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## Article

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EconomiA

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*Suggested Citation:* Marçal, Emerson Fernandes; de Prince, Diogo; Zimmermann, Beatrice; Merlin, Giovanni; Simões, Oscar (2020) : Assessing global economic activity linkages: The role played by United States, Germany and China, EconomiA, ISSN 1517-7580, Elsevier, Amsterdam, Vol. 21, Iss. 1, pp. 38-56,  
<https://doi.org/10.1016/j.econ.2020.01.001>

This Version is available at:

<https://hdl.handle.net/10419/266948>

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# Assessing global economic activity linkages: The role played by United States, Germany and China<sup>☆</sup>

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Received 4 February 2019; received in revised form 23 August 2019; accepted 25 January 2020

Available online 4 February 2020

## Abstract

Economic performance increasingly relies on global economic environment due to the growing importance of trade and financial links among countries. This work aims to analyze the possible effects of a potential economic growth downturn or one large negative shock in China, Germany and United States on the growth of other economies. We use a univariate Global autoregressive approach to assess interdependence across 38 countries. We simulate two types of phenomena. The first one is a one time large shock of  $-2.5$  standard deviations. The second experiment simulates the effect of a hypothetical downturn of the aforementioned economies. Our results suggest that the United States play the role of a global economy affecting countries all over the globe whereas Germany and China play an important regional role.

*JEL classification:* C52; F41; F47

*Keywords:* Economic growth; International linkages; Global autoregressive

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## 1. Introduction

Economic growth is a topic of intense research and debate in Economics. Although the dynamics of growth are strongly related to domestic issues, we cannot neglect that the global environment and its linkages play a central role in explaining growth and economic cycles. For that matter, policy makers and practitioners should have good estimates of the magnitude of those economic linkages across nations.

<sup>☆</sup> Peer review under responsibility of National Association of Postgraduate Centers in Economics, ANPEC.

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According to [Blanchard et al. \(2010\)](#) and [Eaton et al. \(2016\)](#), trade and financial flows across regions are essential to explain why there might be significant linkages between world economies. Recent events, such as the subprime crisis in the United States and Euro crisis, have raised questions about spillover effects onto the economic performances of countries around the world. The dependency of the eurozone members on German's economic performance is one point of concern that has been raised recently, specially in critical moments of the euro crisis. China's emergence and, particularly, its apparent relative growth slowdown have raised concerns about the magnitude of its relevance in helping the sustenance of world growth.<sup>1</sup>

At the same time, it is not just China's economy that makes the policy makers fear a global slowdown. After some years with very low interest rates and slow recovery, in the post-2008 period, [Baldwin and Teulings \(2014\)](#), [Summers \(2015\)](#), among, started to rediscuss the theory of secular stagnation in the USA. Looking at this new international scenario, this paper intends to analyze the possible effects of Chinese economic growth downturn on other countries involved in world trade. Considering the importance of the U.S. economy to the rest of the world and the relevance of the German economy to the European continent, we also examine what would happen if these countries suffered a downshift in their growth rate as well. We further analyze the effect of a negative shock of 2.5 standard deviations on growth in the USA, China or Germany in the other economies of the world. We consider the effect of a shock in these countries because USA and China are currently the largest Gross Domestic Products (GDP) in the world respectively – since 2010 according to International Monetary Fund (IMF) data. Additionally, Germany was chosen because it has the highest GDP in Europe (4th largest GDP in the world since 2007) and because of its regional economic importance, considering that Europe is the region with the largest number of countries in the sample (17 countries including Turkey, that mounts to approximately 45% of the sample of countries).

We investigate the existence and strength of the economic growth dependence on a sample of 38 countries to shocks in three major economies: United States, Germany and China. In order to achieve this goal, we opt to use the Global Autoregressive Regression (GAR) approach, an adaptation of the GVAR of [Pesaran et al. \(2004\)](#) to an univariate case. We consider the GAR approach together with the discovery methodology proposed by [Hendry and Doornik \(2014\)](#), where automatic selection techniques allow to check and control for structural change. [Castle and Hendry \(2014\)](#) discuss how the approach in this paper can control biases introduced by possible omitted variables that faces structural change and contaminates the analysis. We construct the model by carefully investigating their specification and controlling for outliers, instabilities and structural change in Data Generating Process. As robustness, we consider the price of oil as a global variable and we change weights between countries to analyze the result.

We rely on the Global Vector autoregression (GVAR), but we use univariate GAR model and analyze the shocks dynamics in the output of China, USA and Germany in the output of the other countries over time. The advantage of the GAR model over the VAR model for example is because the GAR model is more parsimonious. We estimate three coefficients (considering one lag for each variable) associated with covariates for each equation in the GAR model, while we would have 38 coefficients for each equation in the VAR model. The intuition of the GAR model is as if we modeled the per capita GDP growth of a given country as a function of the per capita GDP growth of all other countries. That is, the variable between the different countries are related, which is interesting for the purpose of the work to analyze the spillover effect of a shock in a given country.

This is the only article that estimates a GAR model with a foreign variable, approach proposed by [Pesaran et al. \(2004\)](#), that is concern about analyzing the effect across countries and over time. In addition, this article considers 38 countries in order to have an idea of the global effect, while [Bussiere et al. \(2009\)](#) contemplate a more restricted sample of 21 countries.

We analyze two types of events. The first one is an impulse shock originated in United States, Germany or China. The second event is a downturn in the long-run growth trend. The first can be seen as an abnormal one-shot shock whereas the second can be characterized as a permanent change. Our results indicate that a shock of  $-4.4$  p.p. in GDP per capita of USA significantly reduces the GDP growth in most countries contemporaneously. The estimated effect is still statistically different from zero in some countries even after five years. Also our estimates suggest a great

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<sup>1</sup> China's average growth in the last three decades was approximately 10% per year, which led the country to the top of the list of biggest economies of the world. However, the Chinese pace of economic expansion has changed in the last three years, when the Gross Domestic Product growth was of 7.8%, 7.7% and 7.4% for 2012, 2013 and 2014 respectively, for example. For the future, we expect Chinese growth to be driven by rising in household spending, but the growth should be lower than achieved in previous decades. This change may affect the economies around the world as well.

impact on Finland, Chile, Uruguay, Portugal, Greece, and Spain. The German shock dies out faster than a shock in United States and affects fewer countries. The final effect is stronger on oil producing countries such as Indonesia, Venezuela, Norway and Mexico. The effects of a Chinese negative shock is notably smaller compared to the previous ones and the effect of this shock does not spread out to the world. This negative shock in China has stronger impact on South American and Asian countries. Our results suggest that only a downturn in United States long-run growth tend to generate relevant effects on a wider set of countries. These results are robust to changes in specification, such as modeling China as a dominant country, including the price of oil as a global variable, and the presence of structural breaks, when structural break dummy variables are added.

Beside this introduction, the paper has four additional sections. The second provides the literature review. The third presents the applied methodology, followed by the fourth section which describes the data and presents the results of the empirical exercise. Finally, the fifth section provides the final remarks.

## 2. Literature review

The literature on economic linkages between countries increased considerably after the subprime financial crisis due to its spillover effects to the world economy. We focus on the links between countries through GDP, but there are articles that analyze the spillover of economic policy uncertainty index, trade, commodity price, inflation between countries for example (Zhang et al., 2019; Gauvin and Rebillard, 2018; Andritzky et al., 2019; Eickmeier and Kühnlenz, 2018; Han et al., 2016).

