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. Among the many results that our index unveils, we highlight that we do not find that output shocks in the US have a different impact in other countries during periods of crises and we also find that there is a growing decouple between EM and DM on how domestic inflation is affected by US output shocks. Our approach can also be used to elucidate previously unanswered channels or 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 a shock in 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.

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

[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)

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).

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 first tackle the empirical side of the measurement problem by proposing 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 existing empirical literature - which embraces more the idea of comovement than vulnerability to shocks - while also enumerating the required characteristics that we believe an international vulnerability index should have and how our index incorporates such characteristics.

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, 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 [8] consists of simply calculating the absolute differential in GDP growth without any discussion of causality[9]. 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.

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

[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] Giannone, Lenza and Reichlin (2010)

[9] 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)

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[10] (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.

Our approach allows us to evaluate different sources of shock in the large economy and its impacts on different variables in the small economy across time. Among the many results that our index unveils, we highlight that We find that output shocks in the US have the same impact in other countries during periods of crises or not and there is a growing decouple between EM and DM on how domestic inflation is affected by US output shocks.

With our new index, we reach new stylized facts on vulnerability. We find that countries are more

[10]Or even a set of domestic variables

vulnerable to US inflationary shocks during crises and that there has been a decouple on how Emerging Markets and Developed Markets get affected by US output shocks over time. Our findings suggest that the global financial factor has not affected relevantly the vulnerability of countries.

We then apply this new index to a global banks context for a subset[11] 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.

Now, considering the discussion above, suppose that we allowed parameters to change over time, but

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

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 [12].

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 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[13] which can be

[12] 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.

[13] We choose to display a VAR with only one lag and no exogenous variables in order to make the exposition more simple and clear.

expressed as follows:

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

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.

More specifically, our variables of choice for the small open economy will be output, inflation, interest rate and exchange rate: $y_t^1 = (y_t, \pi_t, i_t, e_t)$. For the large economy, variables will be output, inflation and interest rate: $y_t^2 = (y_t^*, \pi_t^*, i_t^*)$. The VAR then assumes the following form:

$$\begin{bmatrix} a_{11,t} & a_{12,t} & a_{13,t} & a_{14,t} & a_{15,t} & a_{16,t} & a_{17,t} \\ a_{21,t} & a_{22,t} & a_{23,t} & a_{24,t} & a_{25,t} & a_{26,t} & a_{27,t} \\ a_{31,t} & a_{32,t} & a_{33,t} & a_{34,t} & a_{35,t} & a_{36,t} & a_{37,t} \\ a_{41,t} & a_{42,t} & a_{43,t} & a_{44,t} & a_{45,t} & a_{46,t} & a_{47,t} \\ a_{51,t} & a_{52,t} & a_{53,t} & a_{54,t} & a_{55,t} & a_{56,t} & a_{57,t} \\ a_{61,t} & a_{62,t} & a_{63,t} & a_{64,t} & a_{65,t} & a_{66,t} & a_{67,t} \\ a_{71,t} & a_{72,t} & a_{73,t} & a_{74,t} & a_{75,t} & a_{76,t} & a_{77,t} \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \\ i_t \\ e_t \\ y_t^* \\ \pi_t^* \\ i_t^* \end{bmatrix} = \begin{bmatrix} c_{1,t} \\ \vdots \\ c_{7,t} \end{bmatrix} + \begin{bmatrix} b_{11,t} & b_{12,t} & b_{13,t} & b_{14,t} & b_{15,t} & b_{16,t} & b_{17,t} \\ b_{21,t} & b_{22,t} & b_{23,t} & b_{24,t} & b_{25,t} & b_{26,t} & b_{27,t} \\ b_{31,t} & b_{32,t} & b_{33,t} & b_{34,t} & b_{35,t} & b_{36,t} & b_{37,t} \\ b_{41,t} & b_{42,t} & b_{43,t} & b_{44,t} & b_{45,t} & b_{46,t} & b_{47,t} \\ b_{51,t} & b_{52,t} & b_{53,t} & b_{54,t} & b_{55,t} & b_{56,t} & b_{57,t} \\ b_{61,t} & b_{62,t} & b_{63,t} & b_{64,t} & b_{65,t} & b_{66,t} & b_{67,t} \\ b_{71,t} & b_{72,t} & b_{73,t} & b_{74,t} & b_{75,t} & b_{76,t} & b_{77,t} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} \\ y_{t-1}^* \\ \pi_{t-1}^* \\ i_{t-1}^* \end{bmatrix} + \begin{bmatrix} \sigma_{1,t} & 0 & \dots & 0 \\ 0 & \sigma_{2,t} & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & \sigma_{7,t} \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \vdots \\ \varepsilon_{7,t} \end{bmatrix} \tag{2}$$

In this setting, the Cushman and Zha (1997) hypothesis means that both A_t and B_t are block triangular, i.e., coefficients $(a_{51}, ..., a_{54}, ..., a_{71}, ..., a_{74})$ as well as $(b_{51}, ..., b_{54}, ..., b_{71}, ..., b_{74})$ are all equal to zero. This means that the large economy is not affected contemporaneously nor in lags by the small open economy. At the same time, the small open economy can be affected either contemporaneously or in lags by the large economy.

