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International Macroeconomic Vulnerability

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We propose and implement an index of macroeconomic vulnerability to foreign shocks based on a structural time-varying bayesian VAR with a block-exogeneity hypothesis for a given pair of a large economy and a small open economy. The index is based on the sum of the responses of the small open economy to shocks in the large economy over time, thus allowing us to disentangle and measure the source of the shock, impact variables and duration of impact. Our approach brings light not only to vulnerability across countries and over time, but it can be also be used to elucidate previously unanswered channels. We provide an application of this approach to a global banks framework, allowing us to measure some yet unmeasured theoretical mechanisms. Using a sample of developed and developing countries, we find that global banks do not increase the macroeconomic vulnerability of a country.

Keywords: index of business cycle co-movement, synchronization, time-varying structural vector auto regression, impulse response functions, decoupling, global banks.

JEL: C11, C32, F36, F41, G15.

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1 Introduction

September 2008 marked the beginning of what would become known in economic history as the Great Recession. In the months that followed, several countries were hit, to different extents, by the once local American crisis. Confidence plummeted, the financial American shock spread throughout the world channeled by financial linkages, expectations, trade linkages... At the end of 2009, most countries in the world had seen its GDP be impacted.

The Great Recession spread is the most immediate example of the vulnerability of the different economies to the US[1]. The Great Recession, however, is by no means the only example of such phenomena; there is always a lively discussion about if and which countries would decouple or which countries are more prone to be affected by a given US shock. In fact, international macroeconomic transmission is present in both normal and crisis periods.

The literature on international macroeconomic transmission is both vast and diverse, stemming from studying the heterogeneous impacts of different types of shocks (productivity [2] and banking [3], for example) to different types of transmission mechanisms (real channels [4], finance [5]and coordination or learning [6]) of these shocks. Although the theoretical literature has been able to propose important mechanisms and has achieved some insightful results, the empirical literature has focused much more on evaluating some mechanisms than providing a standard measurement of vulnerability to compare how different countries behave across them and over time, even though policy discussion has revolved around this aspect

In this paper, we fulfill this gap by providing an index of macroeconomic vulnerability of SOEs to foreign shocks. In order to do that, we extend Primiceri(2005) time varying Bayesian VAR framework into a two-country setting by using Cushman and Zha (1997) block exogeneity identification strategy for small open economies. Our proposed index is based on the summation of the impulse response functions of this VAR that allows coefficients and parameters to change over time.

We describe below the required characteristics that we believe an international vulnerability index should have and how our index incorporates such characteristics, while also relating our index to the existing literature, which embraces more the idea of comovement than vulnerability to shocks.

[1]There is no consensus in the economic literature on the name of this phenomenon. Contagion, interdependence, spillover, cross-market linkages and international shocks propagation are documented alternatives. These alternatives, however, have different meanings according to Rigobon(2019).

[2]Backus, Kehoe and Kydland (1992), Kalemli-Ozcan, Papaioannou and Perri(2013)

[3]Allen and Gale (2000) and Kalemli-Ozcan, Papaioannou and Perri(2013)

[4]Gerlach and Smetts (1995)

[5]Goldstein, Kaminsky and Reinhart (2000), Kalemli-Ozcan, Papaioannou and Perri (2013)

[6]Chari and Kehoe (1999) and Calvo and Mendoza (2000)

1. **The index should be time varying** In the early years of the literature of the determinants of the business cycle co-movement, the most widely used way of measuring co-movement was a simple Pearson correlation coefficient of the full sample of GDPs of two countries. A set of country-pairs, then, allowed the researchers to run cross-section analysis of the determinants of business cycles synchronization. However, cross-section analysis in this context misses the fact that some countries may have more correlated economic variables because of time-invariant characteristics [7] Our index allows the structural parameters of the VAR, i.e., how the economy reacts domestically and to the large economy, to change over time.

2. **The index should allow for time varying variance of shocks in the foreign country** The next solution found in the literature was, then, to estimate rolling windows of the Pearson correlation coefficient. Forbes and Rigobon (2001), however, introduced the idea that changes in the variance of the countries' shocks mattered [8], which was not present in the previous literature. A first alternative proposed was to identify through heteroskedasticity, but this approach is a better alternative if one is to test for a structural break in the co-movement of the business cycles or "shift-contagion" in a certain point in time. A second alternative [9] consists of simply calculating the absolute differential in GDP growth without any discussion of causality[10]. However, if at first-sight it appears to be a really intuitive index, this index conflates a measure of co-movement and a measure of dispersion (see Cesa-Bianchi, Imbs and Saleheen (2019)). Our index incorporates possible changes in the variance-covariance matrix of shocks over time. Without taking that into consideration, periods of larger shocks could be mistaken for periods of larger structural co-movement. As an example, suppose that there is a larger-than-usual shock in the large economy activity in period 1 and this reverberates through the system of variables through constant structural parameters. Larger observed impacts could have been the consequence of a larger shock (higher variance of the shock) or it could have been the consequence of a larger transmission mechanism (higher structural parameters). And being able to make this distinction has important consequences for both the correct estimation of parameters and for the correct calculation of our index.

[7] For that see Otto, Voss, and Willard (2001), Baxter and Kouparitsas (2005) and Imbs(2006). Cross-section analysis does not allow us to differentiate between, for example, higher trade volume - which changes over time - and geographic proximity - which is constant over time. In order to be able to control for fixed-effects and other time-varying features, one has to resort to panel data.

[8] For a richer assessment of the Forbes and Rigobon's critique, see Appendix B

[9] Giannone, Lenza and Reichlin (2010)

[10] This is an easy index to implement and one that does not depend on the volatility of the shocks - these characteristics made it the most widely-used index in the literature. See, for example: Giannone, Lenza and Reichlin (2010), Kalemli-Ozcan, Papaioannou and Perri (2013), Cesa-Bianchi, Imbs and Saleheen (2019)

3. **The index should be causal**. Previous indices of business cycle comovement are silent about the direction of causality, but the policy discussion usually refers to which countries are more vulnerable to a given shock in a large economy. Did it matter whether country A affected country B or the other way around? This means that the index must be identified. By identified we mean that we must be able to clearly state an identification hypothesis that allows us to extract information on the direction of causality between two countries: Is a given shock in country A reverberating to country B's economic variables? We depart from the literature that only addresses comovements and we discuss structural causation between small open economies and a large economy. We build that by a combination of two identification schemes. The first one, we follow Cushman and Zha (1995) and we assume that a small open economy does not impact the large economy contemporaneously or lagged. The second one, we assume a zero short run restriction (standard Cholesky decomposition) for the ordering of the variables within each economy.

4. **The index should decompose the sources and ends of the transmission** In such a two-country time-varying vector auto-regression, we have equations for domestic and foreign output, inflation, interest rates and exchange rates. Because of this structure, we are able to set a unitary shock on any foreign variable (for example, a positive shock in the output of country A) and track its impact on any domestic variable[11] (for example, interest rates in country B) over the next S periods for each point in time. By doing that, we know, for example, how strong the transmission mechanism of a unitary country A's output shock over country B's interest rates in 1989 is versus the same unitary country A's output shock over country B's interest rates in 2005.

As it should be now clear, comparing our index to the previous ones is alike to comparing reduced form VARs with structural ones, which does not make much sense. Previous indices deal with comovement, ours deal with vulnerability to shocks. Our index is time-varying, structural, decomposable and intuitive, as the identification provides an economic interpretation.

We implement this index to a set of 24 country-pairs and show some interesting patterns. First, by looking at the long term sample, our indices show a tendency in the direction of decoupling in a considerable part of our sample, meaning that the majority of countries are becoming less affected by US economic fluctuations over time. This is not, though, a rule, once the presence of really different patterns between the countries point to the prevalence of country-pair characteristics over common trends in defining the co-movement dynamics. Interestingly, though, crises periods do not seem to be a main driver of business cycle co-movement changes.

[11] Or even a set of domestic variables

We apply this new index to a global banks context for a subset[12] of 20 country-pairs. Our empirical exercise is based on the Global Banks model by Kalemli-Ozcan, Papaioannou and Perri (2013), in which the authors propose a theoretical channel through which one country's shocks are transmitted via financial linkages to another country. This model provides us with a context in which our index's flexibility allows for the measurement of some important unmeasured variables. In our empirical exercise, for the set of country-pairs studied, we do not find empirical evidence of the authors' proposed mechanisms.

The next sections are organized as follows: after this introduction, section 2 will go through the extension of Primiceri's time-varying Bayesian VAR into a two-country setting. In Section 3, we present, implement and discuss some of the empirical results of the proposed index. In section 4, we apply our index to the Global Banks context, while also providing the results. Section 5 concludes.

2 Methods and Data

2.1 Methodological Choices of the VAR

In this section, we present the time-varying structural bayesian vector auto-regression which will be the basis upon which we build our index. The model below borrows from Primiceri (2005) and expands it into a two-country setting.

We choose to work with a structural VAR for two reasons: first, because we are able to build a multiple equations system which allows us to account for many variables at the same time. Here, we are going to use macroeconomic variables that are usual in the context of the macroeconomics and international economics literature: output, inflation, interest rates and exchange rates. Besides being able to account for many dependent and interrelated variables at the same time, a VAR, subject to identification hypothesis, also allows us to identify structural shocks from the reduced form. So, working with a structural VAR makes it possible to identify a shock in one particular variable and track its impact over all of the variables in the system over time. As our goal is ultimately to track how one country's economy responds to shocks in the other economy, being able to identify shocks is of primary importance.

We choose Primiceri (2005) method for the estimation of time-varying matrices of coefficients (including the intercept) and matrix of variances of the shocks. By doing that, time subscripts are added to the coefficient and variance matrices. Let's see why that matters. First, regarding the allowance of time variation of parameters matrices: in a regular structural VAR context, we are able to calculate only one impulse-response

[12] Due to the lack of relevant data availability for 4 countries

function per pair of variables for the whole sample. This happens because our structural coefficients do not change over time. So, the way that a certain shock is able to affect other variables is constant over time. Why could this potentially be a problem? Suppose that at a certain point in time, the relation between some of these variables change for some reason [13]. This change influences the way in which an inflationary shock would impact the interest rates in different points in time. If one is interested in understanding the dynamics of those impacts over time, allowing for the channels through which the shocks are transmitted to change is crucial and, therefore, allowing structural coefficients to change is necessary[14].

Now, considering the discussion above, suppose that we allowed parameters to change over time, but did not allow the variances of the shocks to do the same. Then, a period of higher economic turbulence - one where shocks were larger, but possibly not transmission mechanisms - would result in some variables reacting more to other variable's shocks, which would lead us to believe that the transmission mechanisms were changing when, in reality, the shocks were simply larger. That is why it is important to take into consideration the possibility of the variance of shocks changing over time, i.e., taking heteroskedasticity into consideration. That's what this model does: taking the change in the variance of shocks into consideration allows us to mitigate the problem of misinterpreting a larger shock for larger transmission mechanisms.

We choose to extend Primiceri(2005) model into a two-country setting by using Cushman and Zha (1995) identification scheme. It consists of working with pairs of one large economy and one small open economy, where the large economy is not affected contemporaneously nor in lags by the small economy. The small economy, on the other hand, is affected by the large economy both contemporaneously and in lags. Let's take a moment to discuss what these hypotheses mean and whether they are too strong. Suppose that we have a small open economy and a large economy. The large economy is one that is large enough so that it is not affected by other countries' shocks. The small open economy, on the other hand, is - as the name presupposes - small enough and open enough so that international shocks are relevant to its internal dynamics but it does not affect significantly the large economy [15].

For the identification strategy within each economy, we choose zero short run restrictions with the following ordering: output - inflation - interest rate - exchange rate. We must impose an ordering hypothesis

[13]For example, the monetary policy answer to a shock in inflation may change over time according to the characteristics of the central banker

[14]The way in which these changes are modeled is through a random walk: each time-varying parameter is the result of its value in the previous period plus a random shock. This modelling choice reduces the number of parameters to be estimated - and this is a crucial point since we are dealing here with a considerable amount of parameters to be estimated while also dealing with time series, which can be limited in its size. Modelling the time-varying coefficients in another way would be possible, but in the expense of a much longer list of variables to be estimated, which could end up driving the estimation impossible.

[15]In this sense, only a couple of countries in the world would fit the Large Economy criteria in a Global scale: United States and China would probably be the best choices. The SOE, on the other hand, could fit almost every other country in the planet when compared to these two huge economies. In a regional scale, however, other pairings could be done without too much of a stretch.

for the contemporaneous relations between how these variables interact domestically. As is standard in the literature, we impose (for both countries) that the activity affects all of the other variables in that country contemporaneously, but is not affected by any of that country's variables contemporaneously. The idea behind this assumption is that production decisions are far more slow than prices, monetary policy or exchange rates. Inflation, on the other hand, responds to activity fluctuations contemporaneously, but not to interest rates or exchange rates. The monetary authority, which is usually expected to follow a Taylor Rule, responds contemporaneously to activity and inflation, but not to exchange rates. Lastly, the exchange rate responds instantaneously to all of the other variables in the block. Many other variables could have been added to our VAR. However, although we are using an identification procedure which greatly reduces the dimension of the problem, we are still subject to a huge amount of parameters to be estimated.

Based on what we described before, we have a time-varying vector auto-regression[16]:

$$A_t y_t = B_t y_{t-1} + \Sigma_t \varepsilon_t$$

where $y_t = (y_t^1 y_t^2)'$ is a vector which comprises both another vector containing the variables of the small open economy y_t^1 and a vector containing the variables of the large economy y_t^2. A_t is a matrix of contemporaneous coefficients, while B_t is a matrix of lagged coefficients. Σ_t is a diagonal matrix with entries that can be different. All of the coefficients are allowed to change over time. The consequence of the Cushman and Zha (1997) hypothesis applied to this framework is that both A_t and B_t are block triangular:

$$A_t = \begin{pmatrix} A_t^{11} & A_t^{12} \\ A_t^{21} & A_t^{22} \end{pmatrix} = \begin{pmatrix} A_t^{11} & A_t^{12} \\ 0 & A_t^{22} \end{pmatrix}$$

and

$$B_t = \begin{pmatrix} B_t^{11} & B_t^{12} \\ B_t^{21} & B_t^{22} \end{pmatrix} = \begin{pmatrix} B_t^{11} & B_t^{12} \\ 0 & B_t^{22} \end{pmatrix}$$

which means that the large economy is not affected contemporaneously ($A_t^{21} = 0$) nor in lags ($B_t^{21} = 0$) by the small open economy. At the same time, the small open economy can be affected either contemporaneously (A_t^{12}) or in lags (B_t^{12}) by the large economy. One should note here that each of the entries to the matrices above (A_t and B_t) are in fact blocks, i.e. sub-matrices. As mentioned above, besides this block-exogeneity assumption, we follow regular ordering hypotheses inside the countries (i.e. activity, inflation, interest rates

[16] We choose to display a VAR with only one lag and no exogenous variables in order to make the exposition more simple and clear. This could, however, be easily extended to a p-lags VAR.

and exchange rates).