Bems et al. (2010) analyze the propagation and synchronization of a fall in USA or European Union demand, for example. The authors use an input-output framework to study the effects of a fall in final demand in the USA or the European Union on world demand. This study further considers the effects of a fall in the industrial sector or a decline in the durable goods sector in the USA or the European Union to examine whether there is a difference in the spread to the world economy. According to their study, the changes in demand have an asymmetric nature, which explains why global trade declines four times more than GDP.

Kose et al. (2013) study how the national economic cycle is related to the global economic cycle. The study considers 163 countries throughout 1960 to 2012. The methodology used is an autoregressive distributed lag model that considers the real world interest rate and the world growth rate to explain the country's growth rate. Their results indicate that the national business cycle is tied to the global cycle, but the sensitivity of national cycles to global cycles is greater during global recessions than expansions. In addition, the study finds that advanced economies are more sensitive to the global cycle than developing economies: the more integrated to the global economy, the more sensitive they tend to be.

Montinari and Stracca (2016) rely on a panel data to assess the effect of foreign GDP growth on domestic GDP growth. They consider 39 countries for the annual period between 1970 and 2014. The main regression of the model is similar to ours: the domestic GDP is a function of lagged domestic GDP and current-time foreign GDP (an average between the GDPs of other countries). However, our methodology allows interconnection between countries solving the GVAR model, i.e. we can say that our procedure has an additional second step. This additional step allows us to analyze the effect of one country's GDP growth on the other and not simply the effect of foreign countries' GDP growth on the domestic country – as the structure of Montinari and Stracca (2016). The coefficient of external GDP would be 0.55. In addition, the authors consider homogeneous coefficients in the panel data unlike us with time series framework. For example, Pentecote and Rondeau (2018) run autoregressions for 49 countries from 1978 to 2011 to understand the effect of foreign GDP during fiscal crises on a dynamic specification of Cerra and Saxena (2008). The panel benchmark regression of Montinari and Stracca (2016) is similar to the autoregression of Pentecote and Rondeau (2018), but with time series.

Diebold and Yilmaz (2015) aim to measure the output connectedness between countries but the authors deal with the time-varying relationship between countries over the business cycle. Their sample considers six developed countries for the period between 1962 and 2011. The industrial production index is the proxy for the output variable. Their methodology is the VAR model considering rolling estimation window to obtain time-varying coefficients. Diebold and Yilmaz (2015) measure uses the Generalized Impulse Response (GIRF) and the Generalized Forecast Error Variance Decomposition (GFEVD) techniques of Koop et al. (1996) and Pesaran and Shin (1998). The results indicate that the cross-country comovement of output fluctuates over time in line with other articles like Kose et al. (2003) and Doyle and Faust (2005). A small shock in an individual country should not be transmitted to other countries, but when the

shock is large, it is transmitted so that the correlation between business cycles in different countries increases. About the time-varying behavior, USA and Japan are the main net transmitters of shocks to other countries. This pattern for the first country is for the 1980s and 2000s, while the second country is for the 1970s and 2000s.

In order to analyze the effect of GDP growth between the US, China, and the Eurozone, [Bataa et al. \(2018\)](#) use a VAR model with structural breaks for these three series to analyze how growth shocks between these countries are related. The authors explore how structural breaks affect the link between countries in line with [Diebold and Yilmaz \(2015\)](#). The analysis of spillover measures is based on the GIRF and GFEVD following [Diebold and Yilmaz \(2015\)](#) empirical strategy.<sup>2</sup> [Bataa et al. \(2018\)](#) obtain that USA shocks in the Eurozone are of the same magnitude as those of the Eurozone in the USA. However, China has increasing shocks in the USA and Eurozone. Since 2008 China has had shocks with greater effects in the USA and the Eurozone than vice versa.

Some articles use the GVAR modeling as an effective tool to understand regional and world economic linkages. For example, [Sun et al. \(2013\)](#) use both trade and financial weights to capture the link between Central Eastern and Southeastern Europe (CESEE) and advanced European countries. This close link among these countries is responsible for a boom and bust cycle in the CESEE countries that enabled them to join the advanced countries markets not only as consumers but also as part of their production chain. [Sun et al. \(2013\)](#) find strong co-movements in inflation and credit growth. They also find some interesting results in regards to financial shocks. A UK long term interest rate shock reverberates strongly to the euro area, as well as to Nordic countries, but they have a small effect on CESEE countries. Effects to the inflation of the CESEE countries are small when there is a shock in euro area inflation. The same happens to the credit growth of the CESEE countries when a shock is applied to the credit growth of the euro area. The authors also apply shocks directly to the CESEE countries in order to understand the effects on Western European partners. They document that the rise in size of the CESEE economies have increased the importance of a shock in these economies being transmitted to the Western European countries.

[Bagliano and Morana \(2012\)](#) investigate domestic propagation of subprime crisis and spillovers on OECD countries using a Factor Vector Autoregressive Model (F-VAR). Concerning the domestic factor, they collect evidence of a boom-bust credit cycle. Trade deficits and excess liquidity due to fiscal and monetary expansionist policy are key channels to propagate the crisis to other countries. [Osborn and Vehbi \(2015\)](#) study the effects of economic growth in the USA and China on New Zealand. Their goal is similar to ours but our methodology allows to address this question to a wider group of countries. [Feldkircher and Korhonen \(2014\)](#) investigate the effect of a 1% shock on China's output that leads to a permanent increase of 0.1% to 0.5% in the output of large economies using GVAR. In addition, the authors find that China is little affected by shocks in the USA economy.

[Bussiere et al. \(2009\)](#) use a 21-country GVAR to investigate the effects of shocks on global trade flows. Their main findings are that world exports have a much higher response to a shock in USA output than to a shock in the U.S. real effective exchange rate. Although the focus of the authors is to identify the effects on trade flows, imposing theoretical restrictions on long-run relationships, they also estimate the effects of shocks on output. They look only to the short-run effects, but qualitatively their results are similar to those that we present in this article. The authors consider the shock in the output of the USA and Germany, and in imports in China to try to grasp the effect to the world. They only consider the effect after one year. The present work considers the dynamics and we present the effect over time, in which the output shock in Germany has a shorter effect than the USA in the output of the countries. This movement that we estimate is not seen in [Bussiere et al. \(2009\)](#), for example. Also our sample has 38 countries while [Bussiere et al. \(2009\)](#) use a more restricted sample, 21 countries. We can imagine that we have a more rich environment to analyze a spillover of the shocks in the output of the USA, Germany and China to the world.

[Cesa-Bianchi et al. \(2012\)](#) analyze the effect of shocks from China and USA on developed and emerging countries, especially the five largest economies in Latin America. The authors use the GVAR methodology with time-varying weights for 33 countries with quarterly data from 1979 to 2009. The result indicates that the effect of China's shock on Latin American countries has tripled since the mid-1990s, while the US shock has halved over the same period. This explains why Latin American countries have recovered rapidly from the 2008 crisis, but this raises the point of increasing volatility in Latin American economies. This is because the Chinese economy is more volatile than the USA

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<sup>2</sup> [Bataa et al. \(2018\)](#) address the change in the relationship of the series with their lags and with each other over time by considering the effect of structural breaks on GIRF and GFEVD, while [Diebold and Yilmaz \(2015\)](#) use a rolling estimation window.

because the conditional standard deviation of China’s GDP shock is more than twice that of the USA. The next section discusses the methodology used in this paper.

