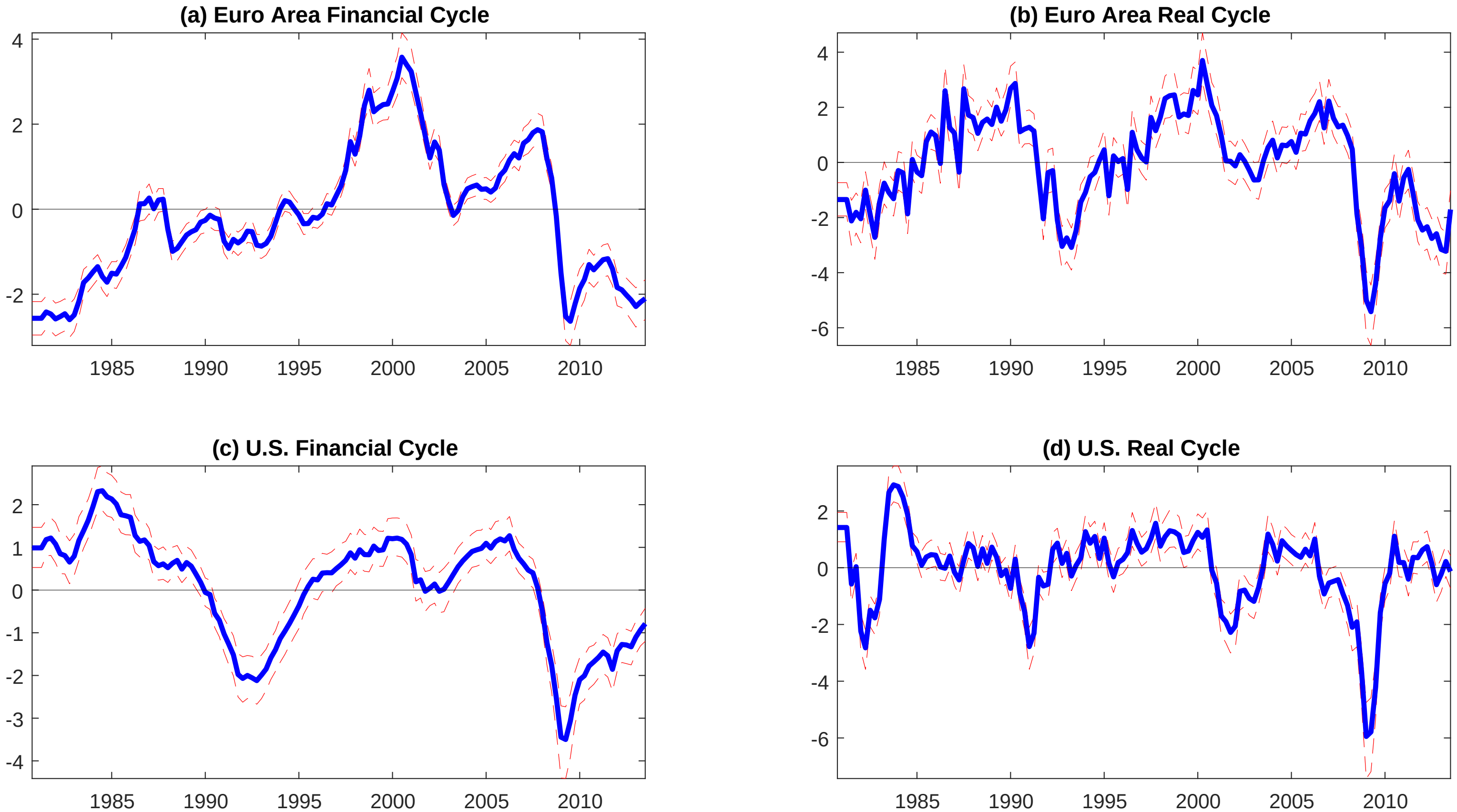


(d) Contribution real shocks to real activity



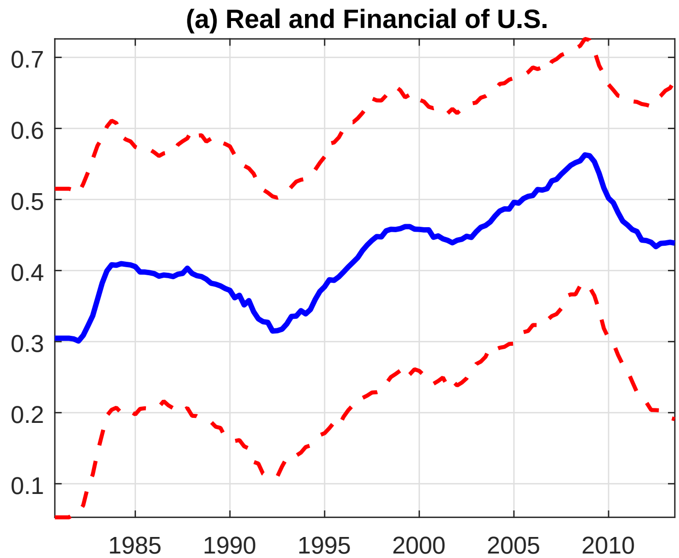
Note: The figure plots the estimated time-varying forecast error variance decomposition for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

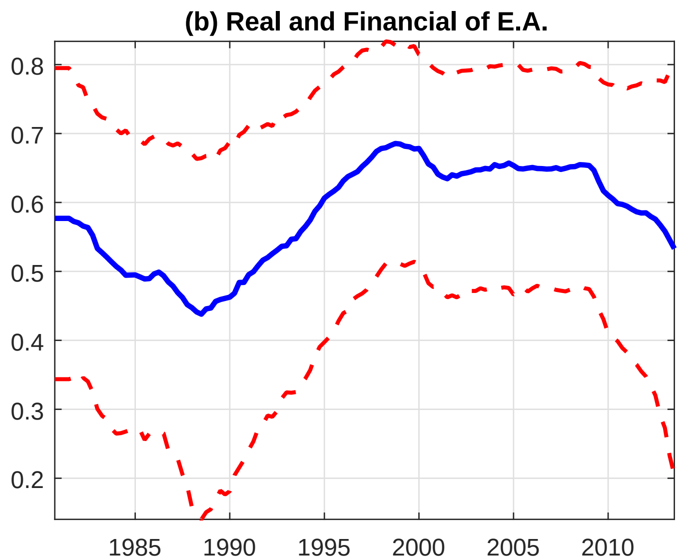
Figure 29: Estimated factors of the US and euro area (Two-economy model)



Note: The figures plot the estimated real and financial cycles for the US and euro area obtained with the (joint) two-economy model. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 30: Estimated correlation between factors associated to a given economy (Two-economy model)

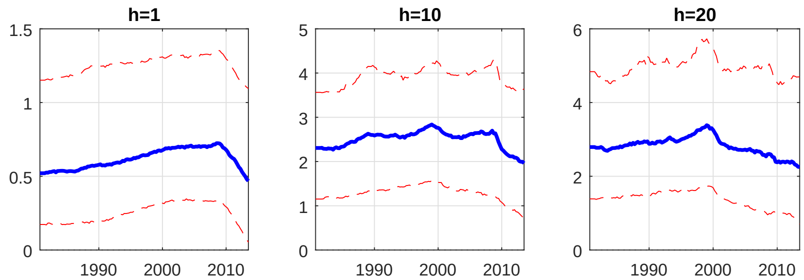




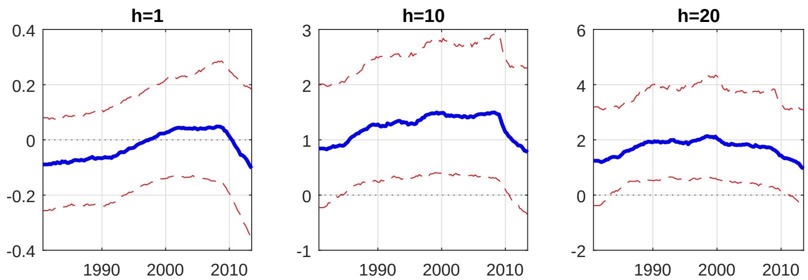
Note: The figure plots the estimated time-varying correlation between the business and financial cycles associated to a given economy. The solid blue line makes reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 31: Cumulated Impulse Response Patterns: Effect of US on E.A.

