Inspecting Cross-Border Macro-Financial Mechanisms*

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Abstract

We model structural time-varying macro-financial linkages between the U.S. and euro area using a large dataset for each region. We rely on factor models with drifting parameters where real and financial cycles are extracted, and shocks are identified via sign and exclusion restrictions. To interpret the mechanisms, we contextualize our empirical estimates using a two-country financial accelerator model. Our evidence speaks clearly of an asymmetric cross-border transmission between U.S. and euro area, especially in the financial domain. This is confirmed by our theoretical complement, which shows a strong transmission of U.S. TFP shocks. Moreover, the U.S. is a more leveraged economy, which accentuates the financial accelerator effect.

Keywords: Dynamic Factor Models, TVP-VAR, DSGE, U.S., Euro Area.

JEL Codes: E44, C32, C55, F44, E32, F41

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1 Introduction

The eagerness to understand macro-financial linkages has been brisk and unprecedented over the past decade and a half. 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 from the financial downturn that 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 in understanding cross-border transmissions of real and financial shocks. The Euro Area and the US have the largest bilateral trade and investment relationship, and enjoy the most integrated economic relationship globally (European Commission, 2023). Thus, disentangling the mechanisms behind shock transmission between the US and Euro Area is crucial to promote global macro and financial stability.

Macro-financial interactions between these two economies are complex, and potentially subject to fundamental changes over time. The aim of this paper is to provide a robust assessment of these interactions by taking into account all the underlying dimensions to the problem. The first part of the issue involves defining what the macroeconomic and financial cycles are. Yet, in the empirical literature there is still a wide debate on the exact definition of a real cycle and how different and more complete it is from the standard business cycle. For the financial counterpart, there is even less consensus on what constitutes a financial cycle, its statistical characterization, and how similar it is to the real cycle. The existing definitions, usually, tend to be narrow, exogenously pre-determined, or based on short time series samples.

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.¹ In addition, to give it structural anchoring, we

¹These 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 relies on the need for robustness in the determination of the most relevant variables driving the financial cycle over time,
reproduce the empirical relationships with a stylized two-country Iacoviello-type model.

The second part of the problem consists of measuring the intensity of the evolving macro-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.\(^2\) To the best of our knowledge, this is the first study of macro-financial spillovers between the U.S. and the euro area, each as single economic units, both from an empirical and theoretical point of view. Moreover, the study covers a longer sample than previous studies, starting in the 1980s.\(^3\)

Our empirical results point to an important asymmetric cross-border transmission of US shocks, which had intensified over time. First, the (mutual) impact of U.S. shocks is much larger than those from euro area. Real as well as financial shocks originating from the U.S. have statistically and economically significant impact on euro area macroeconomic and financial cycles, Conversely, shocks from the euro area tend to produce either small or short-lasting effects, or even negative on the U.S economy. Furthermore, we see a cross-border ‘substitution effect’, akin to flight-to-safety. Second, we observe a heavy dynamic evolution in responses. The intensity in the transmission of shocks increases over time, at least until the Great Recession. The introduction of the Euro did not manage to alter the hegemony of the U.S. in the bilateral relations. Third, since the Great Recession, the transmission of U.S. shocks has weakened, meanwhile the negative transmission of euro area shocks have also been reduced. This can be interpreted as a small change in the global role of the U.S., whereby the weakening of its economy and the protectionism that followed has reduced its’ international exposure and role as originator of cross-border shocks. This is confirmed by our theoretical complement, which shows that the transmission of US TFP shocks is significantly larger and more persistent than any alternative shock specifications. This creates a distinction in responses across economies, even in a symmetric real shock scenario. Moreover, the US is a more leveraged economy, which accentuates the financial
given the lack of consensus about its definition.

\(^2\)Also, in order to provide robust assessments, the identification of real and financial shocks is based on a wide range of schemes that assume exclusion, sign and timing restrictions on the impulse response functions.

\(^3\)In particular, the sample starts in 1981:II for the case of the euro area, which is considerably longer than the sample analyzed in the previous studies that focus on macro-financial linkages in this region. Due to better data availability, for the U.S. we can go as far back as 1960:I.
accelerator effect. That is why we find a hedger (relative to euro area) transmission of financial shocks to U.S. real activity in our empirical estimates.

Our work relates to several strands of the literature. On the empirical side, there are studies that have focused on the measurement of the cycles. Most of these studies find that financial cycles are longer in length and larger in amplitude than business cycles, but with an increasing synchronization over time (Drehmann et al. (2012), Aikman et al. (2015), Gerba (2015), Schuler et al. (2017) and Gerba et al. (2017b)). Other studies have focused on the transmission of shocks from a vector autoregressions (VARs) perspective. Blake (2000) and Calza and Sousa (2006) use Threshold VAR models to measure the effect of credit shocks on real activity, for the U.S. 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 U.S. economic activity. 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.

The two strands of the literature described above have been somehow disconnected. The present paper intends to unify them by extracting both macroeconomic and financial cycles from a large set of information with Kalman filtering techniques, and simultaneously, casting those extracted cycles into a structural VAR model with time-varying parameters to assess changes in the propagation of their shocks. We also incorporate an international dimension to our analysis by looking at cross-border spillovers between the U.S. and the euro area, both within the sectors, and across. In this regard, most of the studies have looked at the U.S. outward spillover, finding that U.S. 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 U.S. financial shocks, with minor role for shocks from other advanced economies. Miranda-Agrippino and Rey (2018) equally find that there are large financial spillovers from the U.S. to the rest of the world.

Kaufmann and Valderrama (2010) apply a similar framework to also assess the case of the euro area.
Our framework is more extensive than previous studies since it allows to identify outward as well as inward spillovers in the U.S. and the euro area, both within the sector as well as across them. Moreover, we allow the degree of spillover effects between the two regions to exhibit potential changes over time.⁵

On the theoretical side, the paper is akin to DSGE models with cross-border mechanisms. Guerrieri et al (2013), Quint and Rabanal (2014), Rubio (2014) have DSGE models for the euro area in which macroeconomic and financial linkages in a monetary union are studied. They find that financial and housing markets matter for cross-country spillovers in business cycles within the euro area. However, none of these papers have considered US-euro area spillovers.

The rest of the paper is organized as follows. Section 2 describes the empirical framework. Section 3 analyzes the results from the two-economy model. In section 4, we dig into the theoretical results. As robustness, we analyze the one-economy case in section 5. Section 6 concludes.

2 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 across regions. 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.

The full empirical model can be stylistically represented by Figure 1. Each economy in the figure has two sectors, macroeconomic and financial. Domestic spillovers between the sectors in the U.S. (euro area) are denoted by red (blue) solid arrows. In parallel, cross-border interactions between the sectors are denoted with dashed arrows. The dashed arrows are central to our cross-border analysis. Moreover, all these relationships may be subject to fundamental changes over time, catering for a dynamic dimension to the model.

To model the dynamics of the two economies, we rely on a dynamic factor model with drifting loadings, where the factors evolve according to a VAR model with time-varying coefficients. We are interested in providing a deep and accurate understanding of their corresponding macro-financial linkages, as well as 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 U.S. to the financial cycle in the euro area, (ii) real shocks in the U.S. to the real cycle in the euro area, (iii) financial shocks in the U.S. to the real cycle in the euro area, (iv) real shocks in the U.S. to the financial cycle in the euro area, (v) financial shocks in the euro area to the financial cycle in the U.S., (vi) real shocks in the euro area to the real cycle in the U.S., (vii) financial shocks in the euro area to the real cycle in the U.S., and (viii) real shocks in the euro area to the financial cycle in the U.S. This information corresponds to the dashed arrows in Figure 1, red for spillovers from U.S. to the euro area, and blue for spillovers from euro area to U.S.

To correctly model all these dimensions, we propose a joint model that is flexible enough to be reduced to a one-country system for individual economies. Accordingly, consider the
following US-euro area dynamic factor model:

\[
\begin{bmatrix}
F_{US}^t \\
R_{US}^t \\
F_{EA}^t \\
R_{EA}^t
\end{bmatrix} =
\begin{bmatrix}
\Lambda_{f,t}^{US} & 0 & 0 & 0 \\
0 & \Lambda_{r,t}^{US} & 0 & 0 \\
0 & 0 & \Lambda_{f,t}^{EA} & 0 \\
0 & 0 & 0 & \Lambda_{r,t}^{EA}
\end{bmatrix}
\begin{bmatrix}
f_{US}^t \\
r_{US}^t \\
f_{EA}^t \\
r_{EA}^t
\end{bmatrix} +
\begin{bmatrix}
v_{US}^{f,t} \\
v_{US}^{r,t} \\
v_{EA}^{f,t} \\
v_{EA}^{r,t}
\end{bmatrix}
\] (1)

\[
\begin{bmatrix}
f_{US}^t \\
r_{US}^t \\
f_{EA}^t \\
r_{EA}^t
\end{bmatrix} =
\begin{bmatrix}
\Psi_{1,t} & 0 & 0 & 0 \\
0 & \Psi_{2,t} & 0 & 0 \\
0 & 0 & \Psi_{3,t} & 0 \\
0 & 0 & 0 & \Psi_{4,t}
\end{bmatrix}
\begin{bmatrix}
f_{US}^{t-1} \\
r_{US}^{t-1} \\
f_{EA}^{t-1} \\
r_{EA}^{t-1}
\end{bmatrix} +
\begin{bmatrix}
u_{US}^{f,t} \\
u_{US}^{r,t} \\
u_{EA}^{f,t} \\
u_{EA}^{r,t}
\end{bmatrix}
\] (2)

where \(F_{US}^t\) and \(R_{US}^t\) denote the set of information on financial and real activity, respectively, for the U.S. economy. Similarly, \(F_{EA}^t\) and \(R_{EA}^t\) denote the same set of information but for the euro area economy. Notice that, consequently, this joint model would extract four latent common factors associated to the financial and real cycles for the U.S. (\(f_{US}^t\) and \(r_{US}^t\)) and for the euro area (\(f_{EA}^t\) and \(r_{EA}^t\)). The idiosyncratic innovations, \(v_t = (v_{US}^{f,t}, v_{US}^{r,t}, v_{EA}^{f,t}, v_{EA}^{r,t})'\), are assumed to be orthogonal and normally distributed, \(v_t \sim N(0, \text{diag}(\Omega))\).