So, let's take, as an example, a pairing of the United States and Brazil. Suppose that we build a model with seven variables: American activity, American inflation, American interest rates, Brazilian activity, Brazilian inflation, Brazilian interest rates and Real/Dollar exchange rates. What the above hypothesis says is that everything that happens to the US activity, inflation or interest rates affects the dynamics of all of the Brazilian variables contemporaneously and in lags. Everything that happens in Brazil, on the other hand, is irrelevant for the dynamics of the US economy, whether contemporaneously or in lags. This should not come as a surprise once the actual dynamics of these economies is taken into consideration, making it a fairly realistic hypothesis.

This hypothesis simplifies the estimation of this international extension of the time-varying VAR. By assuming block-exogeneity, we can estimate two completely independent systems of equations - which we call, respectively, system 1 and system 2:

$$y_t^1 = D_t^{11} y_{t-1}^1 + D_t^{12} y_{t-1}^2 + D_t^{13} y_t^2 + u_t^1$$

and

$$y_t^2 = D_t^{22} y_{t-1}^2 + u_t^2$$

which means that we can estimate the small-open economy system as if the large-economy variables were exogenous variables (controls) in the system, while the large-economy system can be estimated as if the small-open economy did not exist.

After the estimation, we bring these blocks back together to get the impulse response functions of the whole system. In practice, structurally, what happens is that the shocks that affect the large economy will reverberate through the large-economy system (system 2) and will affect large-economy variables over time. These shocks will be felt by the small-open economy through the large-economy parameters that are present in the small-open economy system (system 1). Small-open economy shocks, on the other hand, can only affect small-open economy variables - which are only present is system 1 - and, thus, are irrelevant to all of the large economy's variables.

So, with this model, we have a two-country VAR in which not only the coefficients are allowed to vary over time, but also the variances of the shocks are allowed to vary over time.

2.2 Methodological Choices of the Index

In order to build our index, we start from the time-varying Bayesian VAR presented in the last section, with seven equations and a block exogeneity hypothesis, where the large country is not affected contemporaneously nor in lags by the small country. Our seven equations are composed of: activity, inflation and interest rates for both countries and exchange rate, that enters only on the small open economy block [17].

The idea behind business cycle transmission is that something that happens domestically at one country ends up being transmitted through economic channels to other countries. This ”something” can be an output shock, an inflationary shock or an interest rate shock etc. The economic channels, on the other hand, are the means of transmission of these shocks - the economic linkages that bond together two countries.

In the time-varying VAR that we presented in the last section, the time-varying structural coefficients represent the way in which two variables are related to each other in a specific point in time. Shocks and reactions are synthesized in impulse-response functions - which are functions of the structural parameters in our model. And once we allow the structural parameters to change over time, we are also able to measure impulse-response functions for each point in time. Once we have an identification hypothesis that also allows us to have two countries in the same system of equations, we can calculate impulse-response functions of shocks in the large economy over the small open economy over time.

A vulnerability index should be able to measure how a shock in one country is transmitted to another country over time. It should, then, aim to measure the transmission mechanisms (the structural parameters) - and that is exactly what an impulse-response function does. By looking at impulse-response functions, we are essentially focusing on a counterfactual: what would have happened to these two economies if, at a certain point in time, one of them was subject to a unitary exogenous shock. We are, then, able to compare these same transmission mechanisms, but in other points in time, for a shock with the same magnitude.

The index that we propose, then, is based on impulse-response functions. Our business cycle comovement index is given by:

$$H_t = \sum_{s=0}^{T} (\psi_{t+s}(j, i))$$

where $T = 30$, $\psi_{t+s}(j, i)$ represents the impact over variable j (Small Open Economy) of an exogenous shock in variable i (Large economy - US) in period $t + s$, where t is the period when the shock happened.

[17] Although the exchange rate is a variable that refers to both economies, it is much more intuitive to have it being relevant to the small open economy than to the large economy. If we take, as an example, the case of a pair of countries composed by Brazil and the United States, it is highly unlikely that American activity, inflation or interest rates will be affected by the exchange rate between the Brazilian Real and the US Dollar. The Brazilian economy, economic history tells us, is highly exposed to such exchange rate.

Let's take some time to understand the index above. For every exogenous shock that happens in period t, its impact is felt in period t, $t+1$, $t+2$... [18] The length of the reverberation of one single shock over time is called S above. S is chosen by the economist who is building the index according to its research objectives. So, $\sum_{s=0}^{S}(\psi_{t+s}(j,i))$ means that we are adding all of the impacts of one single shock in variable i that happened in period t over variable j in all periods that follow the moment of shock (until $t+S$). This is similar to taking the integral of the impulse-response function[19]. This means that we are assessing the accumulated impact that an exogenous shock in variable i (US) had over variable j (SOE) over time. The main point here is that most of the shocks in dynamic models do not fade away after the first period, so effectively measuring the impact of a shock over other variables should include the subsequent periods impacts, usually caused by positive coefficients of lagged values. One should note, however, that the index is flexible enough so that the researcher can set $S = 0$ and take only the instantaneous impact into consideration if that is required in the empirical exercise being performed.

This index represents a full assessment, lagged and contemporaneous of the influence, direct and indirect, of any variable in the large economy over whichever other variable the researcher is interested in the small open economy.

It is also important to make two observations before we proceed. First, the exogenous shock should be a unitary shock and not a one standard deviation shock. The reason for that is that, since we allow the variance matrix of the shocks to change over time, the standard deviation of shocks in different periods can, potentially, be different. So, in order to compare comparable objects, a standard unitary shock is required. Second, the impulse response used here is the median impulse response function out of all the iterations. We do not take into consideration significance levels, although that could be possible by computing percentiles of the iterations of the estimation algorithm.

2.3 Data

In order to build our index, we gathered data for 24 countries, plus the United States. Let's first take some time to discuss the reason why we chose the US as the only large economy in our sample: a large economy, as extensively discussed before, is one that is predominantly unaffected by foreign shocks. This is generally true for the United States, but not for any other countries individually. [20]. The small open economies, on the other hand, were chosen not only as to be a representative sample of developed and developing countries,

[18] If the system is dynamic - i.e., if present values are dependent on past values, which is the case in our model - and according to the different hypothesis and values of the estimated coefficients .

[19] Although the analogy is only illustrative since we are dealing with a discrete function.

[20] one could extend our results to consider China as a large economy too without much change.

but also on the basis of data reliability and availability.

Our sample is composed of the following countries: Austria, Belgium, Brazil, Canada, Chile, Colombia, Czechia, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Lithuania, Mexico, Norway, Poland, Russia, South Africa, South Korea, Spain, Sweden and UK. The earlier point in our sample is January 1960 (for some developed countries) and the last point for every country is December 2019, in order to avoid the covid-19 period.

Using FRED St Louis Economic database as the source, we used industrial production data as a proxy for output (percentage change over the same month of the previous year), CPI for inflation (percentage change over the same month of the previous year), and, for exchange rates, domestic country currency over US Dollar (percentage change over the same month of the previous year). For interest rates, we used both short-term interest rates (less than 3 months) and long term interest rates (10Y). Although the results are remarkably similar, we use the short-term interest rate version in this section because it is lengthier for the majority of countries [21].

Many other variables could have been added to out VAR. However, although we are using an identification procedure which greatly reduces the dimension of the problem, we are still subject to a huge amount of parameters to be estimated. This increase in the number of variables has not only consequences for the time length of the estimation, but it requires a much lengthier time-series. Lengthier time-series, however, are even more scarce when we work with small economies, specially those of developing countries. We overcome the problem above by using a monthly sample, instead of a quarterly one [22]

This leads us to the bayesian estimation. In order to calibrate our prior distribution, we set apart a short subset of our sample and estimate the distribution statistics through an OLS. In our index, this subset is exactly 4 years long. One upside of working with priors and bayesian estimation is that, by choosing well behaved distributions, we are able to avoid getting results in implausible regions due to local maximizers. After knowing the prior and its calibration, we can proceed with the estimation following the steps in Primiceri (2005).

[21]Some of the countries in our sample have only been able to supply 10Y bonds recently.

[22]In order to exploit more data points. The monthly sample, however, also helps us mitigating the problem of the ordering in the VAR: assuming an ordering between activity, inflation and interest rates is much less restrictive when one talks about monthly rather than quarterly or annual series.

3 Results

In this topic, we present the results of our index when applied to the sample of 24 countries shown above. For this exercise, we set S to 30 months. In figure 1 we present the results for Austria, Belgium, Brazil, Canada, Chile, Colombia, Czechia, Denmark, Finland, France, Germany and Greece. In figure 2, Hungary, Iceland, Lithuania, Mexico, Norway, Poland, Russia, South Africa, South Korea, Spain, Sweden and United Kingdom. We restrict the time-series of the graphs in this section to the period after January 2000, once this is the period where the majority of the countries have index readings (with the exception of Iceland, Lithuania and Russia, whose index start in December 2004, February 2006 and August 2003, respectively). We make this date restriction in order to enhance visual comparability between the countries.

Choosing which index to use is an important part of the research to be conducted on a case-by-case basis, once these indices, although aiming to address co-movement, measure different things. There are good reasons for, sometimes, using specific variable indices to assess different phenomena. For example, if one is interested in knowing how an exogenous change in Monetary Policy in the US affected the interest rates in an SOE, the researcher should first choose which interest rates he/she is interested in. Then, after building the VAR using this variable, the researcher can build the index of US Monetary policy shock on SOE's interest rates.

Figures 1 and 2 present the indices for an American output shock over SOE's output (responses).

$$H_t = \sum_{s=0}^{30} (\psi_{t+s}(j,i))$$

where j is the output in the SOE (which is going to respond to exogenous shocks over S periods) and i is the American output[23].

Before we proceed to the comparisons between countries, we should understand what this index means: take Germany as an example. In January 2000, one unitary shock in the American GDP (i.e., if the American GDP suddenly grew by 1 extra percentage point when compared to January 1999) would make German GDP grow an extra 1.09 percentage points over the next 30 months. An exogenous unitary American GDP shock that happened in January 2010, however, would make German GDP grow 1.5 percentage points over the next 30 months.

The indices, then, are intuitive and can be readily applicable to different exercises. This index (American output over SOEs output) will, in fact, be used in our empirical exercise on the next section. It is the index

[23] As we are working with a monthly frequency, we use Industrial Production as the output variable.

that more closely matches what the literature usually calls business cycle co-movement, once it relates two countries outputs.

Now, by looking at Figures 1 and 2, some things are worth noting. First, there is no clear pattern between the countries' indices, which suggests that there is also a prevalence of country-pair characteristics over common trends in defining the co-movement between two countries. Second, the scale varies considerably between countries, which again suggests that there are probably some country-pair specificities that affect the scale (intercept) of the indices. This last note reinforces the need of taking into consideration country-pair fixed effects whenever one wants to study the fundamentals driving such phenomenon.

Another interesting feature of the readings of this index is that - although there are some spikes that occur at the grey areas - at first glance the index does not seem to get much affected by crises periods. This is interesting because it is directly related to Forbes and Rigobon's critique: as we have seen in the construction of the index, our proposed measurement takes into consideration the potential heteroskedasticity in the data, i.e. the possibility that GDP shocks in the US get more volatile at times and, in particular, during crises periods. By doing that, our index is able to downplay the importance of US shocks over foreign countries GDPs if such shocks occur during high-volatility periods. The intuition is that this model [24] is able, to some extent, to make a clearer distinction between a stronger transmission mechanism (higher structural parameters) and a stronger shock (higher volatility) over time.

Table 1 shows the results of a panel regression of our index on a dummy variable that takes the value of one during US crises periods and 0 during normal times (columns 1 and 2) that occurred over all of our sample data span. In columns 3 and 4, our index is regressed against a dummy variable that takes the value of one only during the Great Recession of 2007-09 and zero in every other period. Columns 2 and 4 also control for country-pair fixed effects. We can see that, according to this measurement of co-movement, there is no evidence of contagion of a US crisis over the other countries in our sample. If anything, there is even a small negative effect of the Great Recession.

Even though there is no immediate evidence of contagion throughout our sample [25], Mexico stands out as a very vulnerable country when we talk about a US crisis. According to our index, Mexico is consistently more exposed to US shocks during US economic crises, as can be seen in figure 2. If we consider that Mexico is heavily dependent on the US economy, this index reading does not come as a surprise.

[24] Based on Primiceri's model which already had this characteristic

[25] We do not expect this to be a full assessment on the existence or not of contagion. This exercise is only intended to show that the index is not higher during crises by construction.

Table 1: Contagion exercise

	Dependent variable:			
	Co-movement Index			
	(1)	(2)	(3)	(4)
All crises	-0.531	-0.334		
	(0.873)	(0.686)		
Great Recession (07-09)			-1.905^{*}	-1.990^{**}
			(1.136)	(0.898)
Country-pair fixed effects		x		x
Observations	2,778	2,778	2,778	2,778
R^2	0.0001	0.0001	0.001	0.002
F Statistic	0.370	0.236	2.809^{*}	4.911^{**}
Note:		$^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$		

4 Application of the method on a Global Banks context

Now, we are going to present a possible application of our indices. This application highlights some important features of our method, and how it can help solving some important measurement problems in the literature. First, being a structure-based index is helpful once it allows us to focus on changes in the parameters that drive co-movement. Second, this exercise shows the wide range of possibilities that the flexibility of our index [26] provides us with.

The empirical exercise that will follow is based on the theoretical model in Kalemli-Ozcan, Papaioannou and Perri (2013) - KPP hereafter - whose main features are going to be briefly discussed in section 4.1. This article is part of the broad business cycle co-movement literature and, more specifically, is included in the subset of this literature which tries to understand such co-movement from a financial integration perspective. For a more in-depth discussion on the literature that links financial integration and business cycle co-movement, please see the Appendix D.

The KPP article became one of the standard models in the literature to explain the mechanisms that may be in place concerning financial integration and co-movement. According to the authors, one of the (two) main goals of this model is to *"Precisely spell a causal link between financial integration and business cycle co-movement"*[27]. By doing this, the authors provide us with causal links between the model's variables which

[26]By flexibility, we refer to the various formats in which it can presented - shocks and responses of any variables of the model.

[27]The other one is to *"show that our empirical findings can be used to identify sources of output fluctuations"*. We are going to go through this second goal later in this paper.