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:

This could, however, be easily extended to a p-lags VAR.

System 1 (SOE):

$$\begin{bmatrix} a_{11,t} & \dots & a_{14,t} \\ \vdots & \ddots & \vdots \\ a_{41,t} & \dots & a_{44,t} \end{bmatrix} \begin{bmatrix} y_t \\ \pi_t \\ i_t \\ e_t \end{bmatrix} + \begin{bmatrix} a_{15,t} & \dots & a_{17,t} \\ \vdots & \ddots & \vdots \\ a_{45,t} & \dots & a_{47,t} \end{bmatrix} \begin{bmatrix} y_t^* \\ \pi_t^* \\ i_t^* \end{bmatrix} = \begin{bmatrix} c_{1,t} \\ c_{2,t} \\ c_{3,t} \\ c_{4,t} \end{bmatrix} + \begin{bmatrix} b_{11,t} & \dots & b_{14,t} \\ \vdots & \ddots & \vdots \\ b_{41,t} & \dots & b_{44,t} \end{bmatrix} \begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} \end{bmatrix} + \begin{bmatrix} b_{15,t} & \dots & b_{17,t} \\ \vdots & \ddots & \vdots \\ b_{45,t} & \dots & b_{47,t} \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ \pi_{t-1}^* \\ i_{t-1}^* \end{bmatrix} + \begin{bmatrix} \sigma_{1,t} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \sigma_{4,t} \end{bmatrix} \begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix} \tag{3}$$

System 2 (Large Economy):

$$\begin{bmatrix} a_{55,t} & \dots & a_{57,t} \\ \vdots & \ddots & \vdots \\ a_{75,t} & \dots & a_{77,t} \end{bmatrix} \begin{bmatrix} y_t^* \\ \pi_t^* \\ i_t^* \end{bmatrix} = \begin{bmatrix} c_{5,t} \\ c_{6,t} \\ c_{7,t} \end{bmatrix} + \begin{bmatrix} b_{55,t} & \dots & b_{57,t} \\ \vdots & \ddots & \vdots \\ b_{75,t} & \dots & b_{77,t} \end{bmatrix} \begin{bmatrix} y_{t-1}^* \\ \pi_{t-1}^* \\ i_{t-1}^* \end{bmatrix} + \begin{bmatrix} \sigma_{5,t} & \dots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \dots & \sigma_{7,t} \end{bmatrix} \begin{bmatrix} \varepsilon_{5,t} \\ \varepsilon_{6,t} \\ \varepsilon_{7,t} \end{bmatrix} \tag{4}$$

This decomposition makes clear that the SOE is influenced by shocks in the Large Economy but the opposite is not true. Our system of interest when computing the vulnerability index is obviously System 1. Solving and estimating it will allow us to measure the impact that shocks to the large economy will have over the variables of the SOE.

As we mentioned before, for the identification strategy within each economy, we choose zero short run restrictions with the following ordering: output - inflation - interest rate - exchange rate. This assumption implies that coefficients $(a_{12,t}, a_{13,t}, a_{14,t}, a_{23,t}, a_{24,t}, a_{34,t})$ are all equal to 0. We can then rewrite System 1 as follows:

$$\underbrace{\begin{bmatrix} a_{11,t} & 0 & 0 & 0 \\ a_{21,t} & a_{22,t} & 0 & 0 \\ a_{31,t} & a_{32,t} & a_{33,t} & 0 \\ a_{41,t} & a_{42,t} & a_{43,t} & a_{44,t} \end{bmatrix}}_{A_t^1} \underbrace{\begin{bmatrix} y_t \\ \pi_t \\ i_t \\ e_t \end{bmatrix}}_{y_t^1} = \underbrace{\begin{bmatrix} c_{1,t} \\ c_{2,t} \\ c_{3,t} \\ c_{4,t} \end{bmatrix}}_{c_t} + \underbrace{\begin{bmatrix} b_{11,t} & \dots & b_{14,t} \\ \vdots & \ddots & \vdots \\ b_{41,t} & \dots & b_{44,t} \end{bmatrix}}_{B_t^1} \underbrace{\begin{bmatrix} y_{t-1} \\ \pi_{t-1} \\ i_{t-1} \\ e_{t-1} \end{bmatrix}}_{y_{t-1}^1} + \underbrace{\begin{bmatrix} a_{15,t} & \dots & a_{17,t} \\ \vdots & \ddots & \vdots \\ a_{45,t} & \dots & a_{47,t} \end{bmatrix}}_{A_t^2} \underbrace{\begin{bmatrix} y_t^* \\ \pi_t^* \\ i_t^* \end{bmatrix}}_{y_t^2} + \underbrace{\begin{bmatrix} b_{15,t} & \dots & b_{17,t} \\ \vdots & \ddots & \vdots \\ b_{45,t} & \dots & b_{47,t} \end{bmatrix}}_{B_t^2} \underbrace{\begin{bmatrix} y_{t-1}^* \\ \pi_{t-1}^* \\ i_{t-1}^* \end{bmatrix}}_{y_{t-1}^2} + \underbrace{\begin{bmatrix} \sigma_{1,t} & 0 & 0 & 0 \\ 0 & \sigma_{2,t} & 0 & 0 \\ 0 & 0 & \sigma_{3,t} & 0 \\ 0 & 0 & 0 & \sigma_{4,t} \end{bmatrix}}_{\Sigma_t} \underbrace{\begin{bmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \\ \varepsilon_{3,t} \\ \varepsilon_{4,t} \end{bmatrix}}_{\varepsilon_t} \tag{5}$$

where a more compact notation yields:

$$A_t^1 y_t^1 = c_t + B_t^1 y_{t-1}^1 + A_t^2 y_t^2 + B_t^2 y_{t-1}^2 + \Sigma_t \varepsilon_t \tag{6}$$

After that, we multiply both sides of the equation by the inverse of the now lower-triangular matrix A_t^1:

$(A_t^1)^{-1}$. This leaves us with:

$$y_t^1 = (A_t^1)^{-1}c_t + (A_t^1)^{-1}B_t^1 y_{t-1}^1 + (A_t^1)^{-1}A_t^2 y_t^2 + (A_t^1)^{-1}B_t^2 y_{t-1}^2 + (A_t^1)^{-1}\Sigma_t \varepsilon_t \tag{7}$$

which for ease of notation can be represented as:

$$y_t^1 = c_t^* + \tilde{B}_t^1 y_{t-1}^1 + \tilde{A}_t^2 y_t^2 + \tilde{B}_t^2 y_{t-1}^2 + (A_t^1)^{-1}\Sigma_t \varepsilon_t \tag{8}$$

Up to this point everything except for the time subscripts is standard. Stacking all the coefficients of the right hand side of equation (8) in vector B_T and all the variables in vector X_t, we can further rewrite the equation as:

$$y_t^1 = X_t' B_t + (A_t^1)^{-1}\Sigma_t \varepsilon_t \tag{9}$$

where $B_t = vec(c_t^*, \tilde{B}_t^1, \tilde{A}_t^2, \tilde{B}_t^2)$ and $X_t' = I \otimes (1, y_{t-1}^1, y_t^2, y_{t-1}^2)$

We now follow Primicieri (2005), in assuming that the elements of B_t and A_t^1 change over time according to a random walk and the standard deviations as a geometric random walk. Letting a_t be the vector of stacked elements of matrix A_t^1 and σ_t the vector of diagonal elements of matrix Σ_t, the system can thus be represented as:

$$B_t = B_{t-1} + \upsilon_t \tag{10}$$

$$a_t = a_{t-1} + \xi_t \tag{11}$$

$$log\sigma_t = log\sigma_{t-1} + \eta_t \tag{12}$$

Additionally all innovations in the model are assumed to be jointly normal distributed:

$$\begin{pmatrix} \varepsilon_t \\ \upsilon_t \\ \xi_t \\ \eta_t \end{pmatrix} \sim N \left(0, \begin{pmatrix} I_n & 0 & 0 & 0 \\ 0 & \sum_B & 0 & 0 \\ 0 & 0 & \sum_a & 0 \\ 0 & 0 & 0 & \sum_\sigma \end{pmatrix} \right),$$

The VAR is estimated following the method in Primicieri(2005) with Markov chain Monte Carlo. We follow Primicieri (2005) and Del Negro and Primicieri (2015) in the choice of priors and estimation.

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.

The computation of our vulnerability index will rely on the Impulse Response Functions of the system we presented above. We discuss the method behind the vulnerability index in the next session.

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 [14].

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

[14] 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.

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 co-movement index is given by:

$$H_t = \sum_{s=0}^{S} (\psi_{t+s}(j,i)) \tag{13}$$

where $S = 30$, $\psi_{t+s}(j,i)$ 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.

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, $t+1$, $t+2$... [15] 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[16]. 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.

[15] 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 .

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

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. [17]. The small open economies, on the other hand, were chosen not only as to be a representative sample of developed and developing countries, 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 [18].

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. 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 [19]

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

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

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

[19] 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.

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).

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.