The main advantage of this joint model is that we allow for the four latent factor to be endogenously interrelated in a VAR fashion.\(^6\) The reduced form innovations from the VAR, \(u_t = (u_{f,t}^{US}, u_{r,t}^{US}, u_{f,t}^{EA}, u_{r,t}^{EA})'\), are also assumed to be normally distributed, \(u_t \sim N(0, \Sigma)\). To be able to assess the propagation of real and financial shocks, we let \(u_t = A^{-1} \varepsilon_t\), where the vector \(\varepsilon_t = (\varepsilon_{f,t}^{US}, \varepsilon_{r,t}^{US}, \varepsilon_{f,t}^{EA}, \varepsilon_{r,t}^{EA})'\), denotes the underlying structural shocks, such that \(E(\varepsilon_t \varepsilon_t') = I\), and \(E(\varepsilon_t \varepsilon_{t-k}') = 0, \forall k\), and \(A\) denotes the impact multiplier matrix.

The main challenge associated to the joint model arises when defining the restrictions to identify cross-border spillovers. As noticed in 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 help us to identify the underlying structural shocks. In particular, we assume that, within each region, there

\(^6\)In the empirical applications, we assume \(k = 2\).
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 U.S. developments, with only one exception. We allow for
the possibility that the financial conditions in the U.S. and euro area contemporaneously
influence each other. Finally, we assume that positive U.S. real shocks are favorable for both
real and financial conditions in the euro area. However, a positive financial shock in the
U.S. would take at least one period to build up an influence on the euro area macroeconomic
conditions. This set of restrictions can be summarized in Table 1.

| Table 1: Sign and Exclusion Restrictions for the Two-economy model                  |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Financial Cycle E.A.            | +                               | +                               | *                               | +                               |
| Real Cycle E.A.                 | +                               | +                               | 0                               | +                               |
| Financial Cycle U.S.            | *                               | 0                               | +                               | +                               |
| Real Cycle U.S.                 | 0                               | 0                               | +                               | +                               |

Note: The symbol * indicates that no restriction is imposed in the corresponding relationship. E.A. refers to euro area.

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 \( \psi_t = vec(\Psi_t) \), where \( \Psi_t = [\Psi_{1,t}, ..., \Psi_{k,t}] \), and the factor loadings \( \lambda_t = vec(\Lambda_t) \),
where \( \Lambda_t = [\Lambda_{US}^{f,t}, \Lambda_{US}^{r,t}, \Lambda_{EA}^{f,t}, \Lambda_{EA}^{r,t}]' \), to be time-varying by following random walk dynamics,

\[
\psi_t = \psi_{t-1} + w_t, \quad (3)
\]
\[
\lambda_t = \lambda_{t-1} + \omega_t. \quad (4)
\]

The innovations \( w_t \) and \( \omega_t \) are white noise Gaussian processes with zero mean and constant
covariances, \( \Theta_w \) and \( \Theta_\omega \), respectively. Appendix A provides details regarding the Bayesian
procedure employed to estimate the model.

The overall output retrieved by this empirical framework 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. First, we shut off the international dimension and contrast our findings in the one-economy version to those including a cross-border dimension. Next, we employ a number of alternative estimation approaches: we alter the estimation method of the latent cycles, the identification of structural shocks, and potential changes in the volatility of macroeconomic and financial cycles. In sum, given the high complexity of measuring macro-financial linkages at the international level, we adopt a series of alternative exercises with the only aim of gathering main messages that describe, from a robust and meaningful way, how macroeconomic and financial shocks propagate across borders.

3 International Macro-Financial Linkages

This section provides a comprehensive overview of the time-varying interactions between macroeconomic and financial sectors, for the U.S. and euro area, and across borders. In doing so, we provide different pieces of information designed to study these interactions from various perspectives. The first layer assess the evolving strength of commonalities within each of the two sectors, that is, macroeconomic and financial. This is done by jointly characterizing the underlying cycles and inferring the segments of the real and financial sectors that are most important for driving those cycles over time. The second layer characterizes the joint propagation of macroeconomic and financial shocks. This is performed by examining the time-varying correlation between the cycles, and analyzing information contained in impulse responses. We aim to provide a discussion that is comparative in nature, consequently, the description of the results is structured per type of features, and not per economy. The third layer, the most important in our study, disentangles the complex cross-border transmission, both within and across (macroeconomic and financial) sectors.

Notice that in the analysis, we use the terms linkages and interactions interchangeably, 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 that we interpret as not profoundly changing over time.
3.1 Data

The data has been gathered from a variety of existing sources, where particularly the series for the euro area have been constructed by previous studies. The description of the variables for the U.S. economy is reported in Table 2, they were retrieved from the St. Louis Fed database. The available sample spans from 1960:I to 2017:IV, covering four very distinct episodes in U.S. 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 3. 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.\(^7\) For the pre-EMU period, the series have 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, 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.

\(^7\)One set of variables comes from the ECB’s euro area Wide Model including variables F1-F3, F9-F11, R1-R5 in Table 3. Variables F4-F7 come from Datastream, while F8 and R6-R7 come from 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.
Table 2: List of variables for the U.S.

<table>
<thead>
<tr>
<th>ID</th>
<th>Trans.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>2</td>
<td>Nonfinancial Corporate Business; Net Worth, Billions of Dollars</td>
</tr>
<tr>
<td>F2</td>
<td>2</td>
<td>Nonfinancial Corporate Business: Profits After Tax (without IVA and CCAdj), Billions of Dollars</td>
</tr>
<tr>
<td>F3</td>
<td>2</td>
<td>Private Residential Fixed Investment, Billions of Dollars</td>
</tr>
<tr>
<td>F4</td>
<td>2</td>
<td>Households and Nonprofit Organizations; Net Worth, Billions of Dollars</td>
</tr>
<tr>
<td>F5</td>
<td>2</td>
<td>Nonfinancial Corporate Business; Credit Market Instruments; Liability, Billions of Dollars</td>
</tr>
<tr>
<td>F6</td>
<td>2</td>
<td>Households and Nonprofit Organizations; Credit Market Instruments; Liability, Billions of Dollars</td>
</tr>
<tr>
<td>F7</td>
<td>2</td>
<td>Households and Nonprofit Organizations; Home Mortgages; Liability, Billions of Dollars</td>
</tr>
<tr>
<td>F8</td>
<td>2</td>
<td>All Sectors; Commercial Mortgages; Asset, Billions of Dollars</td>
</tr>
<tr>
<td>F9</td>
<td>2</td>
<td>Households and Nonprofit Organizations; Total Time and Savings Deposits; Asset, Level, Billions of Dollars</td>
</tr>
<tr>
<td>F10</td>
<td>2</td>
<td>Households and nonprofit organizations; corporate equities; asset, Level, Billions of Dollars</td>
</tr>
<tr>
<td>F11</td>
<td>2</td>
<td>Federal Government; Credit Market Instruments; Liability, Level, Billions of Dollars</td>
</tr>
<tr>
<td>F12</td>
<td>2</td>
<td>S&amp;P500</td>
</tr>
<tr>
<td>F13</td>
<td>2</td>
<td>M1 Money Stock, Billions of Dollars</td>
</tr>
<tr>
<td>F14</td>
<td>2</td>
<td>Velocity of M1 Money Stock, Ratio</td>
</tr>
<tr>
<td>F15</td>
<td>2</td>
<td>Velocity of M2 Money Stock, Ratio</td>
</tr>
<tr>
<td>F16</td>
<td>2</td>
<td>M2-M1 Money Stock, Billions of Dollars</td>
</tr>
<tr>
<td>F17</td>
<td>2</td>
<td>Velocity of MZM Money Stock, Ratio</td>
</tr>
<tr>
<td>F18</td>
<td>1</td>
<td>AAA-spread</td>
</tr>
<tr>
<td>F19</td>
<td>1</td>
<td>BAA-spread</td>
</tr>
<tr>
<td>F20</td>
<td>1</td>
<td>Corporate risk spread</td>
</tr>
<tr>
<td>F21</td>
<td>1</td>
<td>10-Year Treasury Constant Maturity Rate, Percent</td>
</tr>
<tr>
<td>F22</td>
<td>2</td>
<td>Total Consumer Credit Owned and Securitized, Outstanding, Billions of Dollars</td>
</tr>
<tr>
<td>F23</td>
<td>2</td>
<td>Households and Nonprofit Organizations; Consumer Credit; Liability, Billions of Dollars</td>
</tr>
<tr>
<td>R1</td>
<td>2</td>
<td>Real Gross Domestic Product, Billions of Chained 2009 Dollars</td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>Real Personal Consumption Expenditures, Billions of Chained 2009 Dollars</td>
</tr>
<tr>
<td>R3</td>
<td>2</td>
<td>Nonfarm Business Sector: Real Compensation Per Hour, Index 2009=100</td>
</tr>
<tr>
<td>R4</td>
<td>2</td>
<td>Real Gross Private Domestic Investment, Billions of Chained 2009 Dollars</td>
</tr>
<tr>
<td>R5</td>
<td>2</td>
<td>Real Disposable Personal Income, Billions of Chained 2009 Dollars</td>
</tr>
<tr>
<td>R6</td>
<td>2</td>
<td>Average Weekly Hours of Production and Nonsupervisory Employees: Manufacturing, Hours</td>
</tr>
<tr>
<td>R7</td>
<td>2</td>
<td>All Employees: Manufacturing, Thousands of Persons</td>
</tr>
<tr>
<td>R8</td>
<td>2</td>
<td>Nonfarm Business Sector: Real Output Per Hour of All Persons, Index 2009=100</td>
</tr>
<tr>
<td>R9</td>
<td>2</td>
<td>Gross Fixed Capital Formation in United States, Billions of United States Dollars</td>
</tr>
</tbody>
</table>