### 3. Methodology

We start our analysis by modeling a reduced form for the logarithm of Gross Domestic Product per Capita (LGDP)PC).<sup>3</sup> We adapt the Global Vector Autoregressive Regression (GVAR) methodology to an univariate case, as proposed by Pesaran et al. (2004). In this framework we link the domestic performance to the performance of external variables. Since the log of per capita GDP is non-stationary, we use the first difference of LGDP)PC. To derive the Global Autoregressive Model, GAR, we consider the following equations for a set of  $i = 1, 2, \dots, N$  countries:

$$\Delta x_{i,t} = a_i + \phi_{i,1} \Delta x_{i,t-1} + \theta_{i,0} \Delta x_{i,t}^* + \theta_{i,1} \Delta x_{i,t-1}^* + \varepsilon_{it} \tag{1}$$

where  $x_{it}$  is the endogenous variable,  $x_{it}^*$  is the external variable of the country  $i$ , and  $\varepsilon_{it}$  is the idiosyncratic random shock,  $\varepsilon_{it} \sim N(0, \sigma_i^2)$ . The remaining Greek letters refers to the autoregressive and external variables parameters, and  $a_i$  is a drift. We construct the external variable  $x_{it}^*$  using the trade weights (imports plus exports)  $w_{i,j}$  precisely:

$$x_{i,t}^* = \sum_{j=1}^N w_{i,j} x_{j,t} \tag{2}$$

where  $\sum_{j=1}^N w_{i,j} = 1$ ,  $w_{i,i} = 0$  for  $\forall i = 1, \dots, N$ .

We define  $\tilde{x}_{i,t}^* = \begin{pmatrix} x_{i,t} \\ x_{i,t}^* \end{pmatrix} = W_i x_t$  and we rewrite (1) as:

$$A_i \Delta \tilde{x}_{i,t} = a_i + B_i \Delta \tilde{x}_{i,t-1} + \varepsilon_t \tag{3}$$

where  $A_i = (I_1 \quad , -\theta_0)$ ,  $B_i = (\phi_{i,1} \quad \theta_{i,1})$ , and  $\varepsilon_{it} = W_i \varepsilon_t$ .

Now let  $W_1 = \begin{pmatrix} 1 & 0 & 0 & \dots & 0 \\ 0 & w_{12} & w_{13} & \dots & w_{1N} \end{pmatrix}$  until  $W_N = \begin{pmatrix} 0 & 0 & 0 & \dots & 1 \\ w_{N1} & w_{N2} & w_{N3} & \dots & 0 \end{pmatrix}$ . We can use the fact

that  $\tilde{x}_{i,t}^* = \begin{pmatrix} x_{i,t} \\ x_{i,t}^* \end{pmatrix} = W_i x_t$  and we obtain:

$$A_i W_i \Delta x_t = a_i + B_i W_i \Delta x_{t-1} + \varepsilon_t \tag{4}$$

Finally, we stack all equations in a single vector:

$$G \Delta x_t = a + H \Delta x_{t-1} + \varepsilon_t \tag{5}$$

where  $a = \begin{pmatrix} a_1 \\ a_2 \\ \vdots \\ a_N \end{pmatrix}$ ,  $\varepsilon_t = \begin{pmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \vdots \\ \varepsilon_{Nt} \end{pmatrix}$ ,  $G = \begin{pmatrix} A_1 W_1 \\ A_2 W_2 \\ \vdots \\ A_N W_N \end{pmatrix}$ , and  $H = \begin{pmatrix} B_1 W_1 \\ B_2 W_2 \\ \vdots \\ B_N W_N \end{pmatrix}$ .

Since  $G$  is a  $N \times N$  full rank matrix, multiplying by its inverse we get:

$$\Delta x_t = G^{-1} a + G^{-1} H \Delta x_{t-1} + G^{-1} \varepsilon_t \tag{6}$$

Eq. (6) shows that, if we have  $a$ ,  $G$  and  $H$  (we can estimate these parameters consistently equation by equation under the hypothesis of weak exogeneity), we can forecast as a traditional VAR(1) model.

In the long run, if the system is stationary (in our case, if GDP growth rates converges to a stable path), we consider  $\Delta \bar{x}_t$  the long-run average. We can rewrite (6) in the long run as:

$$(I - G^{-1} H) \Delta \bar{x}_t = G^{-1} a + G^{-1} \varepsilon_t \tag{7}$$

<sup>3</sup> We include the logarithm of oil price variable in the model in Section 4.4.2 as a global exogenous variable that is common to all countries.



pre-multiplying both sides by  $(I - G^{-1}H)^{-1}$ , we obtain the expected long-run growth rate of vector  $x$ :

$$E[\Delta \bar{x}] = \Theta_a = (I - G^{-1}H)^{-1}G^{-1}a \quad (8)$$

Eq. (8) shows that the stationary long-run growth rate of countries are linked through  $G$ ,  $H$  and a matrices. These matrices contain parameters of every country in the model, besides the trade weights.

### 3.1. Modeling a hypothetical downturn

Our focus is to assess the effects of changes in per capita income and our exercise relies on hypothetical changes in  $\Theta_a$  vector, more precisely, on the coefficient vector  $a$  in Eq. (8). We can estimate the effect of a permanent Chinese downturn on the rest of the countries by changing permanently  $a_i$ , the drift parameter in the Chinese equation. Note that it is different from a traditional impulse response analysis.

Suppose that we want to estimate the effect of a 1 p.p. slowdown in Chinese long-run growth. Defining  $k_i = (0 \ 0 \ \dots \ -0.01 \ 0 \ \dots \ 0)'$ , the new constant coefficient can be calculated as  $\tilde{a}_i = a_i + k_i / \text{diag}_i((I - G^{-1}H)^{-1}G^{-1})$ , with  $i = 7$  in Chinese case. The new long-run growth vector,  $\Theta_{\tilde{a}}$ , can be recalculated using (8). Note that, although only the constant coefficient on the Chinese equation has changed, the expected long-run growth rates change due to the interdependence among countries. However, if we are interested in addressing the short-run effects of a one-period shock in a specific country, we can directly impose this shock for one period in the specified country equation.

### 3.2. Dealing with structural change: empirical model discovery and autometrics

Empirical model discovery is based on the idea that theory, although important, plays a restrict role in understanding economic data. A quote from Hendry (2011) captures the idea perfectly: “When a theory model is simply imposed on the evidence, little can be learned – reaching outside is essential to reveal phenomena that were not originally conceived . . . Rather than being imposed, theory formulations should be retained when modeling as part of the process of evaluating them, jointly with discovering what additional features are substantively relevant”.