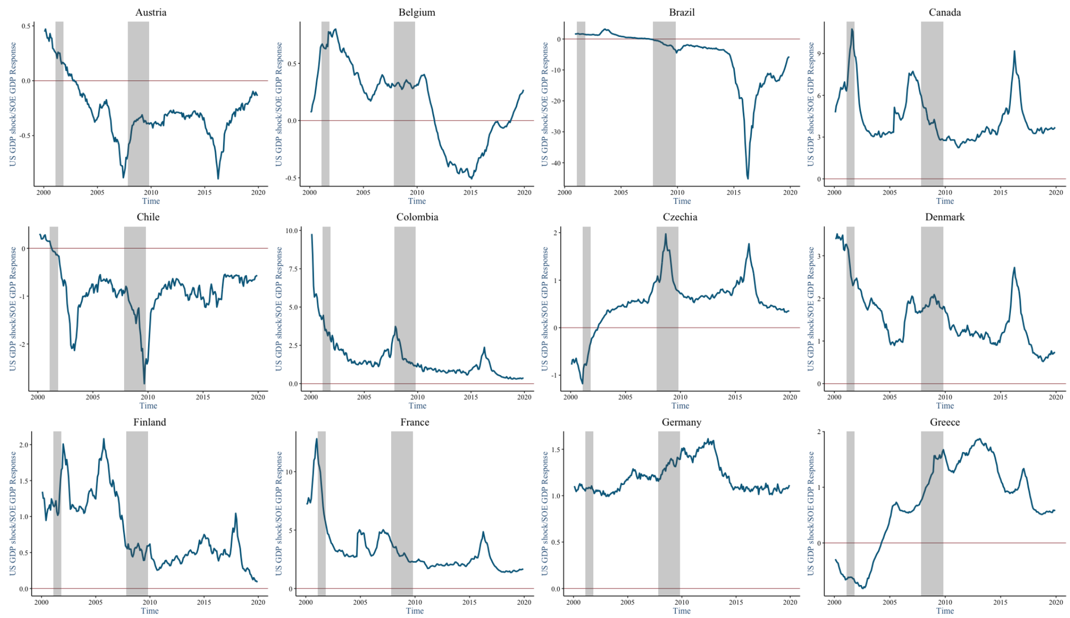

Figure 1: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's GDP for the first half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to NBER data. We restricted our sample here to results between 2000 and 2019 in order to have higher comparability between the countries.

are testable, but which, to the best of our knowledge, could not be satisfactorily tested until now. Putting this model to test is the subject of our last section.

4.1 KPP model - some insights and intuition

KPP is a model with two countries (Home and Foreign), two sectors ($i = 1, 2$) and only one good.

Sector 1 in each country is similar to a closed economy (with households, firms and banks which are only allowed to consume, produce and lend in this sector. Sector 2 in each country, however, differ from sector 1 by having Global Banks (instead of local banks), which are allowed to lend to and take deposits from the firms and households from sectors 2 in both countries (Home and Foreign). What binds the two sectors in each country together are common productivity and banking shocks. The relative size of sectors 1 and 2 in each country, then, represents how closed or open the financial sector of this economy is. Global Banks, on the other hand, represent financial integration between these two countries.

As stated above, the main goal of the KPP paper is to provide the literature with a new theoretical model that gives an explanation to a well-known empirical observation in international economics: two countries

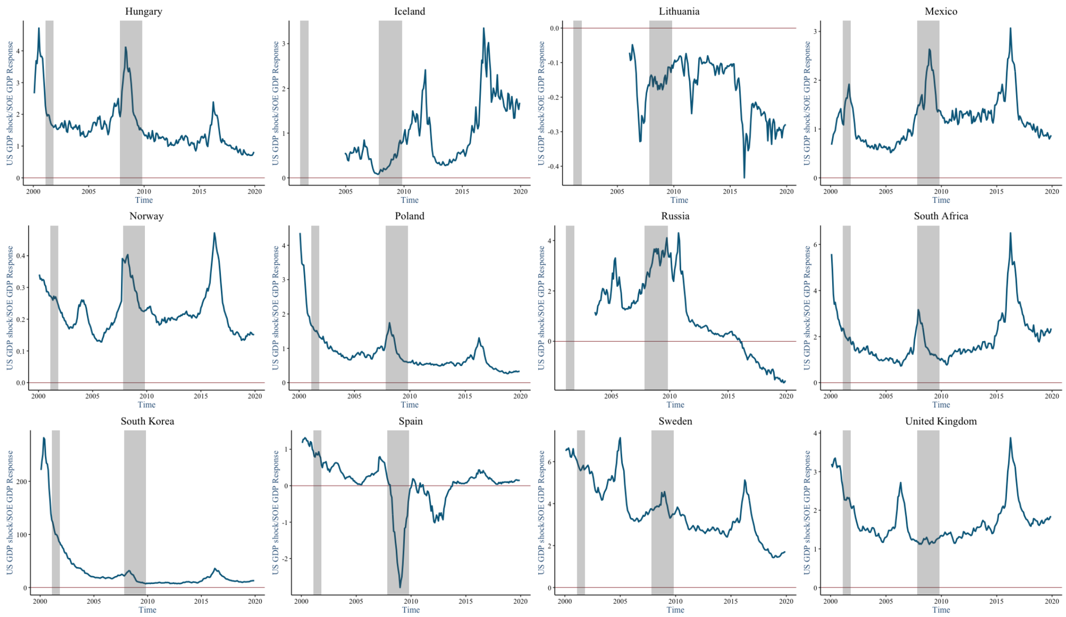

Figure 2: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's GDP for the second half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to NBER data. We restricted our sample here to results between 2000 and 2019 in order to have higher comparability between the countries.

can have switching co-movement [28] over time. And this is achieved through a pair of shocks that may affect these two countries: a productivity shock and a banking shock.

The intuition behind the model's mechanism is the following:

- productivity shock: suppose that there is a positive productivity shock in the Home country. Then two things will happen at the same time: (i) Home country's GDP will be higher and (ii) both sectors 1 and 2 will become more productive in the Home country relatively to sectors 1 and 2 in the foreing country. Because of the higher relative productivity, global banks will divert funds from the Foreign country to the Home country (the model's more technical details are not our focus now, we are just working on the intuition[29]). This will make credit more expensive (higher interest rates) in the Foreign country, making it more expensive to produce, which will make the Foreign country's GDP go down. So, a productivity shock in the Home country makes the cycles less synchronized through higher interest rates in the Foreign country.

- financial shock: now suppose that there is a negative financial shock in the Home country, which

[28] Sometimes their GDPs are positively correlated and, sometimes, negatively correlated.
[29] For a lengthier discussion on KPP model and its technical modelling aspects, please read the Appendix E.

directly affects the global bank's ability to provide credit for both Home and Foreign countries' firms . In this example, the global banks are going to reduce credit for both countries, which is going to make the cost of credit (interest rates) higher in both countries and will, in turn, make both countries' GDPs smaller. So, a financial shock makes the cycles co-move more through higher interest rates in both countries.

As the reader can now see, this is not only a really easy-to-grasp intuition, but the model is also one that effectively identifies two possible mechanisms through which the sign of co-movement may be reversed over time. This allows for the - once apparently conflicting - empirical results of both positive and negative co-movements in GDPs to be consistent with economic theory in one simple framework.

The key to this switch lies in one fundamental variable, though: the reaction of the Foreign country's interest rates to the shock, whichever shock it may be[30]. We will go over this idea again as this insight is fundamental for our empirical test.

4.2 KPP model as a testable equation

In this subsection, we are going to do our best to translate the theoretical model of KPP into a testable equation. The theoretical model in KPP does not admit analytical solutions - which would provide us with ideal testable equations. We are going, then, to base our empirical exercise on the structural numerical results of the model[31].

Now, for the sake of clarity, let's suppose that there are two countries - country h, home, and country f, foreign - of which only country h receives exogenous productivity and financial shocks, while country f is subject to no direct shocks[32].

In a short summary, what the KPP model predicts is that, after a shock (to productivity or to the financial sector) hits country h, it is transmitted to country f through interest rates which, in turn, affect country-f's production. The connection between the two countries is made via Global Banks, which, empirically, implies that there is at least some financial integration between the two countries. The first key aspect of the model, then, is that the interest rates of country f react differently to a productivity or a financial shock in country h. This changing reaction is what drives country-f's production upward or downward, leading to higher or lower co-movement. The other key aspect of the model is that this whole mechanism gets stronger when

[30] Productivity or financial

[31] If the reader is interested in the solutions' details, please check Appendix E. It is not, however, indispensable to understand the exercise.

[32] Country f is only indirectly hit by country-h's shocks, through the channels seen in KPP model. The reader will probably have already related country h to the large economy and country f to the small open economy - and that is, indeed, the goal here.

the two countries are more financially integrated.

In order to test for these mechanisms, we would like to run a panel regression - using several country-pairs - to estimate the equation below:

$$Co\_movement_{h,f,t} = \alpha_{h,f} + \lambda_t + \beta_1 Integration_{h,f,t} + \beta_2 (Integration_{h,f,t} \times IR\_reaction_{h,f,t}) + \beta_3 crisis + X'_{h,f,t}\Phi + \epsilon_{h,f,t}. \quad (1)$$

where $Co\_movement_{h,f,t}$ is a variable that measures the co-movement between the GDPs of country h and country f; $\alpha_{h,f}$ is a fixed-effect of a dummy representing the country-pair h and f; λ_t is a time fixed-effect; $Integration_{h,f,t}$ is a variable that measures the financial integration between country h and f; $IR\_reaction_{h,f,t}$ is a variable that measures the reaction of country f's interest rates to a positive GDP shock [33] in country h; $Crisis_t$ is a dummy variable that assumes the value of 1 if there is a financial crisis in country h in period t; $X'_{h,f,t}$ is a matrix of controls; and $\epsilon_{h,f,t}$ represents the error.

Now lets discuss the reason for why we believe that this would represent a good test for the mechanisms behind the KPP model. As stated by the authors, one of the two main goals of their theoretical model is to: *"Precisely spell a causal link between financial integration and business cycle co-movement"*. The relation - found in the empirical exercise in KPP - between crisis periods and higher co-movement is an observed correlation. The proposed theoretical causal link that binds these two variables together is the reaction of the foreign country's (here, country f) interest rate to a shock in the home country (here, country h). So, being able to test for the proposed causal link between these variables requires being able to test for the reaction of the interest rates of country f to shocks in country h.

One should note, at this point, that there may be numerous reasons for a financial crisis to affect the co-movement of business cycles other than the proposed KPP link[34]. The impact of the proposed KPP mechanism (or channel) interacted with integration over the co-movement of the business cycles would be captured by the estimated β_2.

So, what would be the expected values for each parameter to be estimated in the above model? If the KPP theoretical model is, indeed, valid, then it is necessary that β_2 is negative. The reason for that is that a positive reaction of interest rates in country f to a positive shock in country h means that such shock was a productivity one. If the KPP model is valid, then, a productivity shock combined with higher financial integration should result in lower co-movement. If, on the other hand, country-f's interest rate reaction to a positive shock in country h is negative, then it means that the shock in country h was a financial one. This,

[33] We will go through this in more detail later in the article, but here we consider that a positive GDP shock comes either from a positive productivity shock or a positive financial shock

[34] Appendix D

together with higher integration, would result in higher co-movement of the business cycles. That is the reason why β_2 is the key parameter to be estimated in this equation if one is to test for the KPP mechanisms in place.

Concerning parameters β_1 and β_3, however, the theoretical model is mute. The link between financial integration and business cycle co-movement that does not go through interest rates reaction wasn't modeled in KPP and is represented by β_1 here. Therefore, β_1 assuming any values will not contradict KPP results. However, if this parameter's estimate is statistically significant, then it means that there are also other relevant channels between integration and co-movement that were not considered by KPP. β_3, on the other hand, represents the set of alternative theories that link crisis periods with co-movement of business cycles which do not go through interest rates reaction mechanisms. KPP is also mute regarding β_3, but a statistically significant estimate would mean that there are probably other contagion channels working in the real economy other than the global bank ones.

Estimating the equation above is not an easy task to implement, though. Let's go through the measurement of each variable above:

- The literature has come to a quite consensual way of measuring financial integration through the cross-border banking activities between country h and country f. This is done by adding the banking positions of country h on country f with the positions of country f on country h - which are publicly available informations on the BIS website. In our opinion, this is a satisfactory way of measuring financial linkages and there is no contribution from our paper to the measurement of that variable;

- As extensively reported in the literature review, measuring the co-movement of the business cycles is not straightforward. Usually, when one is able to get around Forbes and Rigobon's critique of a time-varying bias, he/she falls under a non-intuitive and, therefore, economically problematic measurement of such co-movement;

- Measuring the *IR_reaction* variable, however, poses an even higher obstacle than the one of measuring co-movement. This variable requires not only a measurement of the impact of a shock in country h over the interest rates of country f, but it also requires that such reaction from the interest rates is caused by the same shock that affected the co-movement. If, however, one is able to overcome these obstacles of measuring *IR_reaction*, he/she will still be subject to the same Forbes and Rigobon critique of time-varying bias.

4.3 Panel data, measurements and frequency

In order to test for the mechanisms of the KPP model, we proceed to testing the equation 1. To do this, we calculate, for each country in our sample, the financial integration variable by following KPP. For that, we used BIS publicly available data on financial linkages for each of the 24 country pairs in our sample. We used Total financial linkages as a percentage of GDP once this is the measurement that more closely relates to the parameter *lambda* in KPP, which represents how financially open two countries are[35] Due to mismatches in availability of financial integration data and business cycle co-movement data, our sample of 24 countries was reduced to 20 countries.

Total Financial Linkages as a percentage of GDP are calculated as follows:

$$\left[Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t} + Assets_{SOE,US,t} + Liabilities_{SOE,US,t}}{GDP_{US,t} + GDP_{SOE,t}} \right]$$

In the BIS sample, however, there are periods in which the US reported financial data, but not the SOE - and vice-versa. We chose to work only with dates that include both US reports and the SOE reports. This decision somehow reduces our sample, once some of the reported linkages are not considered. In order to make sure that our results are not determined by this research decision, we also present, in Appendix F, the results of our exercise with two alternative [36] measurement options to overcome this. This issue, however, does not change the results in any significant way.

In order to calculate the business cycle co-movement variable, we used our new index, where:

$$Co\_movement_{h,f,t} = \sum_{s=0}^{30} (\psi_{t+s}(f_{gdp}, h_{gdp}))$$

This variable, then, measures how an output shock [37] in the Large economy affects the SOE's output.

The crucial variable $IR_reaction_{h,f,t}$, on the other hand, was measured by:

$$IR\_Reaction_{h,f,t} = \sum_{s=0}^{30} (\psi_{t+s}(f_{ir}, h_{gdp}))$$

which means that this variable measures how strongly an output shock in the large (home - US) economy affects small open economies (foreign countries). This measurement assumes a negative value if, after 30

[35] *lambda* is the measure of relative size of sectors 2 and 1 in KPP. The larger is the open sector (2) relative to the closed sector (1), the more financially open such economy is. This is why it is important to calculate financial integration as a percentage of GDP, as in KPP.

[36] The first one is to consider only the reports of the available country in periods of single-sided availability and to consider the average between the reports in every other period. The second alternative is to consider only US-reported data and ignore the data reported by the SOEs.

[37] Independently on weather it is a productivity or financial shock

months, the accumulated impact of a positive and unitary output shock in the large economy over the interest rates in the SOE is negative. This means that the positive shock in output was actually a banking shock (once, in KPP model, banking shocks were the ones to induce a reduction in the foreign country's interest rates). In order to calculate this variable, however, we should ideally use corporate interest rates [38]. Due to the unavailability of this variable for most of the countries in our sample, we used the 10Y interest rates, which more closely relates to corporate interest rates.

Finally, due to a quarterly availability of the BIS data, our panel had to be estimated on a quarterly basis. Our time-varying VAR, however, is estimated monthly - because of previously mentioned benefits of a higher frequency estimation in this context. In order to build our quarterly indices, then, we used the 3-month mean of our indices readings in each of the quarters.

4.4 Results

Now we proceed to the results of our empirical exercise. We start by running the same regressions as the ones in KPP's stylized facts section [39] in table 2, but with our index as the dependent variable. We choose to do this because part of our results could be driven by the addition of a new, previously unmeasured, variable (the impact of a US shock on the foreign country's interest rates), but part of it could also be driven by a different measurement for the co-movement of business cycles. So, being able to assess the resulting differences of estimating the same equation is of considerable interest for this research.