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.

Since the set of information used for each economic region is not exactly the same due to their idiosyncrasies and availability, our intention here is to be empirically as broad and comprehensive as possible in order to capture the multi-faceted nature of the contemporary financial sector and the macroeconomy. In addition, because of frictions and imperfections, fluctuations and alterations in quantities may not always show up in prices. Equally,
Table 3: List of variables for the euro area

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

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.

fluctuations and alterations in the banking system may not always result in corresponding movements in the private sector, even if it is the counterparty. That is why we require a sufficient and diverse set of indicators to capture these complexities. For that reason, on the financial side we have expanded on the usual credit-and asset price variables to include indicators of other entries in the balance sheets of private sector and banks (including but not only securities, liabilities, net worth, profits after tax, savings), monetary system, corporate financial ratios and different corporate (default) spreads. In a similar manner, we expand our macroeconomic side to include information beyond the usual business cycle
(or GDP). That is why we include detailed information on consumption capacity, labor market, firm inputs, productivity, and the supply side in general. As a result, we expect to have a more comprehensive account of the multi-layered character of macro-financial linkages across all segments of the contemporary advanced economies.

3.2 Strength of Commonalities Within Sectors

The estimated real and financial cycles of the U.S. and euro area for the period 1980:I-2014:IV are plotted in Figure 2. In both economies, the financial cycle lasts much longer than the macroeconomic one. In other words, the frequency of the financial cycle is lower. Volatility of the financial cycle is, in both economies, smaller, depicting the financial cycle as smoother. Also, while financial activity underwent two larger contractions during our sample period (1992 and 2008), macroeconomic activity experienced more (albeit shorter) downturns. The first corresponds to the global economic downturn in the Western world in the early 1990’s, including the U.S. savings & loan crisis and a restrictive monetary policy. The second date corresponds to the onset of the Great Recession.8 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.

Comparing the two economies, there are some differences with respect to the U.S. 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

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8Compared to alternative composite measures of financial activity in the US, 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 (see Figure B-1 of Appendix B). The long cycles and the long build-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 could serve as an early warning signal for financial stress. The swings in the cycle anticipate those of credit-to-GDP and the business cycle (see Figure B-2 of Appendix B). 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.
years shorter. It is also important to notice that there is a stronger co-movement between both cycles starting from mid-1990’s, with boom and bust phases roughly coinciding, albeit the timing and magnitude is not entirely identical.

On the whole, there are significant differences in the nature of the two cycles. Financial cycles are longer and smoother, in particular since 1990’s, 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.\(^9\)

\(^9\)For robustness purposes, we also compute the underlying cycles, independently for each economy, using principal components (PC) and plot them in Figures B-3 and B-4 of the Appendix B. Although PC provides 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 later exhibiting smoother and more stable dynamics,
We also examine 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. This 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 U.S. case, we find that the composition of U.S. real and financial cycles has remained, in general, relatively unchanged as the degree of variability over time in the factor loadings has remained relatively stable. The case of the euro area is somewhat different. 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.\(^\text{10}\) Conversely, other set of financial indicators have exhibited a decreasing correlation with the financial cycle over time.\(^\text{11}\) Regarding the real sector, commonalities have remained relatively steady.\(^\text{12}\)

### 3.3 Depth of Linkages Across Sectors

We now turn to measuring the evolving interaction between macroeconomic and financial cycles. We do so from different perspectives in order to provide robust assessments. We start by computing the time-varying contemporaneous correlation between the two cycles for each economy.\(^\text{13}\) Later, we will examine the cross-sectoral transmissions to financial and real shocks through impulse response functions (IRFs).

Overall, the correlation has been larger in the case of the euro area. Although the contemporaneous co-movement between the two cycles has been high, it is considerably tighter in euro area. One potential reason for that difference is that, by being a bank-confirming our inferences on the two cycles.

\(^{10}\)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.

\(^{11}\)These variables contain information about the financial position of firms, such as, price-earning ratios of non financial firms or price-book ratio of financial firms.

\(^{12}\)Figures B-5 to B-8, located in Appendix B for the sake of space, plot the factor loadings dynamics.

\(^{13}\)Since the cycles, proxied by the factors, evolving 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 a function of the parameters of the VAR, the same procedure is applied for each period of time to obtain the time-varying correlation.
based financial system, the macro-financial transmissions are tighter, which intensifies the comovement between the two cycles.

In the case of the U.S., the correlation has varied significantly over time, as it is shown in Figure 3. It almost doubled in less than 30 years, finishing at almost 0.6 by the eve of the Global Financial Crisis. Although there were some minor corrections in that positive slope during the 1980:1-2014:IV sample, from early 1990’s, the intensification in correlation just continued (almost) uninterruptedly until 2008. This particular period was characterized by heavy deregulation in the U.S. financial system, both across activities/segments and geographically. Also during this time, an intense financial deepening involving many of the known financial innovations occurred during this period. As a result, competition between financial institutions intensified. The U.S. 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 90’s and early 2000’s, the rest of these two decades was characterized by a solid expansion. The increased liquidity in the system also lead 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. Only during the Great Recession has it receded.

Qualitatively, we see something similar in the euro area in Figure 3, but at a higher level. Estimates move around 0.5 and 0.7, which is around 20% higher than those of the US. After the Single European Act in 1987, the correlation started to steadily grow, reaching close to 0.7 by the new millennium. 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 is associated with long-lasting stronger interactions between the financial sector and the real economy. As in the case of the U.S., we see a sharp correlation reversal following the Great Recession.
Altogether, the correlation between the macroeconomic and financial cycles has grown and is high in both economies, albeit at a generally higher level in the euro area.

Next, we turn to potential changes over time in the propagation of real and financial shocks for both economies. The left chart column of Figure 4 plots the response of real activity to a financial shock in a three-dimensional graph, while the right chart column plots the response of financial conditions to a real shock. The top half depicts the U.S. responses, and the bottom euro area responses. The results show a couple of salient asymmetric patterns.

We see opposite relative sizes in responses to shocks across economies. While for real activity, the responses in the U.S. are larger, for financial conditions, it is for the euro area. Financial shocks cause a larger macroeconomic response in the U.S., reflecting a higher overall leverage of that economy. Yet, the persistence in responses of real activity over time is larger in euro area. That could be indicative of inertia in real economy adjustments to financial factors. Conversely, we observe both larger and more persistent response in financial conditions to shocks on the real side in the euro area. That is indicative of higher elasticity of financial conditions to economic states. Meanwhile, we note that
financial conditions are, relatively speaking in cumulative terms, more elastic compared to real activity. This emphasizes the larger adjustments or swings in the financial sector to unexpected disturbances, and why it can be a source of overall volatility or (in)stability, through second-order effects.

Figure 4: National macro-financial spillovers over time: two-economy model

Note: The figure plots the estimated time-varying impulse responses, for different horizons, to a unit shock in the factors structural innovation. 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 in Table 1.

Turning to the dynamics, there is not much variation over time in the propagation of macro and financial shocks within regions. Later, we will show that this is not the case when we look at the propagation of shocks across regions, since we see sizable changes in those IRFs over time.
3.4 International Spillovers

We proceed with the third layer in our analysis, to examine the intensity of cross-border transmissions or spillovers between the two economies, both across the sectors and in-between them, which are described by the dashed arrows in Figure 1. In doing so, we first compute the cross-border and cross-sector time-varying correlations, and report them in Figure 5. The figure shows clear patterns associated with strong and sustained increases in the correlation between (i) U.S. and euro area financial activity, (ii) U.S. and euro area real activity, and (iii) U.S. financial and euro area real activity. Such an increasing interdependence pattern persisted until the eve of the Great Recession, followed by a slight declined afterwards. The only exception is the correlation between the U.S. real and euro area financial activity, which has remained fairly stable over time. This is solid evidence of the strong bilateral relations between the two economies, that also illustrates the importance of accounting for changes over time in the source and intensity of cross-border macro-financial cycles.