Choosing which index to use is an important part of the research to be conducted on a case-by-case basis, since these indices, although aiming to address co-movement, measure different things. There are good reasons for using specific variable indices to assess different phenomena. 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.

3.1 US output shock

In this section, we present the indices for an American output shock. We provide detailed description for a shock over SOE's output (responses) to understand its mechanics of it and we provide further stylized facts that we observe in the following section. 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.

In this exercise, our index can be represented by:

$$H_t = \sum_{s=0}^{30} (\psi_{t+s}(j, i)) \tag{14}$$

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[20].

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

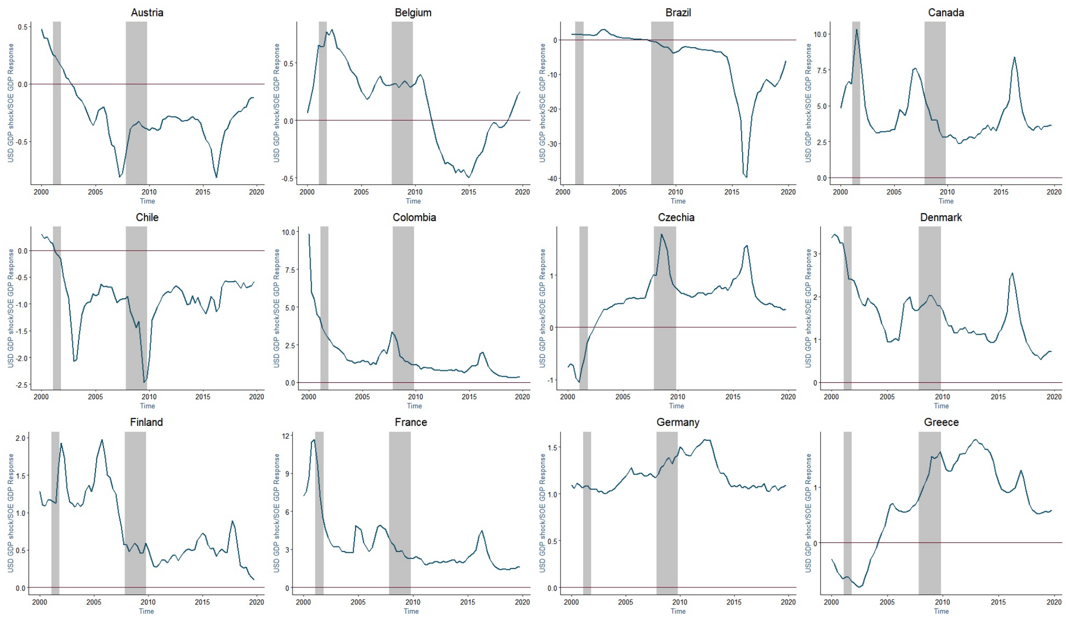

Figure 1: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's GDP for the first half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to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

Before we proceed to the comparisons between countries, we should understand what this index means: take Mexico 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 Mexican GDP grow an extra 1.0 percentage points over the next 30 months. An exogenous unitary American GDP shock that happened in January 2010, however, would make German GDP grow 1.2 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 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 a prevalence of country-pair characteristics over common trends in defining the co-movement between two countries, even though we find some common behavior across countries over time that we will discuss further. 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

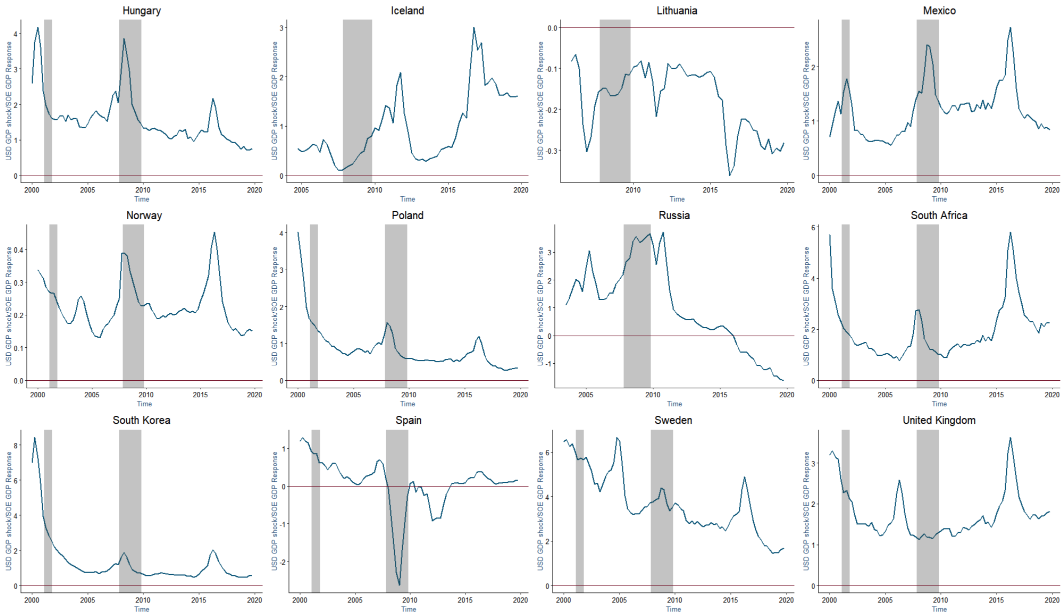

Figure 2: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's GDP for the second half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to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

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 impact on domestic output does not seem to get much affected by crises periods.