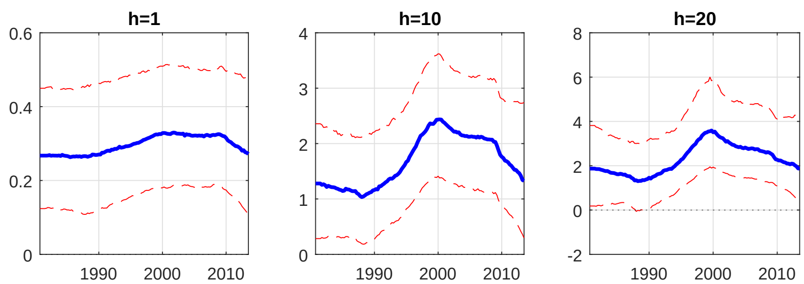
(a) Response of the E.A. Real Activity to a shock in US Real Activity



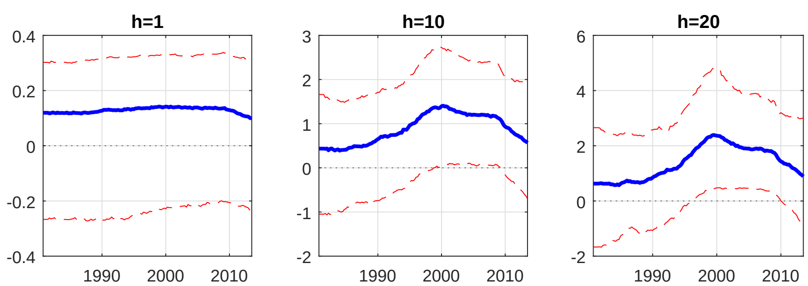
(b) Response of the E.A. Real Activity to a shock in US Financial Conditions



(c) Response of the E.A. Financial Conditions to a shock in US Real Activity

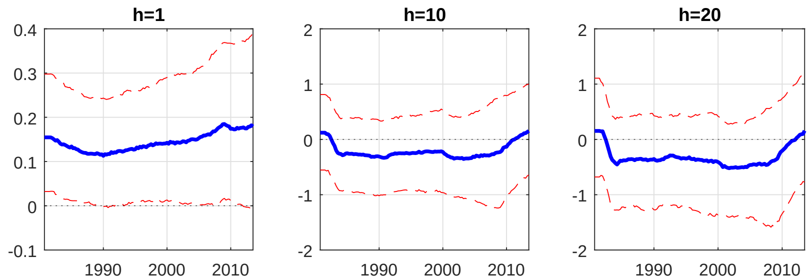


(d) Response of the E.A. Financial Conditions to a shock in US Financial Conditions

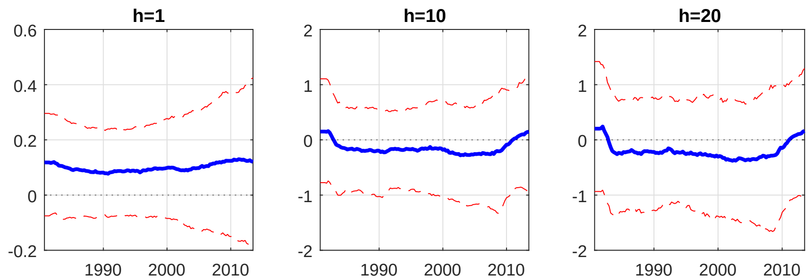


Note: The figure plots the estimated time-varying cumulated impulse responses for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

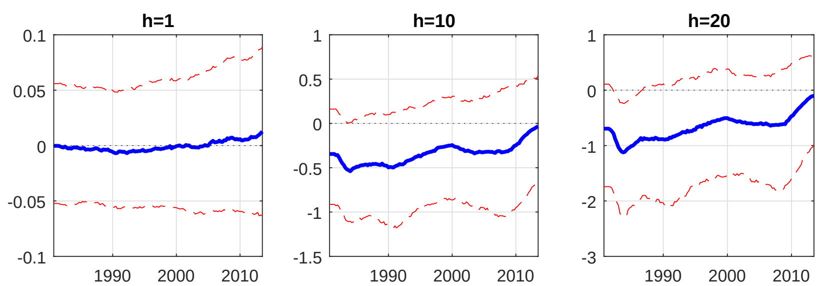
Figure 32: Cumulated Impulse Response Patterns: Effect of E.A. on US