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. There are eight possible ways to consider cross-border interactions in macro-finance, as illustrated by the dashed arrows in Figure 1. Therefore, we proceed to evaluate the impulse response functions retrieved from the two-economy model. Chart A of Figure 6 shows the effect that shocks generated in the U.S. economy have on the euro area, while Chart B of the same figure shows how shocks generated in the euro area could affect the U.S. economy. The shocks are identified by relying on the combination of sign, exclusion and timing restrictions reported in Table 1.

A clear pattern emerges from the estimated IRFs. The (mutual) impact of U.S. shocks is much larger than those from the euro area. Real as well as financial shocks originating from the U.S. have statistically and economically significant impact on euro area macroeconomic and financial cycles.\(^{14}\) Conversely, shocks from the euro area tend to produce either small short-lasting effects, or even negative on the U.S economy (in line with Jensen (2019)).

\(^{14}\)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 U.S. financial volatility. Giorgiadis (2016) find similar results for U.S. conventional and unconventional monetary policy.
Figure 5: Correlation between real and financial cycles of U.S. and euro area: two-economy model

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

Furthermore, we see a cross-border ‘substitution effect’, akin to flight-to-safety, that is, when the financial or real conditions deteriorate (improve) in the euro area, the financial conditions in the U.S. improve (deteriorate).\textsuperscript{15}

\textsuperscript{15}Although, there is a substantial amount of uncertainty associated with these negative responses. Figures B-9 and B-10 of Appendix B plot the cumulative IRFs for selected horizons along with the corresponding credible sets.
Moreover, we see a strong dynamic evolution in responses. 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 factors across sector and regions, shown in Figure 5. Also, there seems to be no evidence about an intensification in transmission of euro area shocks to the U.S. 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 U.S. 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 it (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 2000’s. In particular, after around 2002, transmission of shocks arriving from the U.S. seem to weaken somewhat, having persistently risen previously. Even if it is not enough evidence to establish a causal relation, this coincides with the full introduction of the euro on 1 January 2002. Hence, although the monetary union may not have resulted in an increase in cross-border spillovers of real or financial shocks, it seems to have somewhat weakened the transmission of U.S. 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 U.S. shocks has weakened, meanwhile the negative transmission of euro area shocks have also been reduced. This can be interpreted as a small change in the global role of the U.S., whereby the weakening of its economy and the protectionism that followed has reduced its international exposure and role as originator of cross-border shocks. Cuaresma et al. (2019) also find that the transmission of U.S. monetary policy shocks has weakened in the aftermath of the global financial crisis in a Global VAR framework.

Our empirical results point to an important asymmetric cross-border transmission of U.S. shocks, which had intensified over time. Next, we attempt to decompose further those shocks, and understand the structural sources of those using a two-country DSGE model. By aligning the theoretical framework to the empirical model, we aim to contextualize our empirical findings to a theoretical setting.
Figure 6: International macro-financial spillovers over time: two-economy model

(a) From the U.S. to the euro area

(b) From the euro area to the U.S.

Note: The figure plots the estimated time-varying impulse responses, for different horizons, to a unit shock in the factors structural innovation. 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 in Table 1.
3.5 The Cross-Border Effect

We evaluate the influence of accounting for cross-border relationships in shaping macro-financial linkages. In doing so, we shut off the cross-border dimension, and only focus on the solid lines in Figure 1. Strictly speaking, we do not allow for an international transmission of shocks, and therefore estimate the model for the two economies separately. More details on the one-economy model can be found in Appendix E.

In order to identify real and financial shocks in a one-economy model, we propose an alternative identification scheme. First, we assume that real activity and financial conditions are persistent processes by assuming positive signs in the off-diagonal entries of the impact multiplier matrix. Second, we assume that positive real activity shocks have positive contemporaneous effect on financial conditions, but that a shock in financial conditions does not have a contemporaneous effect on real activity. As noticed in Prieto et al. (2016) (and many other studies), this assumption implies that macroeconomic variables react with a delay to financial shocks, possibly because of wealth effects and other effects which involve financial intermediaries that take time to materialize. In contrast to financial variables, that 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. Although, in the two-economy model, described in the previous section, the restriction on the non-contemporaneous effect of financial on macroeconomic conditions is relaxed and financial shocks are allowed to contemporaneously influence real activity. The restrictions employed in the one-economy model are summarized in Table 4.

By shutting off the cross-border dimension, we find that the dynamic contemporaneous correlations between the two sectors increases overall, as shown in Chart A, for U.S., and Chart B, for the euro area, of Figure 7. However, the levels of correlation are higher when estimating the models for the two economies separately. Also, the correlation in the U.S. is less oscillating and that of the euro area much more accumulative over time than in the one obtained with the two-economy model.\footnote{Also, the uncertainty associated with the one-economy model estimates is smaller than that of the}
account the cross-border effects in the measurement of macro-financial linkages, one may end up overestimating those relationships.

We also compare the impulse responses between the one-economy and two-economy models. Figure B-12, in Appendix B reports the IRFs for the one-economy U.S. model, and Figure B-13 the same for the euro area. There are some important differences. We find important cross-country heterogeneities. In the euro area, the interactions have increased in both directions, from financial to real, and vice versa, but in the U.S., they have increased in only one direction, from financial to real. Also, the financial sector of the U.S. presents a sensitivity to macroeconomic shocks that is of higher magnitude and of shorter duration than in the euro area.

### 3.6 Robustness

For robustness purposes, we additionally estimate the two-economy model by assuming an alternative shock identification strategy, which consists of a Cholesky factorization described in Table 5. We order first the U.S. real cycle, followed by the U.S. 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) U.S. developments could affect contemporaneously euro area developments, but not vice versa.

For further validation purposes, we re-estimate the model using a mixture of recursive two-economy model due to the lager number of parameters involved in the later one.
and sign-restrictions as outlined in Table 6. It consists of three parts: (i) recursive restrictions within each block; (ii) euro area shocks do not contemporaneously impact the US; (iii) leave unrestricted the effects that U.S. 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.

Figures B-14-B-15, and B-16-B-17, located in Appendix B, plot the impulse response patterns associated to 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 with the benchmark identification scheme. The only difference in magnitude we find is that with these alternative identifications, transmission of U.S. financial and euro area real shocks is more intense, while those of U.S. real are of slightly smaller magnitude. Moreover, the negative effects of euro area shocks on U.S. 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 U.S. financial conditions. An explanation for this pattern is that the U.S. may act as a hub that attracts investments and (financial) capital when conditions are adverse in Europe. Since the financial deregulation in early 1980’s and geographical liberalisation in financial services, the flow of capital to U.S. has continuously increased. However, this positive trend broke with the near financial meltdown in 2008 and the deep contraction in the U.S. financial sector. That could explain why the negative transmission from euro area to U.S. financial system has debilitated.

Table 5: Recursive Identification for the Two-economy model

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<td>Real Cycle US</td>
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<td>0</td>
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*Note: The symbol * indicates that no restriction is imposed in the corresponding relationship. E.A. refers to euro area.*

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

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<td>+</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Real Cycle E.A.</td>
<td>0</td>
<td>+</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Financial Cycle US</td>
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<td>0</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Real Cycle US</td>
<td>0</td>
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<td>0</td>
<td>+</td>
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*Note: The symbol * indicates that no restriction is imposed in the corresponding relationship.*

Our international analysis reveals a number of important facts regarding the relation between the euro area and the U.S. since the financial liberalization and trade integration in 1980’s. First and most firmly, we find that the transmission of macro and financial shocks across borders is largely asymmetric, going from the U.S. to the euro area. Previous literature hints towards this asymmetry, but does not fully model the bidirectional spillovers, or does it for only one policy or aspect. For instance, Jarocinski (2019) show 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 U.S. 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 transmission of U.S. shocks has been weakened.
This could be a result from the weakened dominance of the U.S. economy globally, or because of the protectionism that followed the financial crisis of 2007-08. Third, we find a negative relation in transmission between EA shocks and U.S. financial conditions. One could say that adverse (favourable) shocks in euro area developments could be beneficial (damaging) for the U.S. financial conditions. However, this pattern has also been weakened following the near financial meltdown in the U.S. in 2008. Previous works (Berg and Vu (2019), Gourinchas et al. (2019), Jarocinski (2019), Giorgiadis (2016)) have advocated for a dominant position of the U.S. in the international financial, monetary, or macroeconomic sphere. However, as far as we are aware, this is the first study to formally establish it 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.

4 Theoretical Framework

To contextualise our empirical findings, we nest the two sectors in a two-country version of the model in Iacoviello (2005). The model includes infinite-horizon, two-country economy with a flexible exchange rate regime. The two countries represent the U.S. (big open economy) and the euro area (medium open economy), and are denoted by US and EA, respectively. Households consume, work and demand real estate. Each country produces one differentiated good but households consume goods from both countries. For simplicity, housing is a non-traded good. We assume that labor is immobile across countries. Firms follow a standard Calvo problem. In this economy, both final and intermediate goods are produced. Prices are sticky in the intermediate goods sector. The central bank in each country sets the interest rate to respond to domestic inflation. We can then use the model to explore how shocks are transmitted across countries. To do so, we calibrate the model to realistically reflect the characteristic of both countries. In line with the literature, the weight of the U.S. is calibrated higher than that of the euro area, in order to reflect the larger importance of one economy vis-a-vis the other.\textsuperscript{17}

\textsuperscript{17}Full details on the theoretical model and exact calibrated parameters are described in Appendix C.
Impulse response functions derived from the theoretical model help us interpret the mechanisms underlying our empirical findings. The shocks in the theoretical version have a micro-founded rationale, which allows us to interpret the empirical results in a more rigorous way. To disentangle the various layers of asymmetry in the cross-border transmission, we first examine a symmetric shock scenario, followed by an asymmetric one. The first scenario allows us to understand the nature of the cross-border transmission arising from distinct economic structures. All impulse responses are reported in Appendix D, for the sake of space.