The objective of any applied researcher is to unveil the true data generating process (DGP). Theory usually restricts the important economic variables to a set of independent variables ( $\mathbf{x}_t$ ) that are most capable to unveil the true DGP. The derivation of the DGP in which we model  $m+1$  variables  $\mathbf{x}_t$  is called local DGP (LDGP). Thus, the LDGP is then a reduction of the true DGP to a subset of variables that explain sufficiently the most of its relevant behavior. But it would be a naive assumption to think that only a linear model containing  $\mathbf{x}_t$  would be sufficient to explain all of the dependent variable variation. A broader formulation that allows relations between its components (the independent variables), longer lags, wider range of possible functional forms, and multiple shifts and outliers are probably necessary. The ability to add all this possibilities may considerably increase the number of variables to be estimated, making the discovery of the LDGP a real challenge. In this context, we can easily be in a situation where we have more variables to estimate than observations. To solve this issue, one can use automatic selection algorithms that efficiently search for the simplest acceptable representation of the LDGP. They do so by conducting a mixture of general-to-simple and block expanding searches in all possible model candidates. This selection method should be efficient at a point as to present a small probability of retaining irrelevant variables, and a large probability of retaining variables similar to the LDGP when conducting inference at the same significant levels. After having found an “acceptable parsimonious” selection that would characterize the target LDGP (also called the terminal model), we can perform a set of external evaluation tests to validate the model.

In summary, this empirical framework for model discovery uses theory to choose the important variables that can explain the dependent variable behavior and at the same time we analyze a much larger set of possibilities that goes beyond these individual variables. Autometrics, embedded in OxMetrics PcGive software, is a tool that we can use for this computationally intense empirical model search and selection. All estimates were performed in Oxmetrics 7.0.

## 4. Data and results

### 4.1. Data

The data covers the period of 1970 to 2013 and 38 countries (which represents, in average, 88% of world GDP in that period).<sup>4</sup> Frequency of the data is annual. Gross Domestic Product per capita growth rate is obtained from World Bank database. Since our intention is to analyze how a shock from one country spreads to other countries in order to approximate a global effect, we wanted to add as many countries as possible. In this regard, we included countries that had been reporting data since 1970 uninterruptedly, which restricted the number of countries. We started in 1970 because we considered it adequate as a minimum amount of observations so we could estimate a time series model using annual data.

Trade data (Exports plus Imports) are obtained at the International Financial Statistics maintained by International Monetary Fund (IFS-IMF).<sup>5</sup> We consider only data for the last ten years to calculate the weights to be used in the global model.<sup>6</sup>

Since the average share of United States on its trade partners is high (average of 17.9% of total trade) and their great impact in the rest of the world economies, we assume that United States is a dominant unit. This is similar to [Chudik and Smith \(2013\)](#). Given a substantial weight on other countries (10.1% on average) and the strong relevance on other European countries, we also consider Germany as a dominant country.<sup>7</sup> This implies that we should consider the GDP per capita growth of USA and Germany as endogenous variables with respect to their external variables, and then we assume that the parameter  $\theta_0$  (coefficient of the contemporaneous external variable) is zero in both equations. Besides this, GDP per capita growth (contemporaneous and lagged) of USA and Germany also enters in other countries equations as a global variable.

### 4.2. Baseline model

Given the limited number of observations in our model, we choose to perform an automatic model selection via Autometric s, developed by [Hendry and Doornik \(2014\)](#).<sup>8</sup> We use the general unrestricted system (GUM) for a non-dominant country as:

$$\Delta LGDPPC_{i,t} = a_i + \begin{bmatrix} \theta_{i,0} \\ \psi_{i,0}^1 \\ \psi_{i,0}^1 \end{bmatrix}' \begin{bmatrix} \Delta LGDPPC_{i,t}^* \\ \Delta LGDPPCUSA_t \\ \Delta LGDPPCGER_t \end{bmatrix} + \begin{bmatrix} \phi_{i,1} \\ \theta_{i,1} \\ \psi_{i,1}^1 \\ \psi_{i,1}^2 \end{bmatrix}' \begin{bmatrix} \Delta LGDPPC_{i,t-1} \\ \Delta LGDPPC_{i,t-1}^* \\ \Delta LGDPPCUSA_{t-1} \\ \Delta LGDPPCGER_{t-1} \end{bmatrix} + \varepsilon_{it} \quad (9)$$

For dominant countries, United States and Germany, we estimate the following system:

$$\begin{bmatrix} \Delta LGDPPC_{i,t} \\ \Delta LGDPPC_{i,t}^* \end{bmatrix} = \begin{bmatrix} a_i \\ a_i^* \end{bmatrix} + \begin{bmatrix} \phi_{i,1} & \phi_{i,1}^* \\ \theta_{i,1} & \theta_{i,1}^* \\ \psi_{i,1}^1 & \psi_{i,1}^{1*} \end{bmatrix}' \begin{bmatrix} \Delta LGDPPC_{i,t-1} \\ \Delta LGDPPC_{i,t-1}^* \\ \Delta LGDPPCDOM_{i,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{i,t} \\ \varepsilon_{i,t}^* \end{bmatrix} \quad (10)$$

where  $\Delta LGDPPCDOM_{i,t-1}$  is the lagged change in per capita GDP of Germany in United States equation, and vice-versa. Note that only the first equation in the system given by (10) is relevant to solve (6), but we need to jointly estimate the system for inference purposes.

<sup>4</sup> Our sample covers the following countries: Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Denmark, Finland, France, Germany, Greece, Hong Kong, India, Indonesia, Ireland, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Norway, Paraguay, Peru, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland, Turkey, United Kingdom, Uruguay, USA and Venezuela.

<sup>5</sup> In Section 4.4.2, we use oil prices (end of period) which is available from the IFS-IMF.

<sup>6</sup> In Section 4.4.3 we use last twenty years and the main results do not change significantly.

<sup>7</sup> In Section 4.4.1 we also do the analysis by adding China as a dominant country. Without considering USA and Germany as dominant countries, the results do not seem reasonable and are very unstable.

<sup>8</sup> We use the Autometrics, an automatic model selection with target size of 0.1 and unrestricted constant.



Table 1  
Estimated coefficients in baseline specification.

Country	Constant	Contemporaneous Coefficients			Lagged Coefficients (t-1)			R <sup>2</sup>	
		GDP*	GDP USA	GDP GER	GDP	GDP*	GDP USA		GDP GER
Argentina	-0.018	1.803	-	-	-	-	-0.923	-	0.23
Australia	0.013	-	-	-	-	-	0.591	-0.323	0.47
Austria	0.003	0.891	-	-	-	-	-	-	0.63
Belgium	-0.003	1.725	-0.315	-0.323	-	-	-	-	0.76
Brazil	-0.010	0.828	-	-	0.363	-	-	-	0.26
Canada	-0.003	0.868	-	-	0.324	-	-	-0.182	0.75
Chile	-0.026	-	0.776	-	0.287	0.941	-	-	0.28
China	0.047	-	-	-0.260	0.450	-	-	-	0.25
Colombia	0.008	1.399	-0.762	-	-	-	-	-	0.35
Denmark	-0.001	1.101	-	-	0.260	-0.516	-	-	0.65
Finland	-0.027	2.914	-0.488	-0.723	0.289	-	-	-	0.77
France	-0.005	0.857	-	-	0.181	-	-	-	0.79
Germany	0.015	-	-	-	0.027	-0.092	0.287	-	0.07
Greece	-0.006	-	0.681	-	0.440	-	-0.093	-	0.37
Hong Kong	0.019	-	0.566	0.691	-	-	-	-	0.30
India	0.053	-	-	-	-	-0.590	-	-	0.09
Indonesia	-0.019	2.060	-0.909	-	-	-	-0.674	0.826	0.48
Ireland	0.000	0.844	-	-	0.486	-	-	-	0.52
Italy	-0.012	1.697	-0.261	-	0.395	-0.423	-	-	0.78
Japan	-0.012	0.547	-	0.618	-	-	-	-	0.50
Korea	0.025	0.811	-	-	-	-	-	-	0.12
Mexico	0.002	-	-	0.650	-	-	-	-	0.15
Netherlands	-0.005	0.874	-	-	0.516	-	-	-0.237	0.82
New Zealand	0.004	-	0.680	-0.401	0.348	-	-	-	0.34
Norway	0.002	-	-	0.301	0.649	-	-	-	0.56
Paraguay	0.000	0.826	-	-	0.317	-	-	-	0.34
Peru	-0.027	2.226	-1.435	-	0.408	-	-	-	0.32
Portugal	-0.010	1.687	-	-	0.384	-1.021	-	0.483	0.70
Singapore	0.007	1.743	-	-	0.322	-1.084	-	-	0.61
South Africa	-0.015	0.610	-	-	0.506	-	-	-	0.26
Spain	-0.004	1.259	-0.150	-0.274	0.503	-	-	-0.172	0.83
Sweden	0.001	0.938	-	-	0.351	-	-	-0.534	0.69
Switzerland	-0.011	0.653	-	-	-	-	0.364	-	0.48
Turkey	0.024	-	-	-	-	-	-	-	0.00
United Kingdom	0.001	-	0.767	-	-	0.592	-	-0.464	0.64
Uruguay	-0.021	1.752	-	-0.636	0.479	-	-	-	0.60
United States	0.026	-	-	-	0.778	-0.821	-	-0.111	0.27
Venezuela	-0.046	2.675	-2.313	1.042	-	-	-	-	0.17