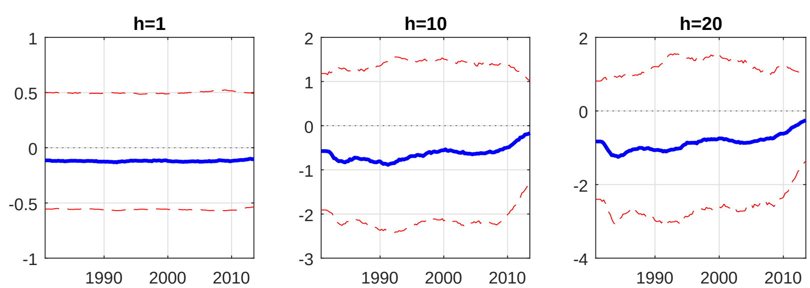
(a) Response of the US Real Activity to a shock in E.A. Real Activity



(b) Response of the US Real Activity to a shock in E.A. Financial Conditions



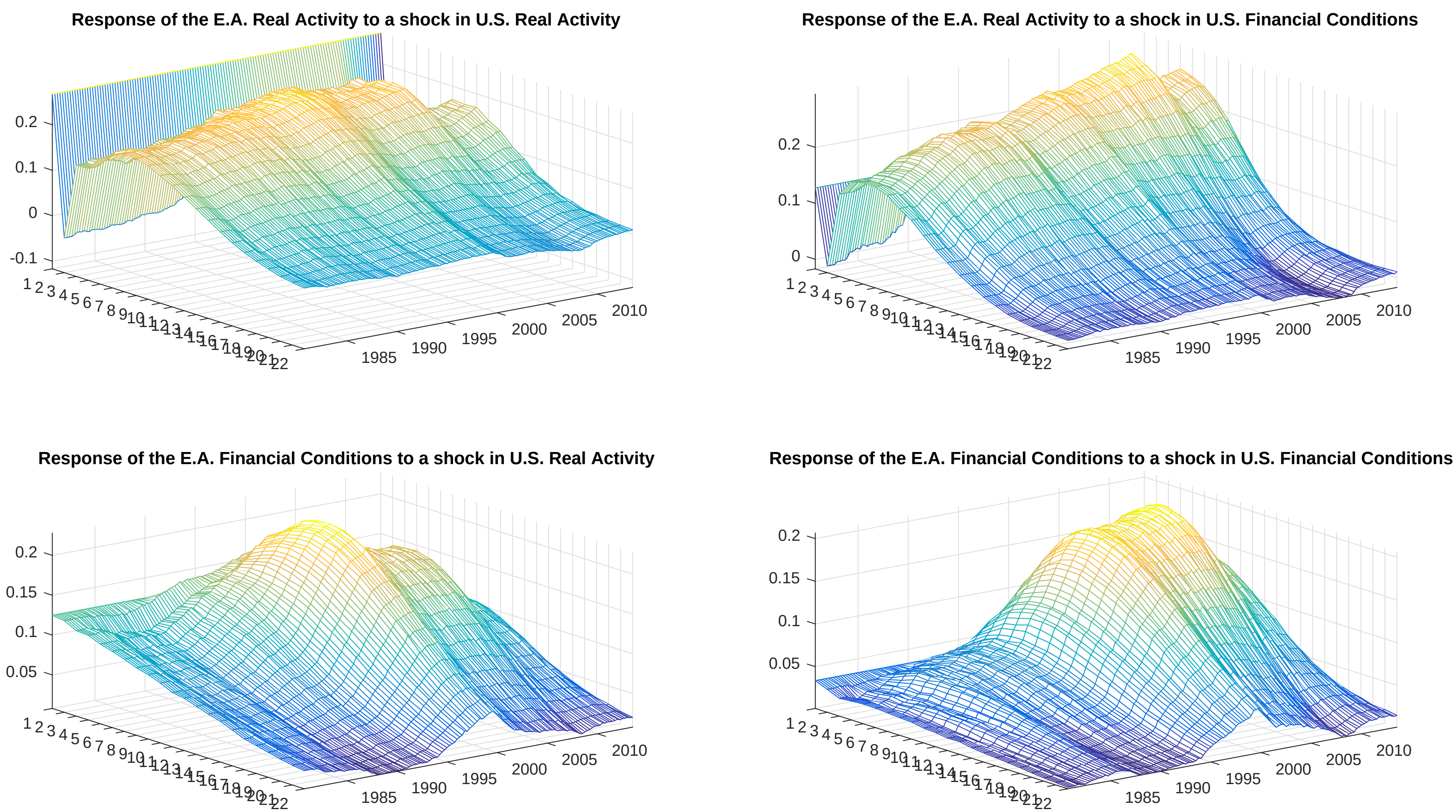
(c) Response of the US Financial Conditions to a shock in E.A. Real Activity