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 [21], Mexico stands out as a very vulnerable country when we talk about a US crisis. According to our index, Mexico is consistently

[21] 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.

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.

Table 1: Output 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	

However, US output shocks also affect also inflation. Images 3 and 4 provide the index on how US output shocks affect inflation. As one can see, we observe a growing decouple on how countries get affected by the shock.

4 Application of the method on a Global Banks context

Now, we are going to present a possible application of our indices. The empirical exercise that will follow is based on the theoretical model in Kalemli-Ozcan, Papaioannou and Perri (2013) - KPP hereafter.

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"*[22]. 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.

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.

[22] 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.

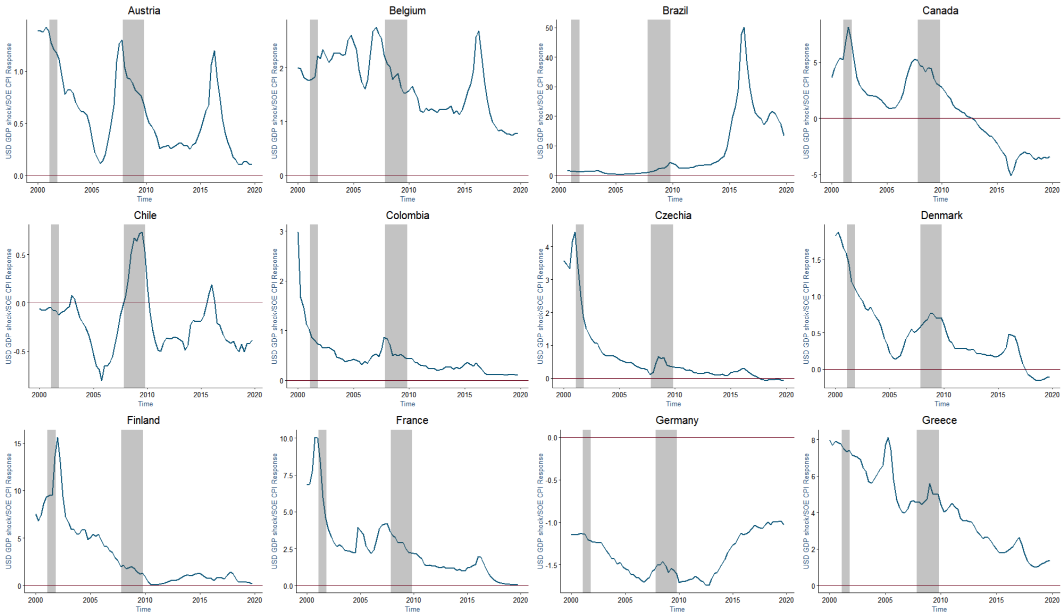

Figure 3: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's CPI for the first half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to NBER data. We restricted our sample here to results between 2000 and 2019 in order to have higher comparability between the countries.

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 can have switching co-movement [23] 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

[23] Sometimes their GDPs are positively correlated and, sometimes, negatively correlated.