Similar to the empirical findings, a symmetric real shock (TFP shock) generates a higher impact on financial conditions (bonds/credit) in the US compared to the EA, and just marginally higher than in the real sector (consumption). Following our benchmark calibration, the US is a more leveraged economy, which accentuates the financial accelerator effect. This creates a distinction in responses across economies, even in a symmetric real shock scenario.\textsuperscript{18} By the same token, a recessionary macroeconomic shock (oil price shock) leads to a stronger response in financial conditions (credit) in the US compared to the EA. At the same time, the response of real variables is also stronger in the US, as confirmed by the data.\textsuperscript{19}

For the sake of completeness, we also consider a pure financial shock, namely a symmetric LTV shock. We find that a symmetric financial (LTV) shock generates a significantly higher response in the macroeconomic cycle (consumption, GDP, labour) in the US compared to EA. The response is also more persistent in the US. In this case, financial conditions are having a stronger effect on the more leveraged economy, transmitting also more strongly to the real side.\textsuperscript{20}

Next, we consider asymmetric shocks, which, by definition should be transmitted differently across countries, independently of calibration. For instance, an asymmetric productivity shock (1 in the US, 0 in the EA) renders similar responses in financial and real

\textsuperscript{18}In terms of correlation between credit and consumption, we find that it is high and positive in both economies, confirming our previous empirical findings.
\textsuperscript{19}Both correlations between credit and consumption continues to be high and positive, although slightly lower than in the previous case, as indicated by the data.
\textsuperscript{20}The correlation between credit and consumption is again high and positive although slightly lower in the EA than in the US.
variables in the EA. However, there is a somewhat stronger reaction in EA real activity. Domestically, the response of financial conditions is persistent, as in the data.

Similarly, an asymmetric productivity shock (0 in US, 1 in the EA) renders weak response in the US, and much weaker than in the opposite case.\textsuperscript{21} Moreover, it causes a negative response of US real activity and in the medium run, in financial conditions. This is strongly in line with the empirical model IRFs, which indicates that the macro shock in the empirical model could be largely driven by a TFP shock.\textsuperscript{22}

When the asymmetric shock comes from the financial side of the economy (LTV shock), we find the following. An asymmetric financial shock (1 in US, 0 in EA) renders higher financial conditions responses in the EA than real activity. Moreover, they are more persistent. Domestically, the response of real activity to a financial shock is very persistent. The persistence parameter is higher than in the data. If the same shock originates in the EA (0 US, 1 EA), we find an analogous response in the US real and financial activity. Compared to the opposite case, financial conditions in the US respond more persistently. Domestically, the response of real activity is similar to that of the US.

Our empirical and theoretical findings are closely aligned. In particular, for real shocks we find that the interaction between macro and financial variables is highly matched. However, our financial shock is more specific compared to the data. Our empirical and theoretical results show some divergence with respect to the financial shock. The reason for that is that the theoretical model only zooms in on a particular type of shock, which had greater importance in the 2000’s. That is not representative of the whole sample used in the empirical estimation.

5 Conclusions

This paper analyses 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: macro-financial linkages, cross-border spillovers and theoretical

\textsuperscript{21} The responses are overall smaller for US to a shock in EA than in the EA to a shock in the US.

\textsuperscript{22} This is the advantage of this approach, as we can extrapolate the TFP shock using an endogenous estimation procedure with a large dataset. Pure TFP shocks are normally very hard to estimate empirically.
Our evidence speaks clearly of an asymmetric cross-border transmission between US and EA, especially in the financial domain. This is confirmed by our theoretical complement, which shows that the transmission of US TFP shocks is significantly larger and more persistent than any alternative shock specifications. Moreover, the US is a more leveraged economy, which accentuates the financial accelerator effect. This creates a distinction in responses across economies, even in a symmetric real shock scenario.

Over time, cross-border spill-overs from US financial to EA real has intensified. At the same time, spill-overs from EA real to US real have also strengthened. However, in spite of that, we find clear evidence of a US hegemony in the cross-border relations, especially on the financial side.

These results shed important light on the structure in the transatlantic cross-border transmissions of both the financial and macroeconomic sectors. They are indeed very useful and relevant for policy practitioners all over the world.
References


Appendix – For Online Publication Only

A Estimation Algorithm

The proposed algorithm relies on Bayesian methods and uses the Gibbs 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, 
\[
\tilde{Y}_T = \{F_{1f,t}, ..., F_{nf,t}, R_{1r,t}, ..., R_{nr,t}\}_t^{T},
\]
real activity index, \( \tilde{f}_T = \{f_t\}_{t=1}^{T} \), financial conditions index, \( \tilde{r}_T = \{r_t\}_{t=1}^{T} \), factor loadings, \( \tilde{\Lambda}_{x,T} = \{\Lambda_{x,t}\}_{t=1}^{T} \), where \( \Lambda_{x,t} = (\lambda_{1x,t}, ..., \lambda_{nx,t})' \), for \( x = \{f, r\} \), and autoregressive coefficients, \( \tilde{\Phi}_T = \{vec(\Phi_{1,t}), ..., vec(\Phi_{k,t})\}_{t=1}^{T} \). The algorithm consists of the following steps:

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

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

\[
\begin{bmatrix}
F_{1f,t} \\
\vdots \\
F_{nf,t} \\
R_{1r,t} \\
\vdots \\
R_{nr,t}
\end{bmatrix} = 
\begin{bmatrix}
\lambda_{1f,t} & 0 & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots \\
\lambda_{nf,t} & 0 & 0 & 0 \\
0 & \lambda_{1r,t} & 0 & 0 \\
\vdots & \vdots & \vdots & \vdots \\
0 & \lambda_{nr,t} & 0 & 0
\end{bmatrix} 
\begin{bmatrix}
f_t \\
r_t \\
f_{t-1} \\
r_{t-1}
\end{bmatrix} + 
\begin{bmatrix}
v_{f,t} \\
v_{r,t} \\
v_{f,t} \\
v_{r,t}
\end{bmatrix},
\]

and transition equation defined as,

\[
\begin{bmatrix}
f_t \\
r_t \\
f_{t-1} \\
r_{t-1}
\end{bmatrix} = 
\begin{bmatrix}
\phi_{ff,t}^{(1)} & \phi_{fr,t}^{(1)} & \phi_{ff,t}^{(2)} & \phi_{fr,t}^{(2)} \\
\phi_{rf,t}^{(1)} & \phi_{rr,t}^{(1)} & \phi_{rf,t}^{(2)} & \phi_{rr,t}^{(2)} \\
1 & 0 & 0 & 0 \\
0 & 1 & 0 & 0
\end{bmatrix} 
\begin{bmatrix}
f_{t-1} \\
r_{t-1} \\
f_{t-2} \\
r_{t-2}
\end{bmatrix} + 
\begin{bmatrix}
u_{f,t} \\
u_{r,t} \\
u_{f,t} \\
u_{r,t}
\end{bmatrix}.
\]

Conditional on \( \tilde{\Lambda}_{x,T} \) and \( \tilde{\Phi}_T \), equations (A-1)-(A-2) constitute an linear and Gaussian state-space model and the Carter and Kohn simulation smoother is applied to generate inferences of the factors.


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

To sample the variance of the time-varying autoregressive coefficient innovations we use an inverse Wishart prior distribution, $IW(\eta, v)$, with $\eta = \tau$ and $v = \kappa^2 \times \tau \times \Psi_{OLS}^w$, where $\tau = 80$ is the size of the training sample, $\Psi_{OLS}^w$ 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 $\Psi_w$ are generated from the posterior distribution,

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

where

$$\bar{\eta} = \eta + T$$

$$\bar{v} = v + (\phi_t - \phi_{t-1})'(\phi_t - \phi_{t-1}).$$

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

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

$$y_t = X_t' \phi_t + v_t, \quad v_t \sim N(0, \Sigma)$$

$$\phi_t = \phi_{t-1} + w_t, \quad w_t \sim N(0, \Psi_w)$$

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

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

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

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

where

$$\bar{m} = m + T$$
$$\bar{\nu} = \nu + (y_t - X'_t\phi_t)'(y_t - X'_t\phi_t).$$

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

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

$$X_{i_{x,t}} = \lambda_{i_{x,t}} x_t + v_{i_{x,t}}, \quad v_{i_{x,t}} \sim N(0, \Omega_{[i_{x},i_{x}]})$$
$$\lambda_{i_{x,t}} = \lambda_{i_{x,t-1}} + \omega_{i_{x,t}}, \quad \omega_{i_{x,t}} \sim N(0, \Psi_{\omega,[i_{x},i_{x}]})$$

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 $\tilde{\Lambda}_{x,T}$.