(d) Response of the US Financial Conditions to a shock in E.A. Financial Conditions

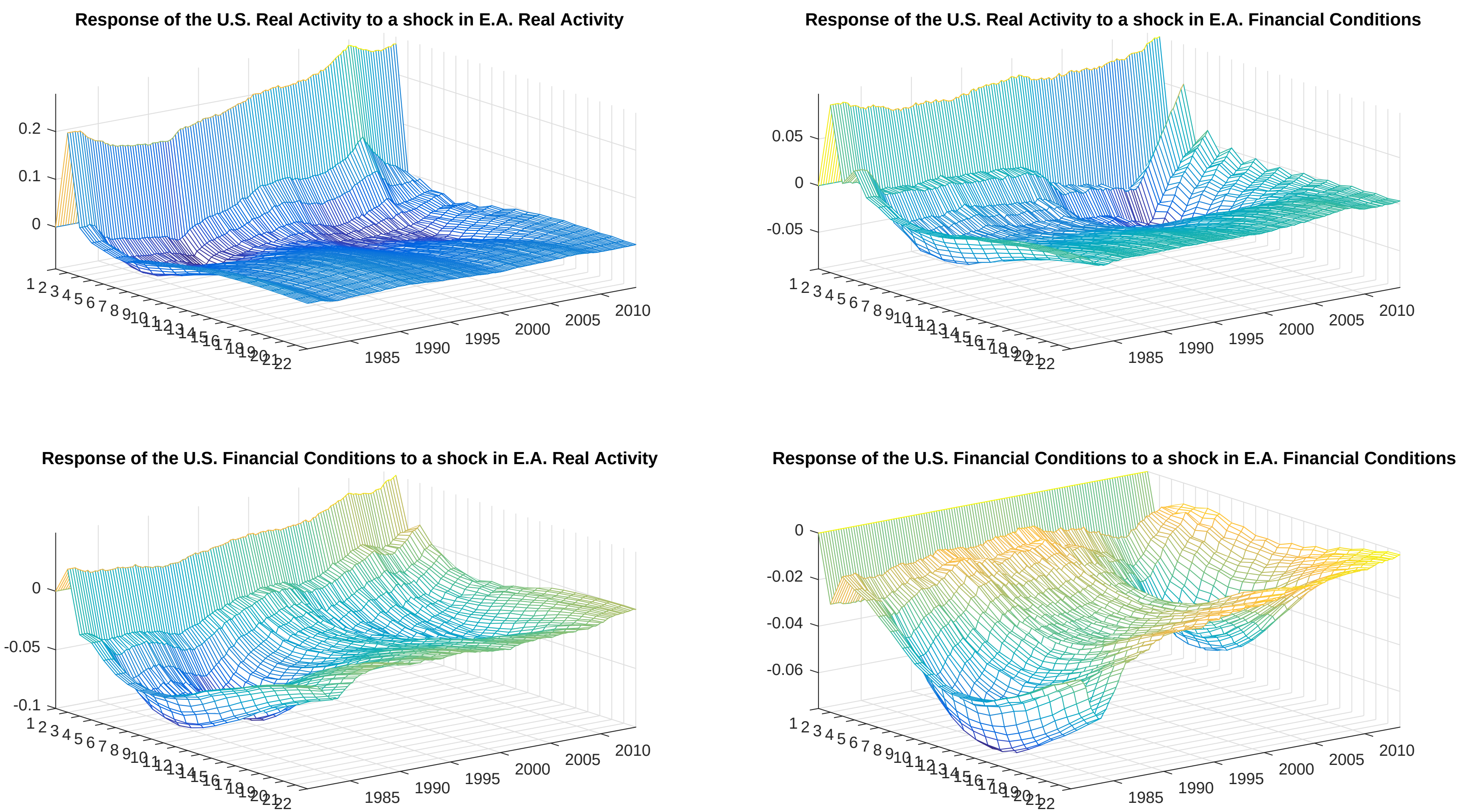
Note: The figure plots the estimated time-varying cumulated impulse responses for different horizons (h). The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentiles 16 and 84 of the posterior distribution.