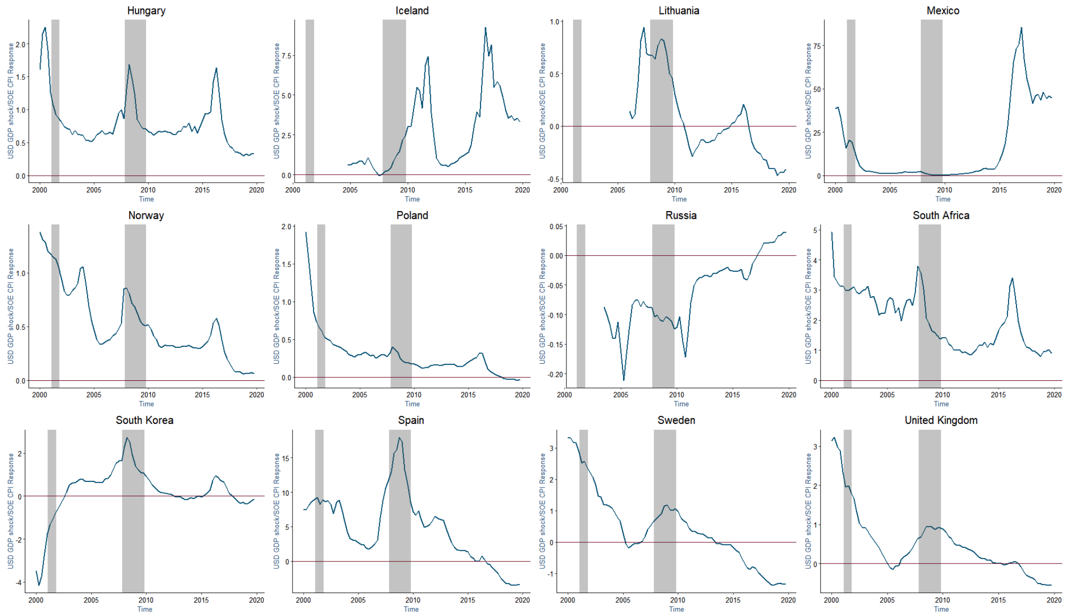

Figure 4: The graphs above represent the estimation of the index which represents the impact of a shock in the American GDP over the SOE's CP for the second half of the countries in our sample (in alphabetical order). The shaded areas correspond to recession periods in the United States according to NBER data. We restricted our sample here to results between 2000 and 2019 in order to have higher comparability between the countries.

2 will become more productive in the Home country relatively to sectors 1 and 2 in the foreign 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). 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 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.

4.2 KPP model as 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.

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[24].

The first key aspect of the model 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 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:

$$Co\_movement_{h,f,t} = \alpha_{h,f} + \lambda_t + \beta_1 Integration_{h,f,t} + \beta_2 (Integration_{h,f,t} \times IR\_reaction_{h,f,t}) + \beta_3 crisis + X'_{h,f,t}\Phi + \epsilon_{h,f,t}. \quad (15)$$

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 [25] 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 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.

[24] 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.

[25] 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

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. 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, 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. 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, since measuring $IR_reaction$ variable poses a great challenge, which we overcome by using our new proposed measurement.

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[26] Due to mismatches

[26] *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.

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:

$$\left[Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t} + Assets_{SOE,US,t} + Liabilities_{SOE,US,t}}{GDP_{US,t} + GDP_{SOE,t}}\right] \tag{16}$$

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 the Robustness section, the results of our exercise with two alternative [27] 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:

$$Co\_movement_{h,f,t} = \sum_{s=0}^{30} (\psi_{t+s}(f_{gdp}, h_{gdp})) \tag{17}$$

This variable, then, measures how an output shock [28] in the Large economy affects the SOE's output.

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

$$IR\_Reaction_{h,f,t} = \sum_{s=0}^{30} (\psi_{t+s}(f_{ir}, h_{gdp})) \tag{18}$$

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 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 [29]. 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

[27] 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.

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

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

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 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.

Table 2

	Dependent variable:			
	$\text{Co\_movement}_{index}$			
	(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

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[30] 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 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.

[30] 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, 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.

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

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, 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 [31], rather than a Global Banking drainage mechanism.

4.5 Robustness

4.5.1 Alternative ordering for the Time-varying VAR

One possible concern involving the identification strategy of the VAR used in this work is related the zero short term restrictions. As mentioned in Section 4 the order for the estimation of VARs used with long term interest rate was: interest rate - output - inflation - exchange rate. The usual interpretation being that exchange rate can be contemporaneously affected by all other variables; inflation can be affected by output and interest rate; output is affected by interest rate and in this case the long term interest rate is not affected contemporaneously by any other variable.

Although the assumption taken in our original exercise is common in the literature, we have rerun our panel regressions using the 10-year rates with an alternative ordering for the VAR: output - inflation - interest rate - exchange rate. In this setting, the long term interest rate is allowed to be affected both by inflation and output contemporaneously. The results are shown in Table 1 and Table 2 below. The alternative ordering of the VAR does not change our results in any significant way.

In Table 1 we regress our co-movement index against a measure of financial integration and other

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

controls. Columns labeled "Orig." correspond to the original estimation presented in Table 2 of Section 4 while columns labeled "Alt." correspond to the VAR with alternative ordering. Our results for the coefficient of interest *Integration/GDP* (row 1) remain unaltered: financial integration seems to make two countries co-move less. Dummies for the Great Recession and Crises periods become statistically insignificant.