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

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

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

where

$$\bar{u} = u + T$$
$$\bar{z} = z + (\lambda_{i_{x,t}} - \lambda_{i_{x,t-1}})'(\lambda_{i_{x,t}} - \lambda_{i_{x,t-1}}).$$

**Step 7**: Sample $\Omega$ from $P(\Omega|\tilde{f}_T, \tilde{r}_T, \tilde{\Lambda}_{x,T}, \tilde{Y}_T)$
To sample, independently, the variance of the idiosyncratic terms we use an inverse Gamma prior distribution, $IG(l, \varrho)$, with $l = 0$ and $\varrho = 0$. Accordingly, draws of the entries in the diagonal of $\Omega$ are generated from the posterior distribution,

$$\Omega_{i,i} \sim IG(\bar{l}, \bar{\varrho}),$$

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

$$\bar{l} = l + T$$

$$\bar{\varrho} = \varrho + (X_{i,x,t} - \lambda_{i,x,t} x_t)' (X_{i,x,t} - \lambda_{i,x,t} x_t).$$

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.
B  Additional Figures

Figure B-1: Financial Conditions in the US

![Financial Conditions in the US](chart)

Note: Chart A plots the National Financial Conditions Index. Chart B plots the detrended non-financial leverage cycle. These data are taken from the Federal Reserve Bank of Chicago (Brave and Butters (2012)).

Figure B-2: Output Gap Based on Real GDP

![Output Gap Based on Real GDP](chart)

Note: The figures plots the business cycles in the U.S. and euro area based on real GDP. The cycles have been extracted using the HP filter with lambda of 1,600 (quarterly frequency). The recession dates are marked in grey and come from the official sources: NBER for the U.S. and CEPR for the euro area.
Figure B-3: Estimated factors of the U.S. - Principal Component

(a) Financial Cycle

(b) Real Cycle

Figure B-4: Estimated factors of the euro area - Principal Component

(a) Financial Cycle

(b) Real Cycle

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 percentile 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 B-5: Time-varying factor loadings of financial conditions for the U.S.

Note: The figure plots the estimated time-varying factor loadings of variables associated to the real activity factor. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentile 16 and 84 of the posterior distribution.
Figure B-6: Time-varying factor loadings of real activity for the U.S. (cont.)

Note: The figure plots the estimated time-varying factor loadings of variables associated to the financial conditions factor. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentile 16 and 84 of the posterior distribution.
Figure B-7: Time-varying factor loadings of financial conditions for the euro area

Note: The figure plots the estimated time-varying factor loadings of variables associated to the real activity factor. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentile 16 and 84 of the posterior distribution.
Figure B-8: Time-varying factor loadings of real activity for the euro area (cont.)

Note: The figure plots the estimated time-varying factor loadings of variables associated to the financial conditions factor. The solid blue lines make reference to the median of the posterior distribution, while the dashed red lines indicate the percentile 16 and 84 of the posterior distribution.
Figure B-9: Cumulative Impulse Response Patterns: Effect of U.S. on Euro Area

(a) Response of the euro area Real Activity to a shock in U.S. Real Activity

(b) Response of the euro area Real Activity to a shock in U.S. Financial Conditions

(c) Response of the euro area Financial Conditions to a shock in U.S. Real Activity

(d) Response of the euro area Financial Conditions to a shock in U.S. Financial Conditions

Note: The figure plots the estimated time-varying cumulative 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 percentile 16 and 84 of the posterior distribution.
Figure B-10: Cumulative Impulse Response Patterns: Effect of Euro Area on U.S.

(a) Response of the U.S. Real Activity to a shock in euro area Real Activity

(b) Response of the U.S. Real Activity to a shock in euro area Financial Conditions

(c) Response of the U.S. Financial Conditions to a shock in euro area Real Activity

(d) Response of the U.S. Financial Conditions to a shock in euro area Financial Conditions

Note: The figure plots the estimated time-varying cumulative 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 percentile 16 and 84 of the posterior distribution.
Figure B-11: National macro-financial spillovers over time: one-economy model

(a) U.S.

(b) Euro Area

Note: The figure plots the estimated time-varying impulse responses, for different horizons, to a unit shock in the factors structural innovation. Left charts plot the impulse responses between real and financial cycles for U.S. Right charts plot the impulse responses between real and financial cycles for euro area. 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 in Table 4.
Figure B-12: Impulse Responses Between Real and Financial Cycles for U.S.

Response of the Real Activity to a shock in Financial Conditions

Response of the Financial Conditions to a shock in Real Activity

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.
Response of the Real Activity to a shock in Financial Conditions

Response of the Financial Conditions to a shock in Real Activity

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 B-14: Macro-financial spillovers from the U.S. 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 B-15: Macro-financial spillovers from the euro area to the U.S. 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 B-16: Macro-financial spillovers from the U.S. 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 B-17: Macro-financial spillovers from the euro area to the U.S. over time - Alternative sign and exclusion restrictions

Response of the U.S. Real Activity to a shock in E.A. Real Activity

Response of the U.S. Real Activity to a shock in E.A. Financial Conditions

Response of the U.S. Financial Conditions to a shock in E.A. Real Activity

Response of the U.S. Financial Conditions to a shock in E.A. Financial Conditions

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.
C Details of Theoretical Model

C.1 The Consumer’s Problem

There are two types of consumers in each country: unconstrained consumers and constrained consumers. Consumers can be constrained or unconstrained in the sense that constrained individuals need to collateralize their debt repayments in order to borrow from the financial intermediary. Interest payments for both mortgages and loans next period cannot exceed a proportion of the future value of the current house stock. In this way, the financial intermediary ensures that borrowers are going to be able to fulfill their debt obligations next period. As in Iacoviello (2005), we assume that constrained consumers are more impatient than unconstrained ones.23

C.1.1 Unconstrained Consumers (Savers). Unconstrained consumers in US maximize as follows:

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t \left( \ln C_u^t + j_t \ln H_u^t - \frac{(L_t^u)^{\eta}}{\eta} \right),
\]  

(C-1)

Here, \(E_0\) is the expectation operator, \(\beta \in (0,1)\) is the discount factor, and \(C_u^t, H_u^t\) and \(L_t^u\) are consumption at \(t\), the stock of housing and hours worked respectively. \(j_t\) represents the weight of housing in the utility function. We assume that \(\log(j_t) = \log(j) + u_{jt}\), where \(u_{jt}\) follows an autoregressive process, where \(j\) is the steady-state value of the weight of housing. A shock to \(j_t\) represents a shock to the marginal utility of housing. These shocks directly affect housing demand and, therefore, can be interpreted as a proxy for exogenous disturbances to house prices or, in other words, as a house price shock.24 \(1/\eta - 1\) is the aggregate labor-supply elasticity.

Consumption is a bundle of domestically and foreign produced goods. The consumption index is defined as: \(C_u^t = (C_{USt}^u)^n (C_{EAt}^u)^{1-n}\) where \(n\) is the size of Country US.

The budget constraint, in units of Country US’ currency, is:

---

23This assumption ensures that the borrowing constraint is binding in the steady state and that the economy is endogenously split into borrowers and savers.

24In this way, we can study the dynamics of the model following a housing-related shock.
\[
P_{\text{US}} \frac{C_{\text{US}}}{P_{\text{US}}} + P_{\text{EA}} \frac{C_{\text{EA}}}{P_{\text{US}}} + Q_t H_t^u + R_{\text{US}t-1} B_{\text{US}t-1}^u + e_t R_{\text{EA}t-1} D_{\text{US}t-1} + \frac{\psi}{2} e_t^2 D_t^2 \leq Q_t H_{t-1}^u + \\
W_t^u L_t^u + B_t^u + e_t D_t + P_{\text{US}t} F_t + P_{\text{US}t} S_t, \tag{C-2}
\]

where \( P_{\text{US}} \) and \( P_{\text{EA}} \) are the prices of the goods produced in Countries US and EA, respectively, \( Q_t \) is the housing price in Country US, and \( W_t^u \) is the wage for unconstrained consumers. Unconstrained consumers can hold bonds. \( B_t^u \) represents domestic bonds denominated in home currency. \( R_{\text{US}t} \) is the nominal interest rate in Country US. Positive bond holdings mean borrowing and negative mean savings. However, as we will see, this group will choose not to borrow at all, they are the savers in this economy. \( D_t \) are foreign bond holdings by savers in Country US. \( R_{\text{EA}t} \) is the nominal rate of foreign bonds, which are denominated in foreign currency. \( e_t \) is the exchange rate between currency in Country US and Country EA. To ensure stationarity of net foreign assets, we introduce a small quadratic cost of deviating from zero foreign borrowing \( \frac{\psi}{2} e_t^2 D_t^2 \). They obtain interests for their savings. \( S_t \) and \( F_t \) are lump-sum profits received from the firms and the financial intermediary in Country US, respectively.

Dividing by \( P_{\text{US}t} \), we can rewrite the budget constraint in terms of the good in the US:

\[
C_{\text{US}t} + P_{\text{EA}t} \frac{C_{\text{US}t}}{P_{\text{US}t}} + q_t H_t^u + \frac{R_{\text{US}t-1} B_{\text{US}t-1}^u}{\pi_{\text{US}t}} + \frac{e_t R_{\text{EA}t-1} D_{\text{US}t-1}}{\pi_{\text{US}t}} + \frac{\psi}{2} e_t^2 D_t^2 \leq q_t H_{t-1}^u + w_t^u L_t^u + b_t^u + e_t D_t + F_t + S_t, \tag{C-3}
\]

where \( \pi_{\text{US}t} \) denotes the inflation rate for the good produced in Country US, defined as \( P_{\text{US}t}/P_{\text{US}t-1} \). Lower-case letters denote real variables.