Let's start by looking at table 2. The first and second columns show the results of regressing our co-movement index on Integration and the interaction between Integration and a dummy for the Great Recession period. We follow KPP in that the first column also has the Great Recession dummies as regressors, while the second column has, instead, a Trade[40] regressor. The trade variable, here, works as an additional control: trade linkages are a well known potential driver of economic co-movement. The first thing to notice here is that, like in KPP, we also find that financial integration seems to make two countries co-move less in normal times. This can be seen in the first row of the two first columns. This suggests that a positive output shock in the Large economy probably does make the Large economy more attractive when compared to the small open economy, causing the cycles to diverge.

The second row (first two columns) of table 2 also goes in the same direction of KPP, showing that this

[38] In KPP, the mechanism works through higher corporate interest rates rather than higher short-term interest rates

[39] In their article, KPP run a similar regression as a stylized fact section. We briefly discuss the differences of their approach to ours in the Appendix G.

[40] We build this variable as in KPP, by adding the exports and imports of both countries and normalizing by the sum of the country-pair's GDPs.

Table 2

	Dependent variable:			
	$Co\_movement_{index}$			
	(1)	(2)	(3)	(4)
Integration/GDP	−1.942*	−3.675***	−2.034*	−3.564***
	(1.068)	(1.232)	(1.044)	(1.203)
Integration/GDP x Great Recession	2.773*	1.229		
	(1.505)	(1.419)		
Great Recession	−0.616***			
	(0.168)			
Integration/GDP x All crises			2.102	1.018
			(1.434)	(1.337)
Crises			−0.408***	
			(0.148)	
Trade/GDP		0.234		0.232
		(0.492)		(0.493)
Ind. FE	x	x	x	x
Observations	1,563	1,506	1,563	1,506
R^2	0.010	0.006	0.007	0.006
F Statistic	5.441***	3.140**	3.456**	3.083**
Note:		*p<0.1; **p<0.05; ***p<0.01		

co-movement is probably higher in periods of crises (although it is not highly significant in the first column - 10% - and is not significant at all in the second column). This means that, if we run the same regression as in KPP, but with our sample and our measurement of business cycle co-movement, we find similar results to KPP - small open economy is indeed more highly affected by shocks in the large economy during financial crises. An important point to make here is that KPP do not work with small open economies and large economies, this is a characteristic of our sample only - KPP works with pairs of all different kinds of economies. This restriction in our sample comes from our identification hypothesis, which, although more restrictive, allows us to identify structural shocks - as already discussed in previous sections. We also find, similarly to the results in KPP, a negative coefficient of the Great Recession dummy (although our coefficient is significantly negative, while theirs is not significant). Lastly, trade is not significant in our exercise and also is not significant in KPP.

The results in these first two columns show remarkable similarities with KPP's results, even when using a completely different sample and co-movement index. We find this remarkable, but not unexpected, since our indices aim to measure the same thing.

In the last two columns (3 and 4), we substitute the Great Recession period dummy by a dummy variable that assumes the value 1 if the US was in any crisis period in the sample - according to the NBER recession data - and 0 if the US was not in a crisis period. So, the variable crises actually contains the variable Great Recession. This is a robustness check to confirm if these results are specific to the Great Recession period of 2008-2009 or if they are also valid under other crises periods. The results are, indeed, really similar, which leads us to believe that these findings are also applicable to other crises periods, not only the Great Recession specifically.

Table 2, then, shows that our results of running the same regression as in KPP holds remarkable similarities with the original article.

Now, let's move to table 3, which presents the results of the regression proposed in equation 1. In the first column, we present results with the Great Recession dummies as controls, in the second column, trade and, in the third column, the every-crises dummies. Here, we can see that the coefficients for the Great Recession dummy, all crises dummy and the trade variable maintain their original signs and levels of significance. The same cannot be said of the two first rows, though.

The first thing to remind here is the expected sign of the coefficient of the interaction between Integration/GDP and IR_reaction following KPP's theory. The IR_reaction variable is positive if a positive output shock in the US results in positive responses of long-term interest rates in the small-open economies. This,

Table 3

	Dependent variable:		
	$Co\_movement_{index}$		
	(1)	(2)	(3)
Integration/GDP	1.252	0.355	0.872
	(0.962)	(1.118)	(0.957)
Integration/GDP x IR_reaction	10.183***	10.654***	10.100***
	(0.810)	(0.879)	(0.812)
Great Recession	−0.548***		
	(0.149)		
Crises			−0.309**
			(0.128)
Trade/GDP		0.497	
		(0.470)	
Country-pair FE	x	x	x
Observations	1,563	1,506	1,563
R^2	0.101	0.095	0.096
F Statistic	57.439***	52.186***	54.624***
Note:	*p<0.1; **p<0.05; ***p<0.01		

according to KPP's theoretical model, means that the shock was one of productivity. The IR_reaction variable, thus, works as an instrumental variable that tells us if the shock was a productivity or a financial one. The more financially integrated two countries are, the more this productivity shock should result in a divergence of movements - which means that, in order to find evidence of this financial integration theory, we should find a negative coefficient of the interaction between financial integration and the SOE's interest rate reaction. This means that, in our sample of large economy vs small open economies, we do not find empirical evidence of the mechanisms proposed by KPP.

These results show the potential that our structural and flexible index provides: we have been able to measure a mechanism which is crucial to test for the empirical validity of a well-known theoretical mechanism.

Which theories, however, could be able to explain the results behind our empirical test? Proposing a novel financial integration mechanism exceeds the scope of this article and is left for future research. But we can discuss what these results mean. Our results tell us that there is some evidence that when two countries (US and an SOE) are more financially integrated and there is a positive shock in the American output, a positive response of long-term interest rates is associated with higher business cycle co-movement. This means that, in our sample of country-pairs, there is a prevalence of higher long-term interest rates combined with higher growth, which could point to an expectations mechanism under work [41], rather than a Global Banking drainage mechanism.

[41] Higher-then-expected growth in the US make individuals more optimistic about future growth prospects of SOE, thus resulting in higher growth today

5 Conclusion

This article contributes to the literature of international economics and, more specifically, international business cycle co-movement, in two ways.

The first contribution is that we propose and implement a new measurement of business cycle co-movement - which can assume multiple formats, according to the specific needs of the research question. The reason for proposing this new measuring method is that we believe that current measurements are unsatisfactory due, mainly, to the lack of a structural form and due to its limited reach in scope. By implementing this index, we are able to assess richer information on business cycle co-movement involving many economic variables such as output, inflation, interest rates and exchange rates.

These benefits do not come for free, though. In order to reach these structural and flexible indices, we have to implement stricter assumptions to our sample - which must be restricted to pairs of large economies and small open economies - and to the ordering of the economic variables. These assumptions, though relatively strong, are usual in the literature and do not pose unrealistic limitations over our dataset.

In order to build these indices, we combine the estimation of a time-varying bayesian VAR with the block- exogeneity hypothesis and explore the time-varying structure of the impulse response functions to build intuitive time-varying measurements of structurally-identified impacts.

The second main contribution is that we apply this index to test for the empirical validity of a well-known theoretical model. This model, presented in the seminal work of Kalemli-Ozcan, Papaioannou and Perri(2013) links financial integration and business cycle co-movement through global banks and interest rate responses to productivity and financial[42] shocks. Our empirical exercise was only possible due to the flexibility provided by our newly proposed index, which allowed us to identify different sources of shocks and, consequently, measure the impacts of these shocks on different variables.

We do not find evidences of the proposed mechanisms in Kalemli-Ozcan, Papaioannou and Perri (2013) in our sample - which is composed of both developed and developing countries. Our findings, however, open the way for further research on the determinants of business cycle co-movement, a relevant and dynamic branch of the international economics literature.

[42] Or banking

References

Allen, F., Gale, D.: 2000, Financial Contagion. *Journal of Political Economy* 108, 1-33.

Backus, D., Kehoe, P. and Kydland, F.: 1992, International Real Business Cycles. *Journal of Political Economy* 100(4), 745-775.

Baxter, M. and M. A. Kouparitsas: 2005, Determinants of business cycle synchronization: a robust analysis. *Journal of Monetary Economics* 52(1), 113157.

Calderón, C., A. Chong, and E. Stein: 2007, Trade intensity and business cycle synchronizatio: Are developing countries any different?. *Journal of International Economics* 71(1), 2-21.

Calvo, G. and Mendoza, E.:2000, Rational Contagion and the Globalization of Security Markets. *Journal of International Economics* 51(1), 79-113

Caporin, M., Pelizzon, L., Ravazzolo, F. and Rigobon, R.: 2013, Measuring Sovereign Contagion in Europe. *NBER Working Paper Series*, n. 18741.

Carter, C. K. and R. Kohn: 1994, On Gibbs sampling for state space models. *Biometrika* 81(3), 541553.

Cesa-Bianchi, A., Imbs, J. and Saleheen, J.: 2019, Finance and Synchronization. *Journal of International Economics*, 116, 74-87.

Cetorelli, N. and Goldberg, L.: 2012, Banking globalization and monetary transmission. *Journal of Finance* 67, 1811-1843.

Chari, V. and Kehoe, P.: 1999, ”Herds of Hot Money”.*Journal of Political Economy* 111(6), 1262-1292.

Clark, T. E. and E. van Wincoop: 2001, Borders and business cycles. *Journal of International Economics* 55(1), 5985.

Cogley, T. and T. Sargent: 2001, Evolving Post-World War II U.S. Inflation Dynamics. *NBER Macroeconomics Annual* pp. 331372.

Cogley, T. and T. Sargent: 2005, Drift and Volatilities: Monetary Policies and Outcomes in the Post WWII U.S. *Review of Economic Dynamics* 8(2), 262302.

Coppola, A., Maggiori, M., Neiman, B. and Schreger, J.: 2020, Redrawing the Map of Global Capital Flows: The Role of Cross-Border Financing and Tax Havens. *Becker Friedman Institute Working Paper*

Cushman, D. O. and T. Zha: 1997, Identifying monetary policy in a small open economy under exible exchange rates. *Journal of Monetary Economics* 39(3), 433448.

Del-Negro, M. and F. Obiols-Homs: 2001, Has Monetary Policy Been so Bad That it is Better to Get Rid of it? The Case of Mexico. *Journal of Money, Credit and Banking* 33(2), 404433.

Del Negro, M. and Primiceri, G.: 2015, Time Varying Structural Vector Autoregressions and Monetary Policy: A Corrigendum. *The Review of Economic Studies* 82(4), 1342-1345

Dooley, M. and M. Hutchison: 2009, Transmission of the U.S. subprime crisis to emerging markets: Evidence on the decoupling–recoupling hypothesis. *Journal of International Money and Finance*, 28, 1331 - 1349.

Forbes, K. and R. Rigobon: 2001, Measuring Contagion: Conceptual and Empirical Issues. *In Claessens S., Forbes K.J. (eds) International Financial Contagion.* Springer.

Frankel, J. and Rose, A.: 1997, Is EMU more justiable ex post than ex ante?. *European Economic Review* 41(3-5), 753760.

Gerlach, S. and Smetts, F.: 1995, Contagious Speculative Attacks *European Journal of Political Economy* 11(1), 45-63.

Giannone, D., Lenza, M. and Reichlin, L.: 2008, Business Cycles in the Euro Area. *Europe and the Euro, Chicago University Press*

Goldstein, M., Kaminsky, G. and Reinhart C.: 2000, Assessing Financial Vulnerability: An Early Warning System for Emerging Markets. *Institute for International Economics* 79(6)

Guillén, D., Luporini, V. and Velloso, J.: 2017, Dominância Fiscal via Teoria Fiscal do Nível de Preços: Análise Empírica por Dados em Painel. *Dissertação de Mestrado (PPGE-UFRJ)*

Haan J., Jacob, J., and Mink, M.: 2007, Measuring Synchronicity and Co-movement of Business Cycles with an Application to the Euro Area. *CESifo Working Paper Series*, n. 2112.

Heathcote, J. and Perri, F.: 2004, Financial Globalization and Real Regionalization, *Journal of Economic Theory* 119, 207-243.

Imbs, J. 2006: The real effects of financial integration, *Journal of International Economics* 68, 296-324.

Kalemli-Ozcan, S., Papaioannou, E. and Peydró, J.: 2013, Financial Regulation, Financial Globalization, and the Synchronization of Economic Activity. *The Journal of Finance* 68(3), 1179-1228.

Kalemli-Ozcan, S., Papaioannou, E. and Perri, F.: 2013, Global Banks and Crisis Transmission. *Journal of International Economics* 89(2), 495-510.

Kaminsky, G. and Reinhart, C.: 2000, On Crises, contagion and confusion. *Journal of International Economics* 51, 15-38.

Kollman, R., Enders, Z. and and Müller, G.: 2011, Global banking and international business cycles. *European Economic Review*, 55(3), 407-426.

Koop, G. and D. Korobilis: 2009, Bayesian Multivariate Time Series Methods for Empirical Macroeconomics. Working Paper Series 47-09, *Rimini Centre for Economic Analysis*. 21

Kose, M. A., E. S. Prasad, and M. E. Terrones: 2003, How Does Globalization Affect the Synchronization of Business Cycles?. *American Economic Review* 93(2), 5762.

Kose, A., Otrok, C. and Prasad, E: 2008, Global business cycles: Convergence or decoupling?, *NBER Working Paper Series* 14292.

Longstaff F., Pan, J., Pedersen ,L. and Singleton, K.: 2011, How Sovereign Is Sovereign Credit Risk?. *American Economic Journal: Macroeconomics* 3 (April 2011): 75–103.

Morgan, D., Rime, B. and Strahan, P.: 2004, Bank Integration and State Business Cycles. *Quarterly Journal of Economics* 119, 1555-1585.

Otto, G., Voss, G., and Willard, L.: 2001, Understanding OECD output correlations. *Reserve Bank of Australia - Research Discussion Paper* 2001(05)

Pan,J. and Singleton, K.: 2008, Default and Recovery Implicit in the Term Structure of Sovereign CDS Spreads. *The Journal of Finance*, v. 63, n. 5.

Peek, J. and Rosengreen, E.: 2000, Collateral Damage: Effects of the Japanese Bank Crisis on Real Activity in the United States. *American Economic Review* 90, 30-45.

Perri, F. and Quadrini, V.: 2018, International Recessions. *American Economic Review* 108(4-5), 935-984.

Primiceri, G.: 2005, Time Varying Structural Vector Autoregressions and Monetary Policy. *The Review of Economic Studies* 72(3), 821852.

Rigobon, R.: 2003, Identification Through Heteroskedasticity. *The Review of Economics and Statistics*, 85(4), 777-792.

Rigobon, R.: 2019, Contagion, Spillover and Interdependence. *Economía*, 19(2), 69-99.

Sims, C. A. and Zha, T. :1998, Bayesian Methods for Dynamics Multivariate Models. *International Economic Review*, 39, 949-968.

Smith, M and Kohn, R: 2002, Parsimonious Covariance Matrix Estimation for Longitudinal Data. *Journal of the American Statistical Association*, 97, 1141-1153.

Van Rijckeghem, C. and Weder, B.: 2003, Spillovers through banking centers: A panel data analysis of bank flows. *Journal of International Money and Finance* 22, 483-509.