Table 4: Robustness - VAR Ordering (Original vs. Alternative)

	Dependent variable:Comovement index							
	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.
	(1)	(1)	(2)	(2)	(3)	(3)	(4)	(4)
Integration/GDP	−1.942*	−1.604*	−3.675***	−2.984***	−2.034*	−1.454*	−3.564***	−2.894***
	(1.068)	(0.865)	(1.232)	(0.999)	(1.044)	(0.844)	(1.203)	(0.975)
Integration/GDPxGR	2.773*	0.764	1.229	1.247				
	(1.505)	(1.219)	(1.419)	(1.150)				
Great Recession	−0.616***	0.026						
	(0.168)	(0.136)						
Integration/GDPxCrises					2.102	0.360	1.018	1.108
					(1.434)	(1.160)	(1.337)	(1.084)
Crises					−0.408***	0.042		
					(0.148)	(0.119)		
Trade/GDP			0.234	−0.428			0.232	−0.431
			(0.492)	(0.399)			(0.493)	(0.399)
Ind. FE	x	x	x	x	x	x	x	x
Observations	1,563	1,563	1,506	1,506	1,563	1,563	1,506	1,506
R^2	0.010	0.002	0.006	0.007	0.007	0.002	0.006	0.006
F Statistic	5.441***	1.167	3.140**	3.256**	3.456**	1.095	3.083**	3.212**
Note:	*p<0.1; **p<0.05; ***p<0.01							

In Table 2 below we rerun our co-movement index against a measure of financial integration and an interaction between integration and the IR_reaction, reproducing the regression reported in Table 3 of Section 4. The coefficient for the interaction between Integration and IR_reaction (row 2) remains positive, contradicting the KPP prediction. Interestingly, coefficients for the Integration (row 1) itself which were insignificant in the original regressions now become negative and significant. We interpret these coefficients as we did in the previous table providing additional evidence that financial integration reduces the co-movement between the large and the small economies.

Table 5: Robustness - VAR Ordering (Original vs. Alternative)

	Dependent variable: $Comovement_{index}$					
	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.
	(1)	(1)	(2)	(2)	(3)	(3)
Integration/GDP	1.252	−7.453***	0.355	−7.545***	0.872	−7.445***
	(0.962)	(0.775)	(1.118)	(0.857)	(0.957)	(0.770)
Integration/GDP x IR_reaction	10.183***	4.910***	10.654***	5.024***	10.100***	4.910***
	(0.810)	(0.245)	(0.879)	(0.257)	(0.812)	(0.245)
Great Recession	−0.548***	0.025				
	(0.149)	(0.113)				
Crises					−0.309**	0.052
					(0.128)	(0.097)
Trade/GDP			0.497	−0.179		
			(0.470)	(0.356)		
Country-pair FE	x	x	x	x	x	x
Observations	1,563	1,563	1,506	1,506	1,563	1,563
R^2	0.101	0.208	0.095	0.209	0.096	0.208
F Statistic	57.439***	135.010***	52.186***	130.552***	54.624***	135.108***
Note:	*p<0.1; **p<0.05; ***p<0.01					

4.5.2 Fixed vs. Floating Exchange Rate Regimes

Another possible concern arising from our identification strategy is related to exchange rate regimes. In Cushman and Zha (1997) a crucial hypothesis is that the SOE will have floating exchange rates. In our estimation of the vulnerability index we used data starting in January 1960 depending on the country. This means our panel regressions use data from periods in which some countries potentially adopted other foreign exchange regimes.

In this robustness exercise we re-estimate our regressions restricting our sample to periods in which each SOE implemented floating exchange rate regimes. In our classification of exchange regimes, we used Ilzetzki, Reinhart, and Rogoff (2019, 2021). Note that according to this classification Czechia, Denmark, Hungary, Iceland, Norway, Poland and South Korea have not adopted a proper floating exchange regime since 1960 [32].

[32] As we mention in Section 4 due to data availability our original regressions using long term rates did not include Brazil, Lithuania and Russia.

Table 6: Foreign Exchange Regimes

County	Regimes	Date
Austria	Freely Floating	Jan 1999 - Dez 2019
Belgium	Freely Floating	Jan 1999 - Dez 2019
Canada	De Facto Moving Band / Freely Floating	May 1970 - Dez 2019
Chile	Managed Floating	Sep 1999 - Dez 2019
Colombia	Freely Floating	Sep 1999 - Dez 2019
Finland	Freely Floating	Jan 1999 - Dez 2019
France	Freely Floating	Jan 1999 - Dez 2019
Germany	Freely Floating	Jan 1973 - Dez 2019
Greece	Freely Floating	Jan 2001 - Dez 2019
Mexico	Managed Floating / Freely Floating	Dez 1994 - Dez 2019
South Africa	Managed Floating / Freely Floating	Feb 1983 - Dez 2019
Spain	Freely Floating	Jan 1999 - Dez 2019
United Kingdom	Managed Floating / Freely Floating	Jan 2009 - Dez 2019

Results are displayed in Table 4 and Table 5 below. As in the previous exercise, we compare regressions in our original setting (Section 4) with this robustness exercise. Note that restricting our sample to countries for which we have data on long term interest rates and to periods in which these countries adopted floating exchange regimes reduces our sample to close to one third of the original one (687 observations). We believe this could explain why magnitude of coefficients vary sensibly when restricting our sample. Signs and significance of the coefficients of interest however are not affected.