Table 1 shows the estimated coefficients for all equations. We can note that the external variable seems relevant for most of the countries. For Australia, China, Greece, Hong Kong, Mexico, New Zealand and Norway the external variable is not relevant, but United States or German growth rates are. Turkey is the only country that the model selection do not choose any variable at all. The reader can note that for most European countries the external/dominant variable is relevant. This fact can be seen by the R-squared in the regressions. Austria, Belgium and UK models do not contain any lagged variable, but external variables explains, respectively, 0.63, 0.76 and 0.64 of the variation of per capita GDP. We highlight that the coefficient estimates of USA and Germany are negative in many equations, but it does not mean that the impact of these countries are negative. There is a direct effect of the variable of these countries and an indirect effect given that they are part of external variable.

Fig. 1, in the Appendix, plots the roots of the system. The dynamics are stable and automatic model selection procedure helps to simplify the system. It is also possible to see that, since there are no roots close to the unit circle, the convergence after a shock is quite fast. In most simulations, the system is already stabilized five periods (years) after a shock.

### 4.3. Impulse response to the baseline model

In the first exercise we try to identify the impacts of a one-period shock to selected country. Particularly, our focus is to address the effects of shocks to the growth rates of United States, Germany and China on other countries. From our estimated model for United States, we obtain a residual in 2009 (the first year after the subprime crisis) of  $-4.44\%$ , which represents roughly 2.5 standard deviations. Since our point is to analyze the effect of crisis in United States, a value of this magnitude is not quite common and we consider as a negative shock that can occur with low probability. We also opt to simulate a shock of 2.5 standard deviations in Germany and China as well. Figs. 2–4 shows the estimated cumulative effect in  $t = 0, 1, 2$  and 5 periods ahead of a negative shock in each country. We also construct the estimated values from the bootstrapped confidence interval of 68% and 95%.

In the United States case, a shock of  $-4.4$  p.p. in GDP per capita significantly reduces the GDP growth in most countries contemporaneously, based on Fig. 2. Besides the impact on Commonwealth members (Canada, UK, Australia, New Zealand, and Singapore), most of European and South American countries also suffer significant impacts. Even after five periods of the shock, the estimated effect is still statistically different from zero in some countries. Our estimates suggest a great impact on Finland, Chile, Uruguay, Portugal, Greece, and Spain.

The scenario is similar in the German case based on Fig. 3. A shock of  $-4.8$  p.p. in GDP per capita also reduces other economies growth contemporaneously, but it has a positive impact in China and New Zealand. However, the shock dies out faster than a shock in United States and the effect spreads less to other countries than the USA shock. The final effect is stronger on oil producing countries such as Indonesia, Venezuela, Norway and Mexico. On the opposite side, the German negative shock has a positive effect on New Zealand, China, UK, Canada, Australia, and USA.

The effects of a Chinese negative shock is notably smaller compared to the previous ones based on Fig. 4. One possible reason is that we do not consider China as the dominant unit in this baseline model, which limits its shock to having only indirect effects in other countries.<sup>9</sup> China is an emerging market, and although it is the second largest economy in world, the scenario was quite different twenty years ago. The volatility of China's growth has been reduced a lot during the last two decades.<sup>10</sup> Shocks applied to China have stronger impact in South American and Asian countries. In Asia, some examples are Indonesia, Singapore, and South Korea. Maybe the effect of China is a regional one.

By doing the procedure described in Section 3.2, we address the effects of hypothetical 2% reduction in the stationary steady-state growth rate of the US, Germany and China. We present the results in Figs. 5–7. Although long-run effects are, by construction, qualitatively similar to the final effect of a one-period shock, the dynamics in first periods are different.

The results of our estimates suggest that a United States downturn would be more deleterious to world growth compared to a Chinese or a German downturn. Germany has a long-run per capita growth estimate close to 2% per year based on our model. China has an estimate of a 7.5% per capita growth rate per year. Basically, our results suggest that only a downturn in United States tend to generate relevant effects on a wider set of countries.

### 4.4. Robustness check and alternative specifications

Given that we are working with a narrow information set, there is a possibility that some equations may suffer from misspecification bias due to outliers or structural breaks. Furthermore, the choice of dominant countries and the time span considered to calculate the trade shares are also arbitrary. We perform some robustness checks to evaluate the sensitivity of our results to these choices.

We run simulations of previous sections under four different specifications given by:

- (a) imposing China as a dominant country, along with USA and Germany;
- (b) including the oil price as a global variable, that is common for all countries;
- (c) changing the trade weights to the mean of the last twenty years;

<sup>9</sup> In Section 4.4.1 we add China as a dominant country, but the results do not change much for most countries.

<sup>10</sup> The overall sample residual standard deviation for China is 2.9. Considering the last 20 years, these values changes to 1.5. In the simulations we consider the value of 1.5.

(d) proceeding an automatic dummy selection (impulse and level) after the choice of the variables did in previous section using Autometrics software.

We compare the estimates of these different specifications with the baseline model in [Table 2](#) for shocks in the USA and Germany and in [Table 3](#) for the shock in China, both tables in the appendix.<sup>11</sup>

#### 4.4.1. China as a dominant unit

Given the growing importance of China in international markets during the last decades, we think that we can consider China as a dominant unit country. In the baseline model, we use trade weights averages from the last ten years. This might help to control this issue, but we also opt to consider China as a dominant unit. In [Table 3](#), we present the impacts results from a negative shock in China on the other countries. China growth seems to be important for some European and Asian countries. However, the results are quite similar to the baseline model for most of countries and simulations that we perform. The major changes occur in the simulation of Chinese effects on other economies (results of [Table 3](#)), but there are also some minor second order changes in other countries simulations (results of [Table 2](#)). The effect of a Chinese downturn seems to be weaker on Indonesia and Finland and stronger in Chile and India.