Maximizing \((C - 1)\) subject to \((C - 3)\) we obtain the first-order conditions for the unconstrained group:

\[
\frac{C_{\text{US}t}}{C_{\text{US}t}^u} = \frac{n P_{\text{EA}t}}{(1 - n) P_{\text{US}t}} \tag{C-4}
\]

\[
\frac{1}{C_{\text{US}t}^u} = \beta E_t \left( \frac{R_{\text{US}t}}{\pi_{\text{US}t+1} C_{\text{US}t+1}^u} \right), \tag{C-5}
\]
\[
\frac{1 - \psi d_t}{C^{u}_{USt}} = \beta E_t \left( \frac{R_{EAt} e_{t+1}}{\pi_{USt+1} C^{u}_{USt+1} e_t} \right), \quad (C-6)
\]

\[
w^{u}_{t} = (L^{u}_{t})^{\eta-1} \frac{C^{u}_{USt}}{n}, \quad (C-7)
\]

\[
\frac{j_t}{H^{u}_t} = \frac{n}{C^{u}_{USt}} q_t - \beta E_t \frac{n}{C^{u}_{USt+1}} q_{t+1}. \quad (C-8)
\]

Equation (C - 4) equates the marginal rate of substitution between goods to the relative price. Equation (C - 5) is the Euler equation for consumption. Equation (C - 6) is the first-order condition for net foreign assets. Equation (C - 7) is the labor-supply condition. These equations are standard. Equation (C - 8) is the Euler equation for housing and states that, at the margin, the benefits from consuming housing have to be equal to the costs.

Combining (C - 5) and (C - 6) we obtain a non-arbitrage condition between home and foreign bonds:

\[
R_{USt} = \frac{R_{EAt} E_t e_{t+1}}{(1 - \psi D_t) e_t}. \quad (C-9)
\]

Since all consumption goods are traded and there are no barriers to trade, we assume in this paper that the law of one price holds:

\[
P^{u}_{USt} = e_t P^{*}_{USt}. \quad (C-10)
\]

where variables with a star denote foreign variables.

**C.1.2 Constrained Consumers (Borrowers).** Constrained consumers are more impatient than unconstrained ones, i.e. \( \tilde{\beta} < \beta \). Constrained consumers face a collateral constraint: the expected debt repayment in the next period cannot exceed a proportion of tomorrow’s expected value of today’s housing stock:
where equations (C-11) represents the collateral constraint for borrowers. $k_{US}$ can be interpreted as the LTV ratio in US.

Borrowers maximize their lifetime utility function as follows:

$$
\max E_0 \sum_{t=0}^{\infty} \beta^t \left( \ln C_t^c + j_t \ln H_t^c - \frac{(L_t^c)^{\eta}}{\eta} \right),
$$

(C-12)

where $C_t^c = (C^c_{UST})^n (C^c_{EAt})^{1-n},$ subject to the budget constraint (in term of goods in US):

$$
C_{UST}^c + \frac{P_{EAt}}{P_{UST}} C_{EAt}^c + q_t H_t^c + \frac{R_{UST-1} b_{UST-1}}{\pi_{UST}} \leq q_t H_{t-1}^c + w_t^c L_t^c + b_t^c,
$$

(C-13)

and subject to the collateral constraint (C-11).

The first-order conditions for these consumers are:

$$
\frac{C_{UST}^c}{C_{EAt}^c} = \frac{n P_{EAt}}{(1-n) P_{UST}}
$$

(C-14)

$$
\frac{n}{C_{UST}^c} = \tilde{\beta} E_t \left( \frac{n R_{UST}}{\pi_{UST+1} C_{UST+1}^c} \right) + \lambda_{UST}^c R_{UST},
$$

(C-15)

$$
w_t^c = (L_t^c)^{\eta-1} \frac{W_{UST}^c}{n},
$$

(C-16)

$$
\frac{j_t}{H_t^c} = \frac{n}{C_{UST}^c} q_t - \tilde{\beta} E_t \frac{n}{C_{UST+1}^c} q_{t+1} - \lambda_{UST}^c k_{UST} E_t q_{t+1} \pi_{UST+1}.
$$

(C-17)

These first-order conditions differ from those of the unconstrained individuals. In the case of constrained consumers, the Lagrange multiplier on the borrowing constraint ($\lambda_t^c$) appears in the equations. As in Iacoviello (2005), the borrowing constraint is always binding, so that constrained individuals borrow the maximum amount they are allowed to and
their saving is zero.\footnote{From the Euler equations for consumption of the unconstrained consumers, we know that $R_{US} = 1/\beta$ in steady state. If we combine this result with the Euler equation for consumption for the constrained individual we have that $\lambda^c = n \left( \beta - \bar{\beta} \right) / C_{US}^c > 0$ in steady state. This means that the borrowing constraint holds with equality in steady state. Since we log-linearize around the steady state assuming that uncertainty is low, we can generalize this result to off-steady-state dynamics.}

The problem for consumers in EA is analogous to that for consumers in US.

**C.1.3 Final Goods Producers.** In Country US, there is a continuum of final goods producers that aggregate intermediate goods according to the production function

$$Y^k_{UST} = \left[ \int_0^1 Y^k_{UST}(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{1}{\varepsilon-1}}, \quad (C-18)$$

where $\varepsilon > 1$ is the elasticity of substitution between intermediate goods.

The total demand of intermediate good $z$ is given by $Y_{UST}(z) = \left( \frac{P_{UST}(z)}{P_{UST}} \right)^{-\varepsilon} Y_{UST}$, and the price index is $P_{UST} = \left[ \int_0^1 P_{UST}(z)^{1-\varepsilon} dz \right]^{\frac{1}{1-\varepsilon}}$.

**C.1.4 Intermediate Goods Producers.** The intermediate goods market is monopolistically competitive. Intermediate goods are produced according to the following production function:

$$Y_{UST}(z) = Z_t (L^u_t(z))^\gamma (L^c_t(z))^{(1-\gamma)}, \quad (C-19)$$

where $Z_t$ represents technology. We assume that $\log Z_t = \rho_Z \log Z_{t-1} + u_{Zt}$ where $\rho_Z$ is the autoregressive coefficient and $u_{Zt}$ is a normally distributed shock to technology. $\gamma$ measures the relative size of each group in terms of labor.\footnote{This Cobb-Douglas production function implies that labor inputs of the two groups are not perfect substitutes. This assumption can be justified by the fact that savers are the managers of the firms and their wage is not the same as that of the borrowers. The Cobb-Douglas specification is analytically tractable and allows for closed form solutions for the steady state of the model.}

The first-order conditions for labor demand are the following:\footnote{Symmetry across firms allows to avoid the index $z$.}

$$w^u_t = \frac{Z_t}{X_t} \gamma \frac{Y_{UST}}{L^u_t}, \quad (C-20)$$
\[ w_t^c = \frac{Z_t}{X_t} (1 - \gamma) \frac{Y_{UST}}{L_t^c}, \]  

(C-21)

where \( X_t \) is the markup, or the inverse of marginal cost.

The price-setting problem for the intermediate goods producers is a standard Calvo-Yun setting. An intermediate good producer sells good at price \( P_{UST}(z) \), and \( 1 - \theta \) is the probability of being able to change the sale price in every period. The optimal reset price \( P^{OPT}_{UST}(z) \) solves:

\[
\sum_{k=0}^{\infty} (\theta \beta)^k E_t \left\{ A_{t,k} \left[ \frac{P^{OPT}_{UST}(z)}{P_{UST+k}} - \frac{\varepsilon}{(\varepsilon - 1)} \right] \frac{Y^{OPT}_{UST+k}(z)}{X_{t+k}} \right\} = 0. \tag{C-22}
\]

The aggregate price level is given by:

\[
P_{UST} = \left[ \theta P_{UST-1}^c + (1 - \theta) \left( P^{OPT}_{UST} \right)^{1-\varepsilon} \right]^{1/(1-\varepsilon)}. \tag{C-23}
\]

Using (C-22) and (C-23), and log-linearizing, we can obtain the standard forward-looking Phillips Curve.\(^{28}\)

The firm problem is analogous in Country EA.

**C.1.5 Aggregate Variables and Market Clearing.** Economy-wide aggregates in Country US are \( C_t \equiv C_t^u + C_t^c \), \( L_t \equiv L_t^u + L_t^c \) and aggregate supply of housing is fixed, so that market clearing requires \( H_t \equiv H_t^u + H_t^c = H \).

The market-clearing condition for the final good in Country US is \( nY_{UST} = nC_{UST} + (1 - n) C^*_U + n^{\psi/2} d_t^2 \). Domestic financial markets clear as follows: \( b_t^c = b_t^u \). The world bond market-clearing condition is \( n d_t + (1 - n) \frac{P_{EUt}}{P_{UST}} d_t^* = 0 \), where \( d_t \) denotes the foreign bonds in real terms. The net foreign asset position follows \( d_t = \frac{R_{EUt-1}}{(1 - \psi d_t) P_{UST}} d_{t-1} + Y_{UST} - C_{UST} - \frac{P_{EUt}}{P_{UST}} C_{EA.t} \). Everything is similar in the EA.