Yeyati E. and Williams, T.: 2012, Emerging economies in the 2000s: Real decoupling and financial recoupling. *Journal of International Money and Finance*, vol. 31, issue 8, 2102-2126.

A Appendix - Images

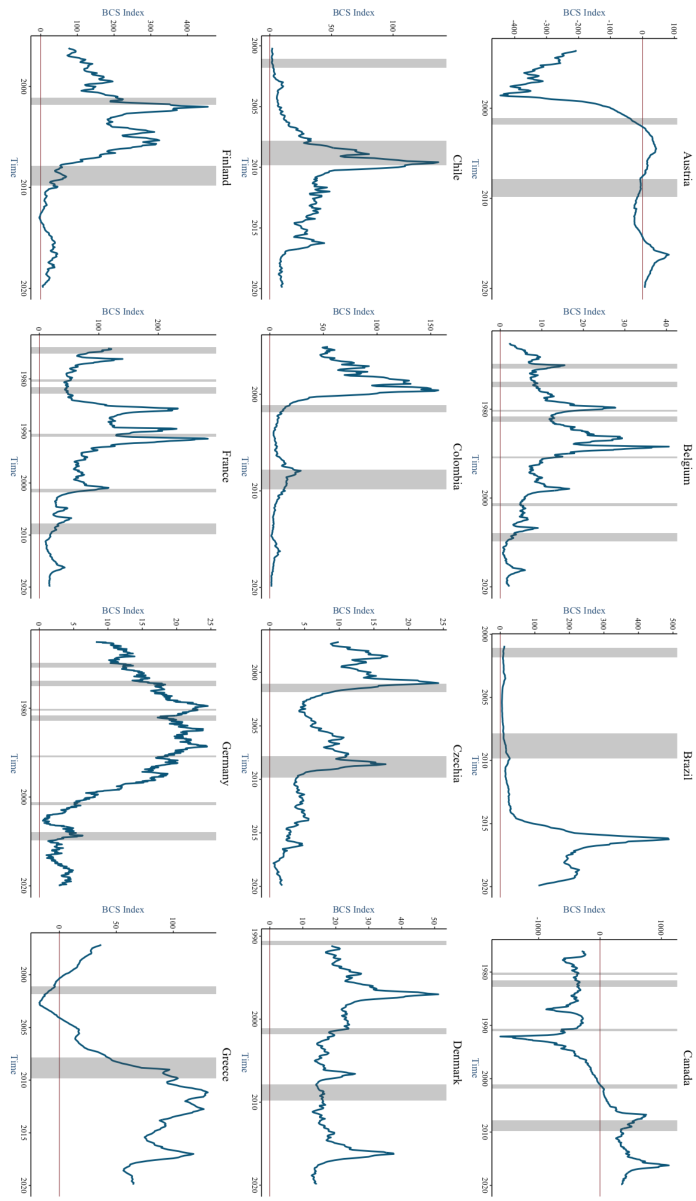

Figure 3: The graphs above represent the full estimation of our aggregated index for the first half of our sample (in alphabetical order).

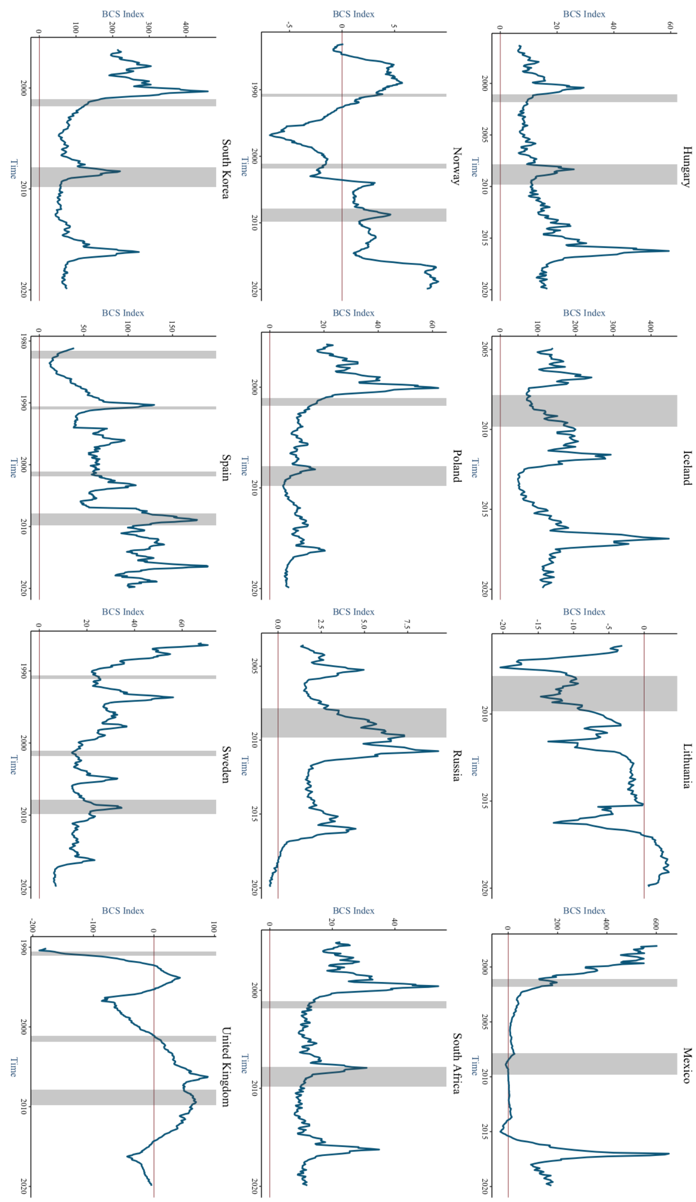

Figure 4: The graphs above represent the full estimation of our aggregated index for the second half of our sample (in alphabetical order).

B Appendix - Forbes and Rigobon's critique

In their 2001 paper, Forbes and Rigobon, although working in a somehow different context - one that focuses more on financial aspects of the co-movement literature known as contagion - showed that, in a framework of multiple and simultaneous equations, the simple existence of a simultaneity bias or hidden variable bias combined with heteroskedasticity in the shocks of one of the equations could result in a misleading time-varying bias on the Pearson correlation coefficient. And they go even further, this critique also extends to Vector Auto Regressions and Least Squares estimators. As we believe this is a crucial point for the literature, we are going to spend the next few lines on how this works and why it could, potentially, affect the empirical results in non-negligible ways. For this, we are going to borrow heavily from Rigobon(2019). [43]

Suppose that our goal is to find the Pearson correlation coefficient between the GDPs of two different countries - e.g. Germany and France. Lets also suppose that, structurally, the GDPs of those countries follow the simultaneous system below:

$$Y_t^{FR} = \beta Y_t^{GE} + \varepsilon_t$$

$$Y_t^{GE} = \alpha Y_t^{FR} + \eta_t$$

where Y_t^{FR} and Y_t^{GE} are, respectivelly, the French GDP in period t and German GDP in period t. ε_t and η_t are idiosyncratic shocks to the French and German GDPs, respectively. Although this is a stylized example [44], it is probably not too far from reality, once France and Germany both have economies of roughly the same size, greatly interrelated and probably also highly dependent of each other. Lets, then, take a moment to understand what the parameters β and α mean here. If β [45] is high, then an exogenous shock to the German GDP in period t will be strongly transmitted to the French GDP in period t. This means that, the higher β, the stronger is the co-movement between French and German GDPs. So, our parameters of interest here are both α and β, which in this context would represent the co-movement between the two GDPs [46].

Supposing that the above system of equations is true, calculating a variance-covariance matrix between

[43] For a more in-depth discussion of the matter and for examples of the same problem regarding OLS, Probit and Logit regressions, Rigobon (2019) and Forbes and Rigobon (2001) are good starting points.

[44] One should note that there are not any lags or other variables here. A correct model would probably need refinement, but we are following Rigobon in keeping the example as clear and simple as possible.

[45] Analogous for α

[46] It is also important to note that we are looking at the simplest example where both α and β are constant over time, but they definitely could change over time in a more complex case. As a matter of fact, we would expect them to change over time if we believe that the co-movement of countries vary according to fundamental characteristics of their economies. We are going to extensively go through that subject in section 4.

the observed values of Y_t^{FR} and Y_t^{GE} would actually leads us to the matrix below:

$$\begin{pmatrix} var(Y_t^{FR}) & cov(Y_t^{FR}, Y_t^{GE}) \\ cov(Y_t^{GE}, Y_t^{FR}) & var(Y_t^{GE}) \end{pmatrix} = \frac{1}{(1-\alpha\beta)^2} \begin{pmatrix} \sigma_{\varepsilon,t}^2 + \beta^2\sigma_{\eta,t}^2 & \alpha\sigma_{\varepsilon,t}^2 + \beta\sigma_{\eta,t}^2 \\ \alpha\sigma_{\varepsilon,t}^2 + \beta\sigma_{\eta,t}^2 & \alpha^2\sigma_{\varepsilon,t}^2 + \sigma_{\eta,t}^2 \end{pmatrix}$$

Where $\sigma_{\eta,t}^2$ is the variance of η_t in period t and $\sigma_{\varepsilon,t}^2$ is the variance of ε_t in period t. The Pearson correlation coefficient is $\rho = \frac{cov(x,y)}{\sqrt{var(x)}\sqrt{var(y)}}$ and, as we know the covariance and variances from the matrix above, we also know that, by calculating the correlation between French and German GDPs, we would actually be calculating the expression below:

$$\rho_t = \frac{cov(x_t, y_t)}{\sqrt{var(x_t)}\sqrt{var(y_t)}} = \frac{\alpha + \beta\theta_t}{\sqrt{(1+\beta^2\theta_t)(\alpha^2+\theta_t)}}$$

where

$$\theta_t = \frac{\sigma_{\eta,t}^2}{\sigma_{\varepsilon,t}^2}$$

Where θ_t is the ratio between the variances of the shocks to each GDP in period t.

So, lets take a moment to understand the expression above: Suppose that a researcher wants to find α and, in order to do that, he builds a co-movement index by calculating correlations between French and German GDPs using a rolling window. This researcher would end up with a time series of ρ_t observations. As we built the example, we know [47] that - once the GDPs of the two countries follow a multiple equations setting where both GDPs affect each other simultaneously and are also subject to exogenous shocks over time - what the researcher is actually measuring is not α, but, instead, $\frac{\alpha+\beta\theta_t}{\sqrt{(1+\beta^2\theta_t)(\alpha^2+\theta_t)}}$.

There are two obstacles separating the researcher from his goal. The first one is that there is a simultaneity bias that was not taken into consideration. This simultaneity bias can be seen by the presence of β on the expression above. This does not come as a surprise once it is standard in the literature of simultaneous equations. The second obstacle is θ_t, which represents the relative heteroskedasticity in the shocks. This is the crucial point. Suppose that, for any reason, the exogenous shock over the French GDP becomes much more volatile (because of a crisis in the French economy, for example) while the variance of the shock over the German GDP does not change [48]. This change in the variance of the French GDP's shock will result in a larger observed Pearson correlation coefficient ρ_t even though the parameters of interest α and β have

[47] But the researcher does not

[48] Or does change, but in a different proportion

not changed [49] at all. In practice, this means that, in the presence of simultaneity [50] or omitted variable[51] bias, heteroskedasticity turns the bias into a misleading time-varying bias. The problem with this is that we may mistakenly think that we found fluctuations in structural parameters when, in reality, it was only a fluctuation in the variance of shocks.

This means that, in order for the literature to be able to track how the co-movement of business cycles actually takes place, it has to find a measurement that has at least one of the following two characteristics: (i) it is not affected by heteroskedasticity; (ii) it takes heteroskedasticity into consideration when calculating such measurement [52].

[49] In this simple example, they are constant over time, but in reality they can possibly change over time. Understanding the determinants of these changes is actually the whole point of the determinants of the co-movement literature.

[50] If β is zero, then heteroskedasticity only affects the precision of the coefficient, i.e., heteroskedasticity will only bring inefficiency, which is standard.

[51] Forbes and Rigobon(2001)

[52] Or also (iii) it avoids any biases - but, as careful as a researcher may be, no one can be completely sure that there are no biases at all in a real-world estimation.

C Appendix - Brief description of Primiceri (2005) methodology

The model in Primiceri (2005) is a Bayesian Vector auto regression where both the coefficients and the variance-covariance matrix are allowed to change over time following a random walk. In this appendix, we are going to briefly go through the main structure of the model so that the reader is able to understand the reasons that lead us to choose this model specifically.

Let there be a VAR with n equations and s lags. Here, for the sake of clarity and simplicity, we show an example with only 2 equations and 2 lags.

$$\underbrace{\begin{bmatrix} 1 & a_{12,t} \\ a_{21,t} & 1 \end{bmatrix}}_{A_t} \underbrace{\begin{bmatrix} y_{1,t} \\ y_{2,t} \end{bmatrix}}_{y_t} = \underbrace{\begin{bmatrix} c_{1,t} \\ c_{2,t} \end{bmatrix}}_{c_t^*} + \underbrace{\begin{bmatrix} b_{11,1,t} & b_{12,1,t} \\ b_{21,1,t} & b_{22,1,t} \end{bmatrix}}_{B_{1,t}^*} \underbrace{\begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \end{bmatrix}}_{y_{t-1}} + \underbrace{\begin{bmatrix} b_{11,2,t} & b_{12,2,t} \\ b_{21,2,t} & b_{22,2,t} \end{bmatrix}}_{B_{2,t}^*} \underbrace{\begin{bmatrix} y_{1,t-2} \\ y_{2,t-2} \end{bmatrix}}_{y_{t-2}} + \underbrace{\begin{bmatrix} \sigma_{1,t} & 0 \\ 0 & \sigma_{2,t} \end{bmatrix}}_{\Sigma_t} \underbrace{\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{bmatrix}}_{\varepsilon_t}$$

where all of the variables with the t subscript are allowed to change over time. We then set the hypothesis that $a_{12,t}$ is zero - which means that the first equation is not contemporaneously affected by the second equation - in order to be able to identify the structural shocks. After that, we multiply both sides of the equation by the inverse of the now lower-triangular matrix A_t: A_t^{-1}. This leaves us with:

$$y_t = \underbrace{A_t^{-1} c_t^*}_{c_t} + \underbrace{A_t^{-1} B_{1,t}^*}_{B_{1,t}} y_{t-1} + \underbrace{A_t^{-1} B_{2,t}^*}_{B_{2,t}} y_{t-2} + A_t^{-1} \Sigma_t \varepsilon^t$$

where the underbraces only refer to a change in notation to make it easier going forward. Until here, everything except for the time subscripts is standard. We now proceed to stacking the vector of intercepts and the matrices of coefficients in a $10x1$ vector. This process is done by first stacking the constants, then moving to the first row of the first-lag coefficient matrix, second row of first-lag coefficient matrix, first row of the second-lag coefficient matrix and, finally, second row of the second-lag coefficient matrix. Such process would go down all of the rows of all of the lag matrices that we had in our model. This new $10x1$ vector of stacked coefficients will be called B_t. This vector would take the following form in our example:

$$B_t' = \begin{bmatrix} c_{1,t} & c_{2,t} - a_{12,t}c_{1,t} & b_{11,1,t} & b_{21,1,t} - a_{21,t}b_{11,1,t} & b_{12,1,t} & b_{22,1,t} - a_{21,t}b_{12,1,t} & b_{11,2,t} & b_{21,2,t} - a_{21,t}b_{11,2,t} & b_{12,2,t} & b_{22,2,t} - a_{21,t}b_{12,2,t} \end{bmatrix}$$

And the system of equations in matrix form would be, then, written as:

$$y_t = X_t' B_t + A_t^{-1} \Sigma_t \varepsilon_t$$

where $X_t' = \begin{bmatrix} 1 & y_{1,t-1} & y_{2,t-1} & y_{1,t-2} & y_{2,t-2} \end{bmatrix} \otimes I_n$.