#### 4.4.2. Oil price as a global variable

In the GVAR framework, it is common to add a global variable as an explanatory variable in all equations. In this subsection we consider the oil price as an exogenous variable, that is common to all countries. The inclusion of oil prices can help to avoid possible sources of misspecification, acting as a control variable.

Suppose now that the DGP is given by:

$$\Delta x_{i,t} = a_i + \phi_{i,1} \Delta x_{i,t-1} + \theta_{i,0} \Delta x_{i,t}^* + \theta_{i,1} \Delta x_{i,t-1}^* + \psi_{i,0} \Delta z_t + \psi_{i,1} \Delta z_{t-1} + \varepsilon_{it} \quad (11)$$

where  $\Delta z_t$  is a global variable. We can solve the system as we do before and obtain:

$$\Delta x_t = G^{-1} a + G^{-1} H \Delta x_{t-1} + G^{-1} \psi_0 \Delta z_t + G^{-1} \psi_1 \Delta z_{t-1} + G^{-1} \varepsilon_t \quad (12)$$

Contemporaneous or lagged oil prices are selected in sixteen out of thirty eight equations, with positive sign in developing countries equations, possibly reflecting their dependence on the price this commodity.<sup>12</sup> The results also do not change for most of countries, as presented in [Tables 2 and 3](#) in the appendix. Korea, Norway, Paraguay, Venezuela and Turkey are the countries whose results have been most affected by the inclusion of the oil price.

#### 4.4.3. Changing trade weights

International trade patterns have changed considerably in the last decades, specially due to globalization and the emergence of many developing countries, like China, India, and South Korea. Emerging countries have more importance in international trade nowadays than decades ago. Taking on the alternative to consider only the last few years to deal with this may reduce the importance of developed countries.

In this subsection, we change the weights used to calculate the external variables of the model by using a 20-year average, instead of the 10-year average used in the base model,<sup>13</sup> to address if and how recent changes in trade patterns alter our results. Results remain quite unchanged for almost all countries, with a small reduction of Chinese effect and an increase of USA effect. This result reflects our previous comment that using the twenty-year average trade weights increases the weight of developed countries and decreases the weight for emerging markets such as China. Our result is different from that obtained by [Cesa-Bianchi et al. \(2012\)](#) because the impact of USA and China shocks on growth in other countries is robust to the change in weights. [Cesa-Bianchi et al. \(2012\)](#) use time varying weights and their results indicate that the effect of Chinese shock on economic growth increases (three times) mainly after 1990 and the effect of USA shock decreases (in half) over the same period. Variables selected to be part of the model using Autometrics are different from baseline case only for Canada, Italy, Greece, Portugal, Chile and Venezuela.

<sup>11</sup> We use the Automatic model selection in the first three cases, with the same criteria as the baseline specification. In the automatic dummy selection (IIS+SIS in Autometrics), we choose the target size in 0.1%.

<sup>12</sup> We omit the results on whether the algorithm selects the oil price variable (similar to [table 1](#)), but these results can be requested from the authors.

<sup>13</sup> We cannot use a longer period due to the availability of data on trade flows.

#### 4.4.4. Searching for structural break/misspecification in the mean using Autometrics

Finally, permanent structural change in the growth rates may have happened during the period of the sample. This can be a possible source of misspecification. Emerging market countries during the time span of our sample suffered from at least one domestic crisis in the sample period. We present that developing countries have lower  $R$ -squared in Table 1. To handle this fact, in this subsection, we perform another automatic model selection procedure. Now we include level and impulse dummies using Autometrics to control for structural changes and instability in the DGP.

Since we want to incorporate only huge changes that have occurred, we opt to work with a very tight target  $p$ -value criteria of 0.1% to select a variable in the final model. In nineteen out of thirty eight countries equations, we select at least one break dummy variable. In Table 3 in the appendix, the effects of a one-period shock in China on other economies change only slightly. For United States and Germany (Table 2 in the appendix), the effects of the one-period shocks in the baseline model are stronger in many cases, possibly due the fact that outlier was affecting the estimates of the parameters of the equations. Nonetheless, the effect of a slowdown in Germany barely changes with respect to the baseline specification.

We can summarize the robustness section of the baseline model in the following points. First, when we consider China as the dominant unit in modeling, the China downturn effect does not change much, there are changes mainly in four countries. Second, when we consider the oil price variable as the global variable, there is more change in estimates for five countries out of the 38 countries in the sample. Third, when we consider the 20-year rather than 10-year trade weight (like the baseline model), the effect of a Chinese downturn decreases in other countries and that of the USA increases. However, the changes are small. Fourth, the inclusion of permanent structural breaks shows little change in estimates, but mainly shocks in the USA and Germany show little reduction.

## 5. Final remarks

Another crisis in USA or in Europe, or the possibility of a slowdown in the Chinese growth, could affect economies throughout the world, raising concerns not only to these countries, but to the countries with which they have high economic linkages. In this work, we assess the effect of those scenarios, using an *ex-ante* counterfactual analysis within a global autoregressive framework. We cover the period of 1970 to 2013 and 38 countries. We use the GAR model to consider the relationship between countries with the *Autometrics* algorithm to select variables from the GAR model to be more parsimonious. We consider a shock of 2.5 standard deviations and 2 p.p. in GDP per capita slowdown of the USA, China and Germany. The global linkages seem to be relevant and strong for European, South American and Commonwealth countries, but more discrete for Asian countries.

The results suggest that the United States still play the role of a global economy, affecting countries across the globe, whereas Germany and China play a regional role. By our estimates, China's slower growth per capita should not seriously affect the global economy. We address the effects of hypothetical 2% reduction in the stationary steady-state growth rate of the USA, Germany and China. The results indicate that, in the case of the shock in the USA, the 10 worst reactions from countries would be between  $-4.7\%$  and  $-2.2\%$  (concentrated between European, South American and Canada). In the case of Germany, the 10 worst falls would be between  $3\%$  and  $0.7\%$  (concentrated between European, Asian and Latin American countries). In the case of China, the 10 worst declines would be between  $2.2\%$  and  $0.5\%$  (concentrated in South American and Asian countries). In our estimates, the effect of the economy slowdown would be worse if the shock comes from the USA. According to our results, a Chinese downturn does not have a more deleterious effect on other countries if compared to a German downturn, for example.

Our results indicate that South American and Asian countries, including Brazil, are the ones most affected by a slowdown in the Chinese economy. Our paper has many policy implications. For example, for Brazil, a simultaneous slowdown of China and United States can probably hit harder this country. However, the United States effects on the South American economies are still greater than China in contrast with Cesa-Bianchi et al. (2012). Our results are robust to changes in trade weights. We analyze the results using the weight of the last 10 years (benchmark) and the last 20 years, but overall results do not change.

A closer look at individual models can help improve the significance of the results, but even with a simple one-variable reduced-form model, we obtained some intuitive and reasonable results. One possible future research would be to allow time-varying weights in order to analyze whether there is any change in the results obtained.