Table 7: Robustness - Foreign Exchange Regimes (Original vs. Alternative)

	Dependent variable:Comovement$_{index}$							
	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.
	(1)	(1)	(2)	(2)	(3)	(3)	(4)	(4)
Integration/GDP	-1.942^{*}	-21.191^{***}	-3.675^{***}	-20.914^{***}	-2.034^{*}	-22.296^{***}	-3.564^{***}	-22.027^{***}
	(1.068)	(4.513)	(1.232)	(4.427)	(1.044)	(4.526)	(1.203)	(4.431)
Integration/GDPxGR	2.773^{*}	10.225^{**}	1.229	4.677				
	(1.505)	(5.094)	(1.419)	(3.761)				
Great Recession	-0.616^{***}	-0.423^{*}						
	(0.168)	(0.219)						
Integration/GDPxCrises					2.102	12.875^{**}	1.018	8.632^{**}
					(1.434)	(5.023)	(1.337)	(3.642)
Crises					-0.408^{***}	0.042		
					(0.148)	(0.119)		
Trade/GDP			0.234	-2.069^{***}			0.232	-2.088^{***}
			(0.492)	(0.380)			(0.493)	(0.379)
Ind. FE	x	x	x	x	x	x	x	x
Observations	1,563	687	1,506	687	1,563	687	1,506	687
R^2	0.010	0.036	0.006	0.072	0.007	0.039	0.006	0.078
F Statistic	5.441^{***}	8.436^{***}	3.140^{**}	17.358^{***}	3.456^{**}	9.107^{***}	3.083^{**}	18.817^{***}
Note:	*p<0.1; **p<0.05; ***p<0.01							

Table 8: Robustness - Foreign Exchange Regimes (Original vs. Alternative)

	Dependent variable: $Comovement_{index}$					
	Orig.	Alt.	Orig.	Alt.	Orig.	Alt.
	(1)	(1)	(2)	(2)	(3)	(3)
Integration/GDP	1.252	-18.684^{***}	0.355	-19.151^{***}	0.872	-18.415^{***}
	(0.962)	(3.467)	(1.118)	(3.383)	(0.957)	(3.466)
Integration/GDP x IR_reaction	10.183^{***}	55.065^{***}	10.654^{***}	53.939^{***}	10.100^{***}	55.666^{***}
	(0.810)	(2.609)	(0.879)	(2.561)	(0.812)	(2.624)
Great Recession	-0.548^{***}	-0.237^{*}				
	(0.149)	(0.128)				
Crises					-0.309^{**}	-0.295^{**}
					(0.128)	(0.125)
Trade/GDP			0.497	-1.633^{***}		
			(0.470)	(0.295)		
Country-pair FE	x	x	x	x	x	x
Observations	1,563	687	1,506	687	1,563	687
R^2	0.101	0.417	0.095	0.440	0.096	0.419
F Statistic	57.439^{***}	160.267^{***}	52.186^{***}	175.732^{***}	54.624^{***}	161.466^{***}
Note:	*p<0.1; **p<0.05; ***p<0.01					

4.5.3 Alternative specifications for missing reports on financial integration data - BIS

Finally, 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:

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t}}{GDP_{US,t}} \tag{19}$$

Whenever the two countries report financial integration data, then:

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t} + Assets_{SOE,US,t} + Liabilities_{SOE,US,t}}{2 * (GDP_{US,t} + GDP_{SOE,t})} \tag{20}$$

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

$$Linkages/GDP = \frac{Assets_{US,SOE,t} + Liabilities_{US,SOE,t}}{GDP_{US,t}} \tag{21}$$

The first thing to notice is that we have 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 9

	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 10

	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: $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$

5 Conclusion

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

The first contribution is that we propose and implement a new measurement of macroeconomic vulnerability - which can take 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 disentangling sources and responses from large economy shocks to small open economies.

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. We believe that more work adding countries and providing a standard index for a wide array of them could help the policy discussion too.

The second main contribution is that we provide new stylized facts on how vulnerability evolved over time and across countries. We find that countries are more vulnerable to US inflationary shocks during crises and there´s been a decouple on how Emerging Markets (EM) and Developed Markets (DM) get affected by US output shocks over time. Our findings suggest that the global financial factor has not affected relevantly the vulnerability of countries, but the literature should focus on why EM and DM behave differently or why crises change the sensitivity to a foreign shock.

The third main contribution is that we 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 or banking 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. Our findings open the way for further research on the determinants of business cycle co-movement, a relevant and dynamic branch of the international economics literature.

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