Figure 33: Macro-financial spillovers from the US to the euro area over time - Cholesky



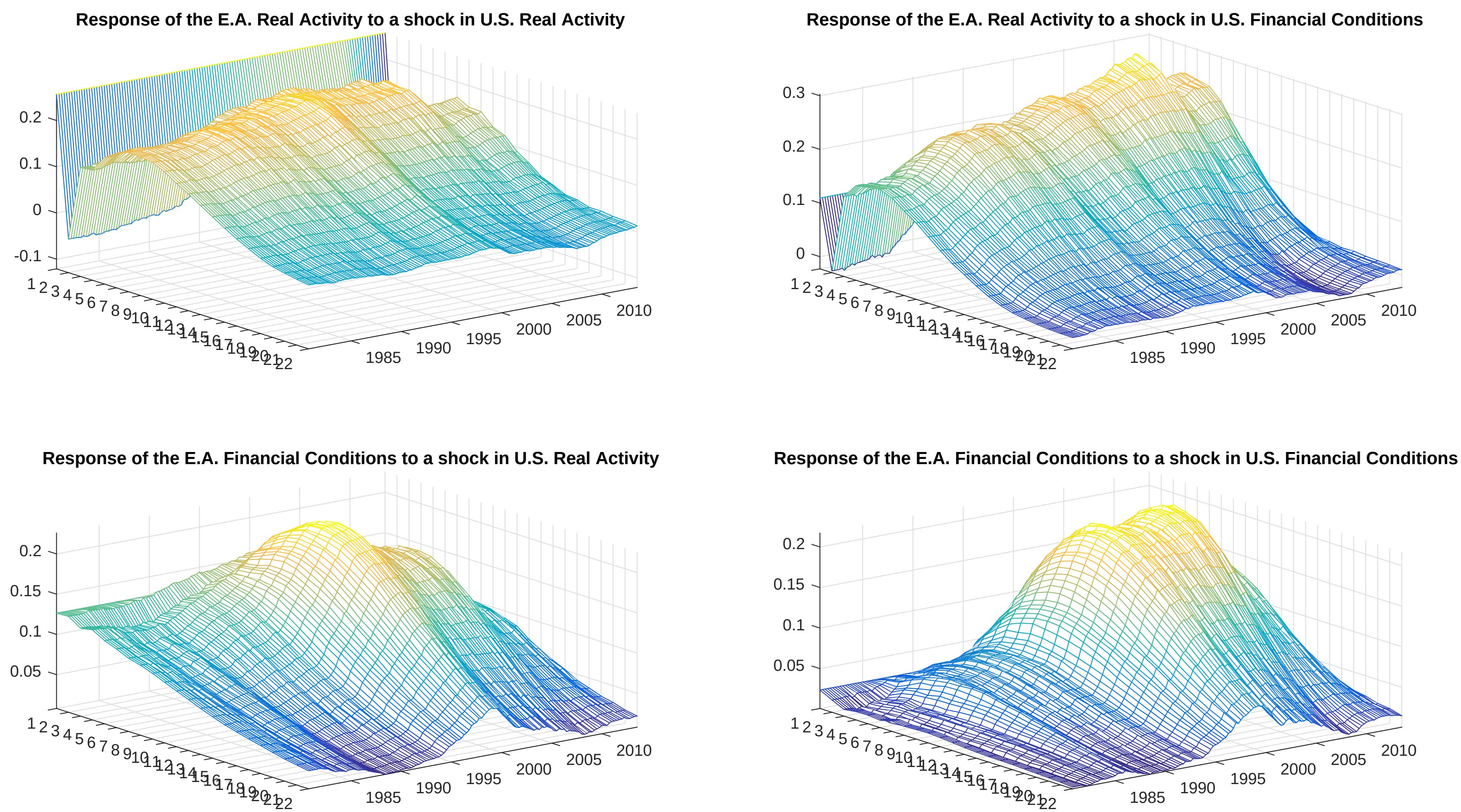
Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using Cholesky factorization to identify the structural shocks.