It is also useful to define $a_t = \begin{bmatrix} a_{21,t} \end{bmatrix}$ and $\sigma_t = \begin{bmatrix} \sigma_{1,t} \\ \sigma_{2,t} \end{bmatrix}$. One should note that a_t is the vector composed of every element in matrix A_t which is different than 0 or 1, in other words, it is a vector composed of all of the contemporaneous coefficients. With n endogenous variables (n equations), a_t would be a vector with $\frac{n^2-n}{2}$ rows and 1 column.

We are left, then, with three column-vectors: B_t, a_t and σ_t, which are the vector of the constants and lagged coefficients of the reduced form, the vector of contemporaneous coefficients and the vector of the variances of the structural shocks. These three vectors are the ones that will be allowed to change over time following a random walk. It is worth noting here that this modelling choice comes with the benefit of reducing the number of hyper-parameters to be estimated. It is, in theory, possible to change the process and use, for example, an AR(q) process. The number of parameters to be estimated, however, is so large that this would be too costly given the somehow short time-series sample available for most countries. Although we are aware that a random walk has no bounds, this still seems to be the best modelling choice once it allows us to focus on permanent shifts and avoids the huge number of parameters to be estimated, as discussed above.

In the end, the three vectors above are modeled as:

$$B_t = B_{t-1} + \upsilon_t$$

$$a_t = a_{t-1} + \xi_t$$

$$\sigma_t = \sigma_{t-1} + \eta_t$$

We follow Primiceri (2005) and Del Negro and Primiceri (2015) in the choice of Priors and estimation.

D Appendix - Literature review on the impact of financial integration on business cycle co-movement

The goal of this section is to provide the reader with a concise overview of the evolution of the theoretical and empirical literatures on the relation between financial integration and business cycle co-movement. Although the evolution of both literatures was based on constant feedbacks from each other - thus making it hard to define a clear distinction between the two - we are going to treat them separately in this section in the benefit of clarity.

It is important to note, however, that the interest in the determinants of the co-movement of the business cycles began with questions regarding trade and co-movement. The interest in financial integration as a determinant of co-movement arose specially after the series of financial crises that shook the developing world in the 90's: Mexican crisis (1994), Asian crisis (1997), Russian crisis (1998) and Brazilian crisis (1999). The interest in this literature gained renewed attention once developed countries were in the center of the crisis: dot-com crash (2001), the Great Recession (2008) and the Euro crisis (2010). After a short period of interregnum, this literature has resurfaced again in the late 2010's and begining of 2020's.

D.1 Theoretical Literature

The theoretical literature on the relation between business cycle co-movement and financial integration has its origins in two separated strands of the economic literature: international economics field and banking/finance field. On the one hand, the international economics literature tended to focus more on productivity shocks in RBC models, which led to divergent cycles between a pair of financially integrated countries. On the other hand, the banking/finance literature focused on banking models with financial shocks, which led to convergent cycles between a pair of financially integrated countries. Thus, both literatures were able to explain different mechanisms and, after a few years, these strands of the economic literature merged in the form of DSGE models that included both types of shocks, leading to ambiguous results - depending on the kind of shock that hit the economy, more financial integration could lead to either more or less synchronized economic cycles.

It is fair to state that the seminal article or founding basis for the international economics side of this literature is Backus, Kehoe and Kydland (1992). This is an early Real Business Cycle model that featured a pair of countries that were both subject to productivity shocks. If one country had a positive productivity shock, than the marginal product of labor would go up, which would also make the supply of labor go up and, consequently, would diverge capital from the unaffected country to the affected country. This mechanism would make the affected country's production go up and the unaffected country's production go down, thus making the business cycles less coincident between the pair of countries.

On the banking/finance strand of the literature, Allen and Gale (2000) built a model where a set of banks operated in one of two countries. In this model, all of the banks had international interbank deposits, which were affected once a domestic bank was hit by a negative or positive financial shock. This shock affected the domestic banks' interbank deposits abroad which, in turn, ended up affecting the foreign banks as well. One should note that the mechanism here implies that a negative shock to a domestic bank is reflected in a negative shock to foreing banks. Now, both foreign and domestic banks had smaller room for credit, which lead to a fall in output in both countries. Thus, this mechanism lead to a higher co-movement of the cycles between two highly integrated countries.

The articles above, although still using different frameworks, set the tone for the articles that came after them. Morgan, Rime and Strahan (2004) built a banking model where both higher or lower business cycle co-movement between two regions could result from higher financial integration. This article differentiated between shocks to the collateral of firms in one region and shocks to the banking sector - which operated in both regions when there was a high level of financial integration. A negative shock on the collateral of a region's firms would result in a set of firms that were able to receive less credit and, consequently, produce less, while freeing credit to be lent to firms in non-affected regions. This would result in less coincident products between regions if there was more financial integration. On the other hand, if there was a shock to a certain region's banks capital, then those banks would be less able to supply credit, thus rearranging its portfolio and providing less credit to both regions. This would result in more coincident products between regions if there was more financial integration. This was, to the best of our knowledge, the first article that was able to find ambiguous co-movement consequences of the financial integration by combining two kinds of shocks in a single framework.

Now moving to a DSGE framework, some articles were also able to combine two kinds of shocks to emulate ambiguous consequences to the financial integration. In this context, following Backus, Kehoe and Kydland (1992), the shocks affecting firms are usually more similar to a productivity shock. Regarding the banking/financial shock, though, it is usually some kind of variant of a credit shock - which restricts the amount of credit that a bank is able to provide. See Perri and Quadrini (2018) and Kalemli-Ozcan, Papaioannou and Perri (2013). The mechanism, though, is somehow similar to what we have already described: a lower domestic product caused by negative shocks to domestic firms result in credit being diverted to the foreign country, thus flooding the foreign country with credit and making its interest rates lower and product, higher. A lower domestic product caused by negative shocks to domestic (but financially integrated) banks result in credit being dried out from all of the financially integrated countries, thus making the foreign country's interest rate higher and product, lower. In DSGE models, in order for the above theoretical mechanism to be in place, the behavior of interest rates is of vital importance. The interest rates, or the cost of capital, are the means through which banking and productivity shocks are transmitted to other economies.

It is important no note, however, that there is also a strand of this literature that focuses on the inverse causation between financial integration and business cycle co-movement. The idea behind this is that economies with uncorrelated cycles represent good investment oportunities from a diversification perspective. For that, see Heathcote and Perri (2004).

D.2 Empirical Literature

The empirical literature on the impact of financial integration on cycles co-movement faces three main challenges that have been tackled with variate success over time. The first challenge concerns a measurement for financial integration. This is probably the least controversial of the three once a considerable agreement on the subject has been achieved on recent research endeavours. The second one is how to measure business cycle co-movement. This is, in contrast to the first challenge, an open question in the literature. As we are going to see throughout this section, there are multiple trade-offs between different measurements, caused by some critiques of which the most famous one seems to be Forbes and Rigobon (2001). The final challenge concerns the direction of causation between the two variables in question. Does financial integration cause business cycle co-movement or is it the other way around? Although some papers have been able to find ingenious ways to mitigate this obstacle, this remains an interesting open - or not as closed as desired - question in the literature. In the remainder of this subsection, we are going to go through some of the papers and solutions in the literature for each of these problems.

D.2.1 Measuring financial linkages

Beginning with the first challenge - the financial integration measurement - the literature has been consistently using bilateral financial linkages obtained from a BIS database called "International Locational Banking Statistics". For that, see Kalemli-Ozcan, Papaioannou and Peydró (2013) and Cesa-Bianchi, Imbs and Saleheen (2019). This database consolidates informations on banking financial assets and liabilities in other countries. There are quarterly data on reporting country's banks claims over counter-party countries' banks and reporting country's banks liabilities over counter-party countries' banks. The usual banking integration measurement results from adding the logs of the normalized [53] assets and liabilities from both sides of the country-pairs. In order to illustrate this measurement, we replicate below the expressions used in Cesa-Bianchi, Imbs and Saleheen (2019) for the financial integration between countries i and j, normalized by population and GDP, respectively:

$$K_{ij,t}^{pop} = \frac{1}{4}\Big[\ln\Big(\frac{A_{ij,t}}{P_{i,t}+P_{j,t}}\Big) + \ln\Big(\frac{L_{ij,t}}{P_{i,t}+P_{j,t}}\Big) + \ln\Big(\frac{A_{ji,t}}{P_{i,t}+P_{j,t}}\Big) + \ln\Big(\frac{L_{ji,t}}{P_{i,t}+P_{j,t}}\Big)\Big]$$

$$K_{ij,t}^{gdp} = \frac{1}{4}\Big[\ln\Big(\frac{A_{ij,t}}{Y_{i,t}+Y_{j,t}}\Big) + \ln\Big(\frac{L_{ij,t}}{Y_{i,t}+Y_{j,t}}\Big) + \ln\Big(\frac{A_{ji,t}}{Y_{i,t}+Y_{j,t}}\Big) + \ln\Big(\frac{L_{ji,t}}{Y_{i,t}+Y_{j,t}}\Big)\Big]$$

where $A_{ij,t}$ denotes the claims on country j held by banks located in country i and $L_{ij,t}$ denotes the liabilities on country j held by banks located in country i. As expected, $Y_{j,t}$ is the GDP of country j at period t and $P_{j,t}$ is the population of country j at period t.

Two aspects of these indices should be briefly discussed before we proceed to the next empirical literature challenge. First, although the indices above are restricted to banking linkages, there are not many alternatives that also consider other classes of assets[54]. The second aspect is that there is a discussion about what exactly would constitute a financial linkage between, for example, Brazil and the United States. The reason for this discussion is that many US claims on Brazilian firms are actually held on third-countries, usually tax-heavens, such as Cayman Islands. Although working with securities, Coppola, Maggiori, Neiman and Schreger (forthcoming) find that these channels are probably non-negligible and a new and better index may be available in the near future. Further research on this area looks like a fruitful path in the upcoming years.

D.2.2 Measuring the co-movement of the business cycle

This topic is appropriately discussed in the main body of the article, so we'll only say that measuring the co-movement of business cycles is a big challenge that the literature is still trying to tackle. Although there is not a clear better index, economists are trying to choose and adapt the ones that are more appropriate for each empirical exercise, given the trade-offs that we pointed out and also many others which transcend the scope of this article. In the empirical section, proposed a novel index of our own, one that we believe is more appropriate to our setting and to the test that we intend to execute.

[53]Normalization over total population of the country-pair or over total GDP of the country-pair

[54]Cesa-Bianchi, Imbs and Saleheen (2019)

D.2.3 Direction of causation between financial integration and business cycle co-movement and some other findings

After considering the two previous challenges and its limitations, the literature has been trying to answer how financial integration affects the co-movement of business cycles between two countries. Usually, though, it is not easy to identify the direction of causation between those two variables.

In the absence of straightforward ways of identifying the causation, some early articles focused more on finding evidence of the correlation between those two variables, usually finding evidence of a positive correlation (i.e., with more financial integration comes more cycle co-movement). Some examples are: Imbs (2006), Otto, Voss and Willard (2001), Peek and Rosengren (2000), Kaminsky and Reinhart (2000), Van Rijckeghem and Weder (2003), Cetorelli and Goldberg (2012). One article, in particular, has found an ingenious way of empirically answering this question. By exploiting the timing of implementation of financial harmonization rules in EU countries, Kalemli-Ozcan, Papaioannou and Peydró (2013) were able to find evidence that the causation goes from financial integration to cycles co-movement. Their article was also one of the first to find evidence that financial integration was actually negatively correlated with output co-movement. After the publication of this article, the subsequent literature sometimes refer to it as a supporting evidence of the direction of causation.

Kalemli-Ozcan, Papaioannou and Perri (2013) find that, during normal times, financial integration and business cycle co-movement seem to be negatively correlated. During crisis times, though, this correlation is non-negative and, sometimes, even positive. It was based on these findings that they proposed the theoretical model that we are going to go through on the next Appendix. Cesa-Bianchi, Imbs and Saleheen(2019) find that the correlation between integration and co-movement seems to be negative in response to common-shocks, but positive in response to country-specific shocks.

E Appendix - The KPP theoretical model

In this section, we are going to present a theoretical model of the relation between financial integration and business cycles co-movement. This is the same model as in Kalemli-Ozcan, Papaioannou and Perri (2013), which is similar in spirit to Kollman, Enders and Müller (2011). This became one of the standard models in the literature to explain the mechanisms that may be in place concerning financial integration and co-movement. According to the authors, one of the (two) main goals of this model is to *"Precisely spell a causal link between financial integration and business cycle co-movement"*[55]. By doing this, the authors provide us with causal links between the model's variables which are testable, but which, to the best of our knowledge, could not be satisfactorily tested until now. Putting this model to test is the subject of section 4.

Here, for conciseness, our goal is that the reader is able to understand the main implications of the KPP model without diving into lesser relevant points to our discussion. For a full assessment of the model, please see the original article in Kalemli-Ozcan, Papaioannou and Perri (2013).

E.1 The economy - general framework

This is a model with two countries (Home and Foreign), two sectors ($i = 1, 2$) and only one good.

Sector 1 in each country is similar to a closed economy. In sector 1 in the Home country, for example, there are:

1. households that only work for firms in sector 1 in the Home country, that only consume the products produced by the firms from sector 1 in the Home country, that only receive dividends from firms from sector 1 in the Home country and that only save with banks in sector 1 in the Home country;

2. firms that only hire workers from sector 1 in the Home country, that only produce for households from sector 1 in the Home country, that only pay dividends to households from sector 1 in the Home country and that only borrow from banks from sector 1 in the Home country;

3. banks that only take deposits (savings) from households in sector 1 in the Home country and that only lend to firms in sector 1 in the Home country.

It is exactly analogous for sector 1 in the foreign country.

Sector 2 in each country, on the other hand, looks like sector 1 except from the fact that:

[55] The other one is to *"show that our empirical findings can be used to identify sources of output fluctuations"*. We are going to go through this second goal in section 4.

1. banks are global, which means that they take deposits (savings) from households from sector 2 in both Home and Foreign countries and lend to firms from sector 2 in both Home and Foreign countries.

Until now, we have 2 independent sectors (sector 1 in the Home country and sector 1 in the Foreign country) and 2 financially integrated sectors (sector 2 in the Home country and sector 2 in the Foreign country). What binds the sectors in one country together are common productivity and banking shocks, which we are going to see in more detail shortly. Figure 1, from KPP, gives us a clear summary of the setting.