\(^{28}\)This Phillips curve is consistent with other two-country models with financial accelerator. See for instance Gilchrist et al (2002) or Iacoviello and Smets (2006).
C.2 Monetary Policy

The model is closed with a Taylor Rule with interest-rate smoothing for interest-rate setting by each country’s central bank. In Country US,

\[ R_{UST} = (R_{UST-1})^\rho \left( \frac{(1+\phi_\pi) R_{US}}{\pi_{UST}} \right)^{1-\rho} \varepsilon_{USR,t}. \tag{C-24} \]

0 ≤ ρ ≤ 1 is the parameter associated with interest-rate inertia. (1 + φ_\pi) measures the sensitivity of interest rates to current inflation. \varepsilon_{USR,t} is a white noise shock process with zero mean and variance \( \sigma^2_\varepsilon \). In Country EU, \( R_{EAt} \) is set similarly.29

C.3 Parameter Values

We can use the model to explore how shocks are transmitted across countries. To do so, we calibrate the model to realistically reflect the characteristic of both countries, the US and the EA. The discount factor parameters correspond to the standard values in Iacoviello-type models. The discount factor for savers, \( \beta \), is set to 0.99 so that the annual interest rate is 4% in steady state. The discount factor for borrowers, \( \tilde{\beta} \), is set to 0.98.30

The steady-state weight of housing in the utility function, \( j \), is set to 0.12 in order for the ratio of housing wealth to GDP in steady state to be approximately 1.40, as in Iacoviello and Neri (2010).31 For the EA, the mean value of the weight of housing in households’ utility function is set at 0.2, following Gerali et al (2014). We assign \( \eta = 2 \), implying a value of the labor supply elasticity of 1.32

We set the LTV parameters in accordance to the data found in the European Mortgage Federation (EMF). LTVs in the US are set to 0.85 as in Iacoviello and Neri (2010). We follow Gerali et al. (2014) for the EA’s LTV and set it to 0.7. For the EA, we set it at 0.7 in line with evidence for mortgages in the main

\[ \text{Note: We assume that country EA is in a monetary union and the interest rate is set by a single central bank, i.e. the ECB. The Taylor Rule is consistent with the primary objective of the ECB being price stability. This type of rule is also used in other monetary union models. See Iacoviello and Smets (2007) or Aspachs and Rabanal (2008).} \]

\[ \text{Note: Lawrance (1991) estimates discount factors for poor consumers between 0.95 and 0.98 at quarterly frequency.} \]

\[ \text{Note: This value corresponds to the US.} \]

\[ \text{Note: Microeconomic estimates usually suggest values in the range of 0 and 0.5 (for males). Domeij and Flodén (2006) show that in the presence of borrowing constraints this estimates could have a downward bias of 50%.} \]
euro-area countries (typically, 0.7 in Germany and Spain, 0.75 in France and 0.5 in Italy), as pointed out by Calza et al. (2009) and Gerali et al (2014). The labor income share of unconstrained consumers in the US, $\gamma$, is set to 0.79, as estimated in Iacoviello and Neri (2010). For the EA, we use the calibrated parameter in Gerali et al (2014), that is, 0.8. We pick a value of 6 for $\varepsilon$, the elasticity of substitution between intermediate goods. This value implies a steady-state markup of 1.2, common value in the new Keynesian literature. The probability of not changing prices, $\theta$, is set to 0.75, implying that prices change on average every four quarters, a realistically acceptable frequency. For the Taylor rule parameters, we use the estimates of Smets and Wouters (2003) and Smets and Wouters (2007) for the EA and US, respectively.

A technology shock will be a one percent positive technology with 0.9 persistence. Housing demand shocks have a 0.95 persistence. We set the size of the shock to the housing-demand parameter at 24.89%, consistent with Iacoviello (2005).

Tables 1 and 2 present a summary of the parameter values:

| Table 1: Common Parameter Values |
|---------------------------|----------------------|
| $\beta$ | .99 | Discount Factor for Savers |
| $\tilde{\beta}$ | .98 | Discount Factor for Borrowers |
| $\eta$ | 2 | Parameter associated with labor elasticity |
| $X$ | 1.2 | Steady-state markup |
| $\theta$ | .75 | Probability of not changing prices |
| $\psi$ | .0001 | Adjustment Cost Net Foreign Assets |

---

33 This high persistence value for technology shocks is consistent with what is commonly used in the literature. Smets and Wouters (2002) estimate a value of 0.822 for this parameter in Europe, Iacoviello and Neri (2008) estimate is 0.93 for the US.

34 The persistence of the housing demand shock is consistent with the estimates in Iacoviello and Neri (2010).
<table>
<thead>
<tr>
<th>Parameter</th>
<th>US</th>
<th>EA</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k$</td>
<td>0.85</td>
<td>0.7</td>
<td>Average LTV</td>
</tr>
<tr>
<td>$n$</td>
<td>0.66</td>
<td>0.33</td>
<td>Country size</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.79</td>
<td>0.8</td>
<td>Labor share for Savers</td>
</tr>
<tr>
<td>$j$</td>
<td>0.12</td>
<td>0.2</td>
<td>Weight of Housing in Utility Function</td>
</tr>
<tr>
<td>$\rho$</td>
<td>0.81</td>
<td>0.92</td>
<td>Smoothing parameter in TR</td>
</tr>
<tr>
<td>$\phi_\pi$</td>
<td>2.04</td>
<td>1.66</td>
<td>Inflation parameter in TR</td>
</tr>
<tr>
<td>$\phi_y$</td>
<td>0.08</td>
<td>0.174</td>
<td>Output parameter in TR</td>
</tr>
</tbody>
</table>
D Dynamics from Theoretical Model

D.1 Symmetric Shocks

Figure D-1: Symmetric Productivity Shock

Figure D-2: Symmetric Inflation Shock
D.2 Asymmetric Shocks

Figure D-4: Productivity Shock in the US
Figure D-5: Productivity Shock in the EA

Figure D-6: LTV shock in the US
Figure D-7: LTV shock in the EA
E One-Economy Model

Consider the model described in the following equations independently fitted to a single economy, either U.S. or the euro area,

\[
\begin{bmatrix}
F_t \\
R_t
\end{bmatrix}
= 
\begin{bmatrix}
\Gamma_{f,t} & 0 \\
0 & \Gamma_{r,t}
\end{bmatrix}
\begin{bmatrix}
f_t \\
r_t
\end{bmatrix} + 
\begin{bmatrix}
v_{f,t} \\
v_{r,t}
\end{bmatrix},
\]  
(E-1)

\[
\begin{bmatrix}
f_t \\
r_t
\end{bmatrix}
= 
\Phi_{1,t}
\begin{bmatrix}
f_{t-1} \\
r_{t-1}
\end{bmatrix} + \cdots + \Phi_{k,t}
\begin{bmatrix}
f_{t-k} \\
r_{t-k}
\end{bmatrix} + 
\begin{bmatrix}
e_{f,t} \\
e_{r,t}
\end{bmatrix},
\]  
(E-2)

where \( f_t \) and \( r_t \) denote the financial conditions and real activity factors, respectively.\(^{35}\) The idiosyncratic innovations, \( v_t = (v_{f,t}, v_{r,t})' \), are assumed to be orthogonal and normally distributed, \( v_t \sim N(0, \text{diag}(\tilde{\Omega})) \). The reduced form innovations from the VAR, \( e_t = (e_{f,t}, e_{r,t})' \), are also assumed to be normally distributed, \( e_t \sim N(0, \tilde{\Sigma}) \). Although, our benchmark specification assumes homoskedastic residual associated to the VAR equation, we also estimate an alternative specification that accounts for changes in the covariance matrix, \( \tilde{\Sigma} \). Both the autoregressive coefficients \( \phi_t = \text{vec}(\Phi_t) \), where \( \Phi_t = [\Phi_{1,t}, ..., \Phi_{k,t}] \), and the factor loadings \( \gamma_t = \text{vec}(\Gamma_t) \), where \( \Gamma_t = [\Gamma_{f,t}, \Gamma_{r,t}]' \), follow random walks,

\[
\phi_t = \phi_{t-1} + \tilde{w}_t,
\]  
(E-3)

\[
\gamma_t = \gamma_{t-1} + \tilde{\omega}_t.
\]  
(E-4)

The innovations \( w_t \) and \( \omega_t \) are white noise Gaussian processes with zero mean and constant covariances, \( \Psi_w \) and \( \Psi_\omega \), respectively.

For robustness purposes. In particular, we account for breaks in the volatility associated to the so-called “Great Moderation” and define \( \tilde{\Sigma}(S_t) \), where \( S_t = \{0, 1\} \) is a variable that differentiate between regimes of low and high volatility, respectively.\(^{36}\) The main results remain qualitatively unchanged after the incorporation of changes in the volatility.\(^{37}\)

\(^{35}\)In the empirical applications, we assume \( k = 2 \).

\(^{36}\)The model is estimated in a Bayesian fashion due to the highly nonlinear environment. Therefore, allowing for more general modelling choices of heteroskedasticity, such as time-varying stochastic volatility (Kastner (2019)), would be computationally demanding since (i) the structural shocks are set identified, and (ii) the variables involved in the VAR are latent, and therefore, also treated as random variables.

\(^{37}\)Results are available upon request.