Figure 34: Macro-financial spillovers from the euro area to the US over time - Cholesky



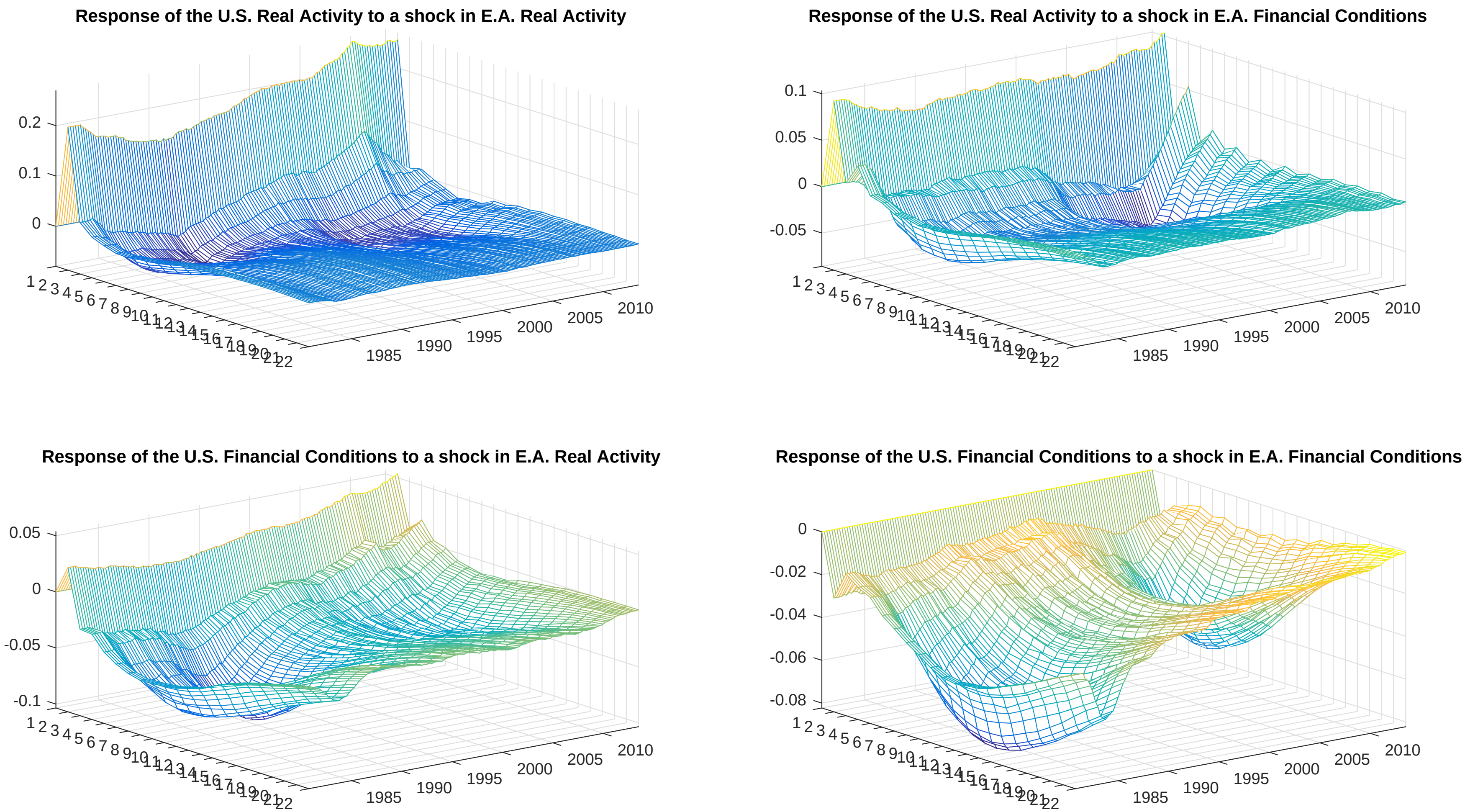
Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using Cholesky factorization to identify the structural shocks.

Figure 35: Macro-financial spillovers from the US to the euro area over time - Alternative sign and exclusion restrictions



Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using Cholesky factorization to identify the structural shocks.

Figure 36: Macro-financial spillovers from the euro area to the US over time - Alternative sign and exclusion restrictions



Note: The figure plots the estimated time-varying impulse responses for different horizons (h). The surface makes reference to the median of the corresponding posterior distribution. The estimates are obtained by using Cholesky factorization to identify the structural shocks.

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