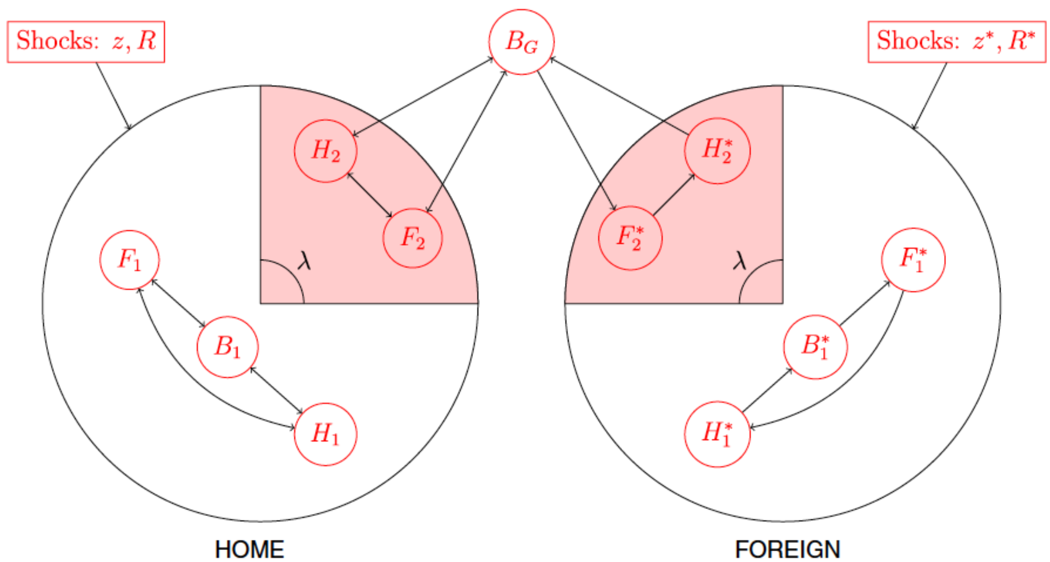

Figure 5: The economy

In the figure above, B_i represents banks in sector i, F_i represents firms in sector i and H_i represents households in sector i. An asterisk represents the Foreign country, while no asterisk is the notation for the Home country. As it becomes clear when looking at the figure, the only connection between the economies is through global banks and between sectors are the productivity (z) and banking [56] (R) shocks.

One of the main features of this model, and what makes it so easy to grasp, is λ which is objectively the relative size of the sectors, but which also represents the degree of financial integration between the two countries. If λ is big, then both countries are more dependent on global banks. If λ is small enough (near or equal to zero), then there is financial autarky and there will be no mechanism linking the two countries.

As we are going to see in more depth through the next pages, the intuition of the model's mechanism is the following (if λ is higher than zero):

- productivity shock: suppose that there is a positive productivity shock in the Home country. Then

[56] Or financial

two things will happen at the same time: (i) Home country's GDP will be higher and (ii) both sectors 1 and 2 will become more productive in the Home country relatively to sectors 1 and 2 in the foreing country. Because of the higher relative productivity, global banks will divert funds from the Foreign country to the Home country (the model's mechanism is not important now, we are just focusing on the intuition). This will make credit more expensive (higher interest rates) in the Foreign country, making it more expensive to produce, which will make the Foreign country's GDP go down. So, a productivity shock in the Home country makes the cycles co-move less through higher interest rates in the Foreign country.

- financial shock: now suppose that there is a negative financial shock in the Home country, which directly affects the global bank's ability to provide credit for both the Home and Foreign countries' firms . In this example, the global banks are going to reduce credit for both countries, which is going to make the cost of credit (interest rates) higher in both countries and will, in turn, make both countries' GDPs smaller. So, a financial shock makes the cycles co-move more through higher interest rates in both countries.

As the reader can now see, this is not only a really easy-to-grasp intuition, but the model is also one that effectively identifies two possible mechanisms through which the sign of the co-movement may be reversed over time. This is a game-changer for this literature once it allows for the - once apparently conflicting - empirical results of both positive and negative co-movements in GDPs to be consistent with economic theory in one simple framework.

The key to this switch lies in one fundamental variable, though: the reaction of the Foreign country's interest rates to the shock, whichever shock it may be[57]. We will go over this idea again both in the end of this section (when the mechanics of the model have been internalized) and in section 4, as this insight is fundamental for our empirical test.

E.2 Households

In this economy, there are 4 types of households: households in sector 1 in the domestic country, households in sector 2 in the domestic country, households in sector 1 in the foreign country, and households in sector 2 in the foreign country. Each of these types of sector/country pairs of households are actually composed of a continuum of homogeneous households which maximize their preferences (represented by their utilities) while taking into consideration their budget constraints.

[57]Productivity or financial

Each household in sectors 1 or 2 ($i = 1, 2$) of the domestic country maximizes:

$$E \sum_{t=0}^{\infty} \beta^t U(c_{it}, l_{it})$$

subject to a budget constraint:

$$c_{it} + \frac{D_{it+1}}{R_{it}} = w_{it} l_{it} + d_{it} + Dit$$

where c_{it} is the consumption of the household in sector i of the domestic country in period t, l_{it} is its labor effort, β is the discount factor which brings the utility in each period to present value, E is the expectation over time and all possible shock realizations, D_{it} is the deposit (savings) of the household on his sector's bank, R_{it} represents the interest rate on the deposits in the banks of sector i in the domestic country, w_{it} represents the wages for households in sector i of the domestic country and d_{it} represents the share of profits from sector i firms in the domestic country that goes to each household of that pair of sector/country. An analogous problem applies to the foreign country and its sectors.

The problem above is standard in the economic literature and shows that the households - in whichever sector or country - value consumption and have disutility in working. These households also pay for their consumption and savings by using their labor income ($w_{it} l_{it}$), previous savings brought from the previous period (Dit) and share of the sector's firms profits (d_{it}).

The household, then, must maximize its utility by choosing how much to work (l_{it}), consume (c_{it}) and save ($Dit + 1$) in each period. In order to be able to do that, he/she takes as given the interest rates on deposits (R_{it}), the wages (w_{it}), the dividends (d_{it}) and also the initial values of deposits (D_0).

A few things are worth noting here before we proceed to the analysis of the problems of firms and banks, though. First, each household can only work for and buy from firms in the same sector that he/she resides in. Second, each household in sector 1 can only deposit his/her savings on banks from sector 1, while households from sector 2 can only deposit his/her savings on Global Banks. Third, since all of the households in each sector/country pairs are homogeneous, each type of household will choose the same paths for all of the choice variables in this model. Forth, as we have already mentioned, while sectors 1 - in the home and foreign countries - work almost like a closed economy[58], sectors 2 in both countries have a particularity that they share common banks (known as Global Banks). For this reason, the interest rates on deposits will be the same for sector 2 in the home country and sector 2 in the foreign country.

[58] The only difference is that it shares two common shocks with sector 2 in each country - each of which we are going to see in the firms and banks subsections.

E.3 Firms

In this model, firms are restricted to operating in their own sector and country. Thus, firms can only sell their products to households in the same sector/country, they can only hire labor and capital from the same sector/country and they also can only borrow from banks that operate in the same sector/country [59]. Other than that, the problem of the firms here is also standard. The following discussion applies for a firm in any pair of sector/country.

Each firm has a production function that uses capital and labor as inputs and that is also subject to a productivity shock (which is common to both sectors in the same country). There is only one product in this economy.

While firms invest in and own their own capital, they have to borrow from banks in order to be able to pay for the workers' wages. This is standard in the literature when one wants to model a timing mismatch between paying workers and receiving the proceeds from sales. Here, however, the goal of this modeling choice is to make it mandatory for firms to depend on banks for production. This is crucial here because banking shocks (which we are going to see in the next subsection) must be able to affect the real economy. This modeling choice, then, allows for the real production to depend on banks. But once real world firms do depend on credit from banks in one way or another, this represents a realistic channel through which shocks may be transmitted.

So, firms' profits are the result of what is produced minus the cost of labor (including the costs of borrowing from banks) and investment:

$$d_{it} = e^{z_t} F(k_{it}, l_{it}) - R^e_{it} w_{it} l_{it} - x_{it}$$

where d_{it} is the profit to be maximized, z_t is the log of national productivity - which is the productivity shock in this model -, $F(\cdot)$ is a production function, R^e_{it} is the cost of borrowing from a bank and x_{it} represents investment in physical capital. Capital evolves according to:

$$k_{it+1} = (1 - \delta)k_{it} + x_{it} - \phi k_{it} \Big[\frac{x_{it}}{k_{it}} - \delta \Big]^2$$

where δ is the depreciation rate, the expression $k_{it} \Big[\frac{x_{it}}{k_{it}} - \delta \Big]^2$ represents the adjustment costs of investing and ϕ is the magnitude of such adjustment costs.

So, the problem of the firm is to choose how much work, capital to hire and how much to invest as to

[59] Which, in sectors 2, are Global Banks.

maximize future and current profits as in the expression below:

$$\max_{l_{it},k_{it},x_{it}} E \sum_{t=0}^{\infty} d_{it} Q_{it}$$

subject to the constraint of the evolution of capital and the exogenous productivity shock. $Q_{it} = \beta_t U_c(c_{it}, l_{it})$ and represents the price of profits in terms of consumption, i.e., the marginal rate of substitution of domestic consumers in sector i, which own the firms.

The problems of the firms in both sectors and countries are analogous, expect from the fact that in sector 2, the interest rates on borrowing from banks must be the same in both countries (once the same banks operate in both countries). So, $R^e_{2t} = R^{e*}_{2t}$, where the asterisk represents variables in the foreign country.

E.4 Banks

In this model, there is a continuum of competitive banks whose ultimate role is to intermediate funds between households (who deposit their savings) and firms (who need to borrow in order to produce). Banks in the financially separated sector only raise deposits from households in their own sector. Global banks - the ones in sector 2, raise deposits from households in sector 2 of both countries and also lend to firms in sector 2 of both countries. These funds, whether in sector 1 or 2, however, are not immediately channeled from households to firms. There is an intermediary step - that is crucial to the mechanism in this model - which is the financial market.

After receiving deposits from households, banks must allocate these deposits into two different assets: First, they can buy a risky (stochastic) asset with expected return R^m.[60] These banks, however, can only allocate up to a percentage of $\bar{m}$ of the available funds into this risky asset. In practice, however, this constraint will always be binding and banks will always allocate exactly $\bar{m}$% of the available funds into such asset [61]. After the realization of the risky asset, banks will then choose a lending rate (R^e) to firms which equates the amount of deposits left to be lent (which will be $1 - \bar{m}$) to the amount of credit that the firms want to borrow in order to be able to produce. This can be seen in the following equation for the banking sector within sector 1 of the Home country:

[60] One can think of R^m as a return on investing in a stock market index, for example. This brings the financial markets - and, specially, its shocks - into the model in a really simple way.

[61] This is more of a calibration outcome of the model than an intrinsic one. The reason for the authors to choose modelling banks with such a fixed percentage is to replicate the observed allocation of the real world banking sector, which is quite stable. To do so, they calibrate the mean of the returns to the risky asset in a way that banks always want to hold at least $\bar{m}$% of the deposits into such asset. For more details on the calibration, please check the original article.

$$(1-\bar{m})\frac{D_{1t}}{R_{1t}} = w_{1t}l_{1t}$$

The equation above must hold in equilibrium. And the variable that makes it possible for these two expressions to be equal is R_t^e, which will pinpoint - in the problem of the firm - how much credit the firm is willing to borrow. One should note that an analogous equation will also hold for sector 1 of the foreign country. However, in sectors 2 of both countries, the equation will be slightly different:

$$(1-\bar{m})\frac{(D_{2t}+D_{2t}^*)}{R_{2t}} = w_{2t}l_{2t} + w_{2t}^*l_{2t}^*$$

One should note, however - and this applies to both sectors and countries - that once there is a continuum of competitive banks, there will always be zero profits in the banking sector. Because of this characteristic and because there is a limited availability of deposits from the households, the realization of R^m - which is called the financial shock in this model - will impact directly on the lending rates R^e to the firms. Intuitively, the idea is that losses in the financial markets (represented by R^m) have to be compensated with higher R^e when lending to firms. This is reflected in the following equilibrium equations of the banking sector:

$$\bar{m}R_t^m + (1-\bar{m})R_{1t}^e = R_{1t} + \iota$$

$$\bar{m}\Big(\frac{1}{2}R_t^m + \frac{1}{2}R_t^m\Big) + (1-\bar{m})R_{2t}^e = R_{2t} + \iota$$

where the first equation refers to the banking equilibrium in the Home country's sector 1 - an analogous equilibrium will be in place in the Foreign country's sector 1 - and the second equation refers to the banking equilibrium in sector 2, which involves both countries.

The reader has probably already figured out where this is leading us to: When there is a positive shock to R^m, the bank will be left with a higher availability of funds to lend to the firms, which will result in lower lending rates that will allow firms to produce with lower costs - thus being able to produce more. An analogous mechanism works in the case of a negative financial shock. We will go through all of the mechanics of the impacts of shocks in much more detail on the next subsection.

Here, we can make a short digression: channeling funds from households to firms could be achieved without a banking sector, by letting households lend their savings directly to firms. However, as this will be a crucial point to the mechanism of the model, the choice of modeling a banking sector explicitly makes the channeling of funds much clearer.

E.5 Equilibrium

Here, we briefly report the equilibrium of the model following KPP. For a more complete description of the equilibrium, please check the original article.

The equilibrium in this model is a collection of sequences of the following variables, given an exogenous level of financial integration λ: R_{it}, R^*_{it}, w_{it}, w^*_{it}, R^e_{it}, R^{e*}_{it}, Q_{it}, Q^*_{it}, c_{it}, c^*_{it}, l_{it}, l^*_{it}, k_{it}, k^*_{it}, x_{it}, x^*_{it}, d_{it}, d^*_{it},D_{it}, D^*_{it}, L_{it} and L^*_{it} and a sequence of exogenous shock processes - z_t, z^*_t, R^m_t, R^{m*}_t such that, (i) given prices and shocks, households, firms and banks solve their problems in each period and sector; (ii) goods markets clear; (iii) financial intermediation markets also clear.

It is important to note, however, that the equilibrium above has no analytical solution.

E.6 Outcomes and mechanisms of the model

After the description of how the model works, we can now proceed to what matters most to our goal, which is understanding the authors' proposed dynamics and mechanisms between financial integration and business cycle co-movement. This subsection will work as an intuitive summary of the model and a discussion of the effects - as predicted by the KPP model - of financial integration on co-movement.

Before we begin the analysis of how each sector reacts to shocks, it is important to reinforce the fact that in any country (whether in sector 1 or 2), there are 2 possible shocks: a productivity shock - which hits the firms directly - and a financial (or banking) shock - which hits the banks directly. These shocks are always country-specific. There are no sector-specific shocks in this model. So, when a financial shock or a productivity shock hits country A, it will hit directly both sectors 1 and 2 of country A. The consequences and reverberations of these shocks, however, are different among sectors and, consequently, between countries that are more or less financially integrated. That is what we are going to go through in details in the remainder of this section.

As a short summary for the ease of understanding, in this model, households are not directly hit by any kinds of shocks, they only feel the consequences of these shocks through general equilibrium mechanisms. Firms, on the other hand, are directly hit by productivity shocks in their own country. Banks are directly hit by financial shocks in their own country if they are located in sector 1, but Global banks, which are located in sector 2 and operate in both countries, are directly hit by financial shocks in both countries.