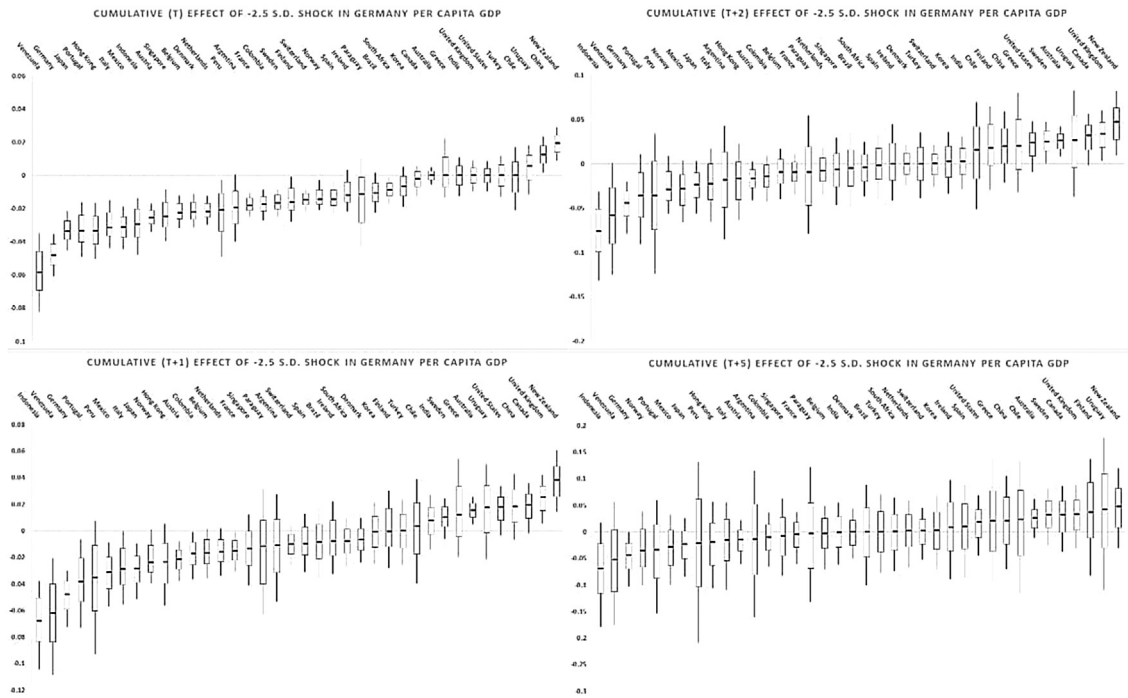


Fig. 3. Cumulative effect in T, T+1, T+2 and T+5 of a 2.5 S.D. shock in German GDP per capita.

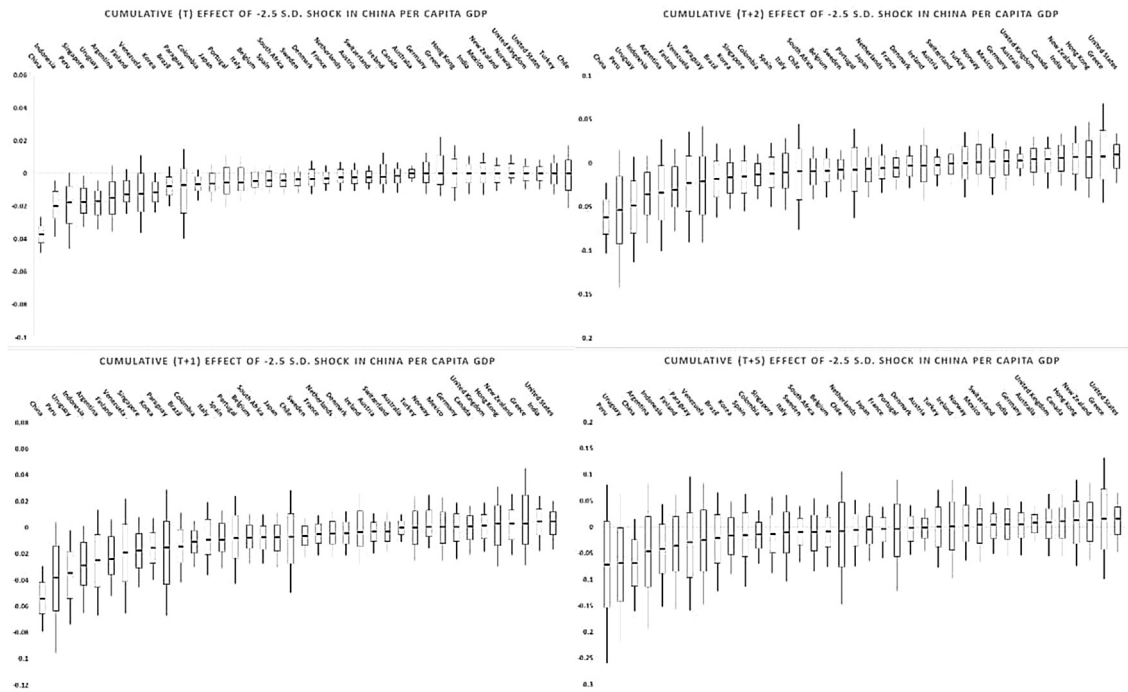


Fig. 4. Cumulative effect in T, T+1, T+2 and T+5 of a 2.5 S.D. shock in China GDP per capita.





Table 2  
Robustness check and alternative specifications for USA and Germany simulations.