E.6.1 Productivity shock

A productivity shock is a country-specific shock - i.e. common to both sectors in the country - that directly affects the productivity in the production function of firms. We are going to focus here on a productivity shock in the Home country.

E.6.1.1 Productivity shock and sector 1 in the Home country

Let's first focus on sector 1 in the Home country, the sector which is not financially integrated. A positive productivity shock will make all sector 1 firms more productive, which will result in a higher labor demand and higher investment - once both inputs will present higher marginal productivity. This will, in its turn, increase the product in this sector.

E.6.1.2 Productivity shock and sector 2 in the Home country

Now let's focus on sector 2 of the Home country. As in sector 1, a positive productivity shock will result in higher labor demand and higher investment, which will also increase the production. However, one should notice that, once the labor demand is higher, firms in sector 2 of the Home country will need to borrow a higher amount from banks - which are Global Banks. These banks raise deposits from households in both countries and the amount of these deposits is fixed before the shock. Once the Home-country firms in sector 2 are hit by productivity shocks, they will have to pay a higher interest rate in order to be able to absorb a higher share of the available funds from Global Banks. The equilibrium in time 0 will be, then, set with higher product in sector 2 of the Home country, but also with higher interest rates in sector 2 of the Home-country.[62]

E.6.1.3 Productivity shock and sector 2 in the Foreign country

The foreign country was not directly hit by the productivity shock in the Home country, so the productivity of foreign-country's firms stay the same both in sector 1 and 2.

However, as the sector 2 in the Foreign country shares the same banks with sector 2 in the Home country, it also shares the same interest rates. Once the impact of the shock in sector 2 in the Home country resulted in higher interest rates, sector 2 in the Foreign country will then see its cost of borrowing to hire labor rise as

[62] For the sake of clarity, we could note that the same mechanism works in sector 1, but it is not as important as the one in sector 2 because it does not affect the Foreign country, which we are going to see shortly.

well. This will make it much costlier for sector 2 firms in the Foreign country to produce, which will result in a lower production.

E.6.1.4 Productivity shock and sector 1 in the Foreign country

As sector 1 in the Foreign country is not hit by any shock and is completely isolated financially from the Home country, it is not affected at all by the productivity shock in the Home country.

E.6.1.5 Productivity shock and co-movement of the business cycles

Let's start this discussion by defining that the aggregate production of a country is the weighted average of the productions of its sectors, where the weight is given by the relative size of the sectors λ. Similarly, lets define the aggregate interest rate of a country as the weighted average of the interest rates of the two sectors.

Now, let's put together what we have learnt from the productivity shocks in the Home country: After a positive productivity shock in the Home country, there will be a higher aggregate production in the Home country (because the productions of both sectors were raised). After the same shock, there will be a lower aggregate production in the Foreign country (because sector 2's production is lower and sector 1's production is stable). And the mechanism that enabled this relation to be in place is a higher aggregate interest rate in the Foreign country (there will also be a higher aggregate interest rate in the Home country).

Now suppose that we are in the extreme scenario of financial autarky ($\lambda = 0$). As there is no sector 2 (in any country) in this case, the mechanism above will not allow the shock to reverberate on the Foreign country and, consequently, while the production in the Home country will be higher, the production in the Foreign country will remain stable.

As λ grows larger (i.e. $0 < \lambda < 1$), the mechanism above will have larger effects and the Foreign country will be more exposed to productivity shocks of the Home country. In the extreme scenario where $\lambda = 1$, the mechanism above will present its most powerful form.

So, what we have learnt from the outcomes[63] of this model is that the productions of two countries will co-move less in the presence of two features:

1. A country-specific positive productivity shock; and
2. Financial integration

[63] Or results

However, what we have learned from the mechanisms of this model is that the productions of two countries will be less synchronized in the presence of three features:

1. A country-specific positive productivity shock;

2. Financial integration; and

3. Higher aggregate interest rates in the Foreign country

E.6.2 Financial shock

A financial shock is also a country-specific shock - i.e. common to both sectors in the country - that directly affects the return of the risky assets in the portfolio of the banks that operate in a country. We are going to focus here on a financial shock in the Home country.

E.6.2.1 Financial shock and sector 1 in the Home country

As we have seen, banks in sector 1 raise deposits from households in sector 1 and allocate those deposits to two types of assets: (i) risky assets and (ii) riskless credit to firms.

Now, suppose that there is a positive financial shock (R_t^m) in the Home country - one example of this shock could be an unexpected and exogenous positive shock on any stock index such as SP 500, for example. The banks in this sector will see $\bar{m}$% of its assets get higher returns than expected, which could raise their profits if they were in a monopolistic competition setting. One should remember, however, that there is a continuum of competitive banks in this economy and that the interest rates charged for the credit lent to firms (R_t^e) is defined after the realization of the financial shock. The competitive setting mandates a zero-profit for the banks, which, in its turn, makes the extra-earnings in the risky assets be converted into lower interest rates charged on firms for the working-capital credit.

Once firms face a lower interest rate, it is as if the labor cost became cheaper, which allows the firm to hire more labor and, consequently[64], invest more. This raises the Home-country sector 1's production and a side effect is lower interest-rates. The reader should remember that these real-economy movements in sector 1 do not affect any other sectors or countries once sector 1 is an autarky.

[64]The functional form of the production function implies some complementarity between labor and capital

E.6.2.2 Financial shock and sector 2 in the Home country

Similarly to the case with sector 1 in the Home country, a positive financial shock in the Home country also has a positive effect on the risky assets that Global Banks possess in the Home country. As the Global Banks are also a continuum of competitive banks, this unexpected higher return on its risky assets allows the interest rates for the firms to get lower. In terms of sector 2, the effect is similar to the one in sector 1, where firms located in the Home-country's sector 2 will be able to increase their production as a consequence of the reduction in financing costs.

E.6.2.3 Financial shock and sector 2 in the Foreign country

Although the financial shocks only affect risky assets on the Home country, all of the banks that operate in the Foreign country's sector 2 also have allocated part of its deposits in the Home country's risky assets (they are the same banks as we have seen in the Home country's sector 2 example above). Once firms in the Foreing-country's sector 2 also get to borrow from the Global Banks, these firms will also see their cost of borrowing get lower, which will allow them to increase their production through the same mechanisms as we have described above. The Foreign country's sector 2 will, then, also see its production get higher and interest rates get lower.

E.6.2.4 Financial shock and sector 1 in the Foreign country

Banks in sector 1 of the Foreign country do not possess any risky assets of the Home-country on their portfolios and, thus, firms in this sector do not get benefited from lower interest rates. There is no difference in the Foreign-country's sector 2 production or interest rates after the financial shock hits the Home country.

E.6.2.5 Financial shock and co-movement of the business cycles

If we maintain our previous definitions on aggregate production and aggregate interest rates, we can readily come to the conclusion that, in the Home country, the aggregate production gets higher after a positive financial shock. This happens because both Home-country's sectors present higher production after the shock. On the other hand, both sectors also present lower interest rates after the shock, which results in a lower aggregate interest rate in the Home country as well. Now, if we move to the Foreign country, we will see that the aggregate product will also be higher[65] once sector 2 could be benefited from lower interest

[65] In the case in which $0 < \lambda \leq 1$

rates, even though there werer no changes in the production of sector 1. The aggregate interest rate will also be lower once the interest rates in sector 2 are lower and the interest rates in sector 1 remain stable.

In the degenerate case in which $\lambda = 0$, there will be no sector 2 in the Foreign country. This will mean that there is only a sector 1 in the Foreing country, which will result in the aggregate production of the Foreign country being stable after a financial shock in the Home country and will also result in the stability of the aggregate interest rates in the Foreign country following a financial shock in the Home country. Any value of λ which is higher than 0 and lower or equal to 1 will lead the model to predict a reverberation of the shocks in the Home country into the aggregate variables of the Foreign country.

So, what we have learned from the outcomes[66] of this model is that the productions of two countries will be more synchronized in the presence of two features:

1. A country-specific positive financial shock; and
2. Financial integration

However, what we have learned from the mechanisms of this model is that the productions of two countries will be more synchronized in the presence of three features:

1. A country-specific positive financial shock;
2. Financial integration; and
3. Lower aggregate interest rates in the Foreign country

E.7 Conclusion of this appendix

We have presented the main features of a seminal theoretical model which shows a mechanism that could explain the changing observed interrelation between the GDP of two countries over time. We also highlighted the differences between the outcomes of the model (periods of more or less co-movement of business cycles) and the mechanisms behind the model (response of the interest rates after a shock, which causes the co-movement patterns of the business cycles), which are part of the same structure, but which should not be mistaken one for the other.

In the main body of this text, we argued that the empirical exercises that have been, so far, used to test the model above are not well suited to test for the validity of the mechanisms, but only for the validity of the outcomes. This appendix provides more context on the theory behind our empirical test.

[66] Or results

F Results with alternative ways of dealing with missing reports on financial integration data - BIS

In this Appendix, we show that our main results are not affected by our choice regarding how to deal with dates where there is availability of financial integration data for one side of the country-pair, but not the other. In table 4, we present the results for alternative 1, which consists of the following financial integration formula. If, at any point in time, only one country (of the 2 countries that form a pair) reports financial integration data. Then:

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t}}{GDP_{US,t}}$$

Whenever the two countries report financial integration data, then:

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t} + Assets_{SOE,US,t} + Liabilities_{SOE,US,t}}{2 * (GDP_{US,t} + GDP_{SOE,t})}$$

In table 5, on the other hand, we consider only the reports from the US:

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t}}{GDP_{US,t}}$$

The first thing to notice is that we have, in this Appendix, a larger number of observations - which is expected as the exercise that we presented in the main body of the text considered a financial integration measurement which was much more restrictive (it required availability of financial integration data for both countries at the same time). The second thing to notice is that the vast majority of the results point to the same direction as the ones in the main body of this paper.

Table 4

	Dependent variable:						
	$Co\_movement_{index}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Integration/GDP	−4.996***	−5.868***	−4.804***	−5.761***	0.446	0.270	0.264
	(1.353)	(1.368)	(1.318)	(1.335)	(1.159)	(1.212)	(1.149)
Integr/GDP x Great Recession	2.926	2.314					
	(1.937)	(1.606)					
Integration/GDP x IR_reaction					16.158***	13.814***	16.161***
					(0.798)	(0.833)	(0.798)
Great Recession	−0.309				−0.194		
	(0.209)				(0.177)		
Integration/GDP x Crises			1.668	2.249			
			(1.832)	(1.511)			
Crises			−0.010				0.077
			(0.173)				(0.143)
Trade_GDP		−2.607***		−2.612***		−0.586	
		(0.370)		(0.370)		(0.365)	
Ind. FE	x	x	x	x	x	x	x
Observations	1,885	1,798	1,885	1,798	1,885	1,798	1,885
R^2	0.008	0.036	0.007	0.036	0.186	0.165	0.186
F Statistic	5.26***	22.16***	4.48***	22.21***	142.28***	116.50***	141.90***

Note: *p<0.1; **p<0.05; ***p<0.01

Table 5

	Dependent variable:						
	$Co\_movement_{index}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Integration/GDP	−3.866***	−4.133***	−3.780***	−4.144***	−0.535	−0.340	−0.689
	(1.487)	(1.475)	(1.453)	(1.443)	(1.229)	(1.260)	(1.220)
Integr/GDP x Great Recession	2.639	1.691					
	(2.207)	(1.845)					
Integration/GDP x IR_reaction					19.788***	16.947***	19.810***
					(0.909)	(0.968)	(0.909)
Great Recession	−0.312				−0.163		
	(0.207)				(0.174)		
Integration/GDP x Crises			1.661	1.934			
			(2.128)	(1.772)			
Crises			−0.003				0.087
			(0.171)				(0.142)
Trade_GDP		−2.587***		−2.591***		−0.151	
		(0.371)		(0.371)		(0.370)	
Ind. FE	x	x	x	x	x	x	x
Observations	1,885	1,798	1,885	1,798	1,885	1,798	1,885
R^2	0.005	0.030	0.004	0.031	0.206	0.173	0.206
F Statistic	2.98**	18.54***	2.28*	18.66***	161.15***	123.49***	160.94***
Note:							*p<0.1; **p<0.05; ***p<0.01

G KPP findings

In their article, KPP ran the following regression:

$$Sync_{h,f,t} = \alpha_{h,f} + \lambda_t + \beta_1 Integration_{h,f,t} + \beta_4(Integration_{h,f,t} \times Crisis_t) + X'_{h,f,t}\Phi + \epsilon_{h,f,t}$$

Where we have adapted the variable names to coincide with the ones shown above.

First, there is a point to be made regarding the measurement of the business cycle co-movement. The co-movement variable was measured by the Giannone et al index described in the literature review section. This index measures co-movement as the negative of divergence in growth rates between two countries:

$$Sync_{h,f,t} = -|y_t^h - y_t^f|$$

This is a non-structural measurement that has its advantages [67], but that also has some pretty important flaws: suppose that two countries had zero GDP growth from period $-\infty$ until period $t = 0$ and then were subject to a sudden growth of, respectively, 2% and 3% in period $t = 1$. In this case, the Giannone et al co-movement index would report a co-movement of -1. Now, suppose that, instead of the growth rates shown above, country h sees its GDP be reduced by 1% while country f is not affected at all and keeps its 0% growth rate intact. In this case, the above index would also report the same co-movement of -1. The index, then, is a bit misleading, even though it may be the best option so far.

A second point to be made is that the authors ran the above regression to serve as a basis for their theoretical model and not as an actual test for it. In that sense, they first found out that there was a positive correlation between crisis periods and periods of higher co-movement - i.e. $\beta_4 > 0$ and is statistically significant - and also that there was a negative correlation between financial integration and co-movement in normal times - i.e. $\beta_1 < 0$, statiscally significant. The authors, then, used this empirical fact as a guiding basis for the theoretical model that followed - which we covered in Appendix E. After the theoretical model had been designed, though, the article presents no empirical tests regarding the mechanisms that work behind the model to explain the relationship between financial integration and business cycle co-movement.

As we have argued, the KPP theoretical model implies, necessarily, that the shock is transmitted from the home to the foreign country through a mechanism that involves the interest rates, which is not being tested in the regression above. This wouldn't be a problem if the only channel through which a financial

[67] As the authors argue in their article, it *"does not (directly at least) reflect the volatility of output growth"*, which means that it is less subject to Forbes and Rigobon's critique

crisis could be transmitted to the co-movement was the interest rate channel. If that was the case, then the variable ($Integration_{h,f,t} \times Crisis_t$) would work as an Instrumental Variable for the mechanism of the model. However, we believe that this is a too strong hypothesis to be taken for granted. There are probably many channels through which a financial crisis could potentially affect the co-movement between the production of two related countries - e.g. exchange rates channel, behavioural channel, learning channel etc[68]. With that having been said, the only way of testing for the mechanism of the theoretical KPP model is to measure the impact of a shock in the home country over the interest rates in the foreign country - i.e. the variable $IR\_reaction_{h,f,t}$ - which, to the best of our knowledge, has not been done, at least not in this context. Our new proposed method allows us to measure the necessary remaining variables that will allow the testing of the KPP model.

[68]For more references, please check Rigobon(2019)