Country	2.5 S.D. shock on USA GDP per Capita Growth					−2 p.p. slowdown on USA GDP per capita growth					
	Baseline	China as dominant	OIL	20 years	Dummy	Baseline	China as Dominant	OIL	20 years	Dummy	
Finland	−12.9%	−11.4%	−15.3%	−14.7%	−11.2%	Finland	−4.7%	−4.0%	−5.8%	−5.9%	−3.0%
Uruguay	−11.6%	−10.4%	−13.1%	−13.7%	−14.0%	Uruguay	−4.2%	−3.6%	−4.9%	−5.5%	−3.8%
Chile	−10.3%	−2.2%	−10.1%	−6.8%	−4.2%	Chile	−3.7%	−0.8%	−3.8%	−2.7%	−1.1%
Spain	−9.7%	−8.2%	−10.7%	−12.1%	−11.5%	Spain	−3.5%	−2.9%	−4.0%	−4.8%	−3.1%
Ireland	−8.8%	−7.8%	−9.0%	−8.9%	−10.0%	Ireland	−3.2%	−2.7%	−3.4%	−3.5%	−2.7%
Portugal	−7.5%	−6.8%	−7.6%	−12.2%	−9.4%	Portugal	−2.7%	−2.4%	−2.8%	−4.9%	−2.5%
Netherlands	−7.2%	−6.4%	−7.6%	−8.0%	−7.9%	Netherlands	−2.6%	−2.2%	−2.9%	−3.2%	−2.1%
Italy	−7.0%	−6.9%	−7.4%	−8.2%	−6.4%	Italy	−2.5%	−2.4%	−2.8%	−3.3%	−1.7%
United Kingdom	−6.7%	−5.2%	−6.9%	−6.6%	−10.1%	United Kingdom	−2.4%	−1.8%	−2.6%	−2.6%	−2.8%
Canada	−6.3%	−6.2%	−5.9%	−5.6%	−9.3%	Canada	−2.3%	−2.2%	−2.2%	−2.2%	−2.5%
Paraguay	−6.2%	−5.1%	−3.3%	−7.5%	−6.6%	Paraguay	−2.2%	−1.8%	−1.2%	−3.0%	−1.8%
Greece	−5.8%	−6.1%	−6.7%	−5.4%	−14.1%	Greece	−2.1%	−2.1%	−2.5%	−2.1%	−3.8%
Belgium	−5.8%	−4.7%	−6.3%	−6.8%	−6.0%	Belgium	−2.1%	−1.7%	−2.4%	−2.7%	−1.6%
Sweden	−5.8%	−5.2%	−7.2%	−6.4%	−7.8%	Sweden	−2.1%	−1.8%	−2.7%	−2.5%	−2.1%
United States	−5.6%	−5.7%	−5.4%	−5.0%	−7.3%	United States	−2.0%	−2.0%	−2.0%	−2.0%	−2.0%
France	−5.1%	−4.2%	−5.2%	−5.7%	−4.9%	France	−1.8%	−1.5%	−2.0%	−2.3%	−1.3%
New Zealand	−5.1%	−4.7%	−5.3%	−4.6%	−9.7%	New Zealand	−1.8%	−1.6%	−2.0%	−1.8%	−2.6%
Brazil	−5.0%	−4.7%	−5.2%	−6.3%	−3.9%	Brazil	−1.8%	−1.6%	−2.0%	−2.5%	−1.1%
Switzerland	−4.7%	−3.1%	−4.6%	−4.7%	−5.2%	Switzerland	−1.7%	−1.1%	−1.7%	−1.9%	−1.4%
South Africa	−4.5%	−4.5%	−2.8%	−4.8%	−4.7%	South Africa	−1.6%	−1.6%	−1.0%	−1.9%	−1.3%
Hong Kong	−3.9%	−5.0%	−3.4%	−3.6%	−2.9%	Hong Kong	−1.4%	−1.7%	−1.3%	−1.4%	−0.8%
Denmark	−3.6%	−3.3%	−4.0%	−3.7%	−3.4%	Denmark	−1.3%	−1.2%	−1.5%	−1.5%	−0.9%
Argentina	−3.6%	−2.0%	−4.0%	−4.6%	−0.6%	Argentina	−1.3%	−0.7%	−1.5%	−1.8%	−0.2%
Austria	−3.2%	−3.1%	−3.1%	−3.5%	−1.9%	Austria	−1.2%	−1.1%	−1.2%	−1.4%	−0.5%
Australia	−2.9%	−2.1%	−3.0%	−2.6%	−5.4%	Australia	−1.1%	−0.7%	−1.1%	−1.0%	−1.5%
Peru	−2.8%	−0.8%	−3.5%	−4.6%	−1.7%	Peru	−1.0%	−0.3%	−1.3%	−1.8%	−0.5%
Japan	−2.4%	−3.2%	−1.8%	−2.8%	−0.9%	Japan	−0.9%	−1.1%	−0.7%	−1.1%	−0.2%
Singapore	−2.1%	−6.1%	−1.3%	−3.0%	−2.3%	Singapore	−0.8%	−2.1%	−0.5%	−1.2%	−0.6%
Colombia	−2.1%	−2.2%	−4.1%	−3.2%	−1.9%	Colombia	−0.8%	−0.8%	−1.6%	−1.3%	−0.5%
Korea	−1.9%	−4.9%	0.2%	−3.1%	−1.3%	Korea	−0.7%	−1.7%	0.1%	−1.3%	−0.4%
Germany	−1.1%	−1.2%	−0.5%	−1.1%	3.4%	Germany	−0.4%	−0.4%	−0.2%	−0.4%	0.9%
Norway	−1.0%	−1.1%	−4.2%	−0.9%	2.8%	Norway	−0.4%	−0.4%	−1.6%	−0.4%	0.8%
Mexico	−0.7%	0.0%	−0.2%	−0.7%	2.2%	Mexico	−0.3%	0.0%	−0.1%	−0.3%	0.6%
Venezuela	−0.1%	−4.5%	−3.1%	−4.8%	5.5%	Venezuela	0.0%	−1.6%	−1.2%	−1.9%	1.5%
Turkey	0.0%	0.0%	−3.2%	0.0%	0.0%	Turkey	0.0%	0.0%	−1.2%	0.0%	0.0%
China	0.5%	0.0%	0.2%	0.5%	−0.3%	China	0.2%	0.0%	0.1%	0.2%	−0.1%
India	2.3%	2.5%	2.3%	2.7%	2.6%	India	0.8%	0.9%	0.9%	1.1%	0.7%
Indonesia	2.4%	−5.4%	2.2%	0.8%	2.5%	Indonesia	0.9%	−1.9%	0.8%	0.3%	0.7%

Table 2 (Continued)

Country	2.5 S.D. shock on Germany GDP per Capita Growth					-2 p.p. slowdown on Germany GDP per capita growth					
	Baseline	China as dominant	OIL	20 years	Dummy	Baseline	China as Dominant	OIL	20 years	Dummy	
Indonesia	-6.8%	-1.3%	-6.3%	-6.1%	-3.3%	Indonesia	-3.0%	-0.6%	-2.7%	-2.6%	-1.0%
Venezuela	-5.2%	-5.1%	0.2%	0.5%	-8.6%	Venezuela	-2.3%	-2.4%	0.1%	0.2%	-2.7%
Germany	-4.5%	-4.3%	-4.7%	-4.6%	-6.5%	Germany	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%
Norway	-3.9%	-3.7%	1.2%	-3.9%	-5.6%	Norway	-1.7%	-1.7%	0.5%	-1.7%	-1.7%
Portugal	-3.6%	-3.8%	-5.3%	-2.6%	-1.9%	Portugal	-1.6%	-1.8%	-2.2%	-1.1%	-0.6%
Mexico	-2.9%	0.0%	-2.3%	-3.0%	-4.2%	Mexico	-1.3%	0.0%	-1.0%	-1.3%	-1.3%
Japan	-2.5%	-2.1%	-2.9%	-2.2%	-2.2%	Japan	-1.1%	-1.0%	-1.2%	-1.0%	-0.7%
Hong Kong	-2.1%	-2.3%	-2.3%	-2.5%	-1.9%	Hong Kong	-1.0%	-1.1%	-1.0%	-1.1%	-0.6%
Peru	-1.7%	-6.9%	-2.4%	-0.6%	-3.0%	Peru	-0.8%	-3.2%	-1.0%	-0.3%	-0.9%
Austria	-1.5%	-1.7%	-1.8%	-1.4%	-2.6%	Austria	-0.7%	-0.8%	-0.8%	-0.6%	-0.8%
Italy	-1.5%	-1.1%	-2.2%	-0.4%	-3.4%	Italy	-0.7%	-0.5%	-0.9%	-0.2%	-1.1%
Argentina	-1.0%	-4.6%	-1.2%	0.1%	-3.3%	Argentina	-0.4%	-2.1%	-0.5%	0.0%	-1.0%
Colombia	-1.0%	-1.9%	0.5%	-0.1%	-1.0%	Colombia	-0.4%	-0.9%	0.2%	0.0%	-0.3%
Singapore	-0.8%	1.6%	-2.6%	-0.9%	-0.4%	Singapore	-0.4%	0.8%	-1.1%	-0.4%	-0.1%
France	-0.5%	-0.3%	-1.5%	-0.1%	-1.1%	France	-0.2%	-0.2%	-0.6%	-0.1%	-0.4%
Belgium	-0.2%	-0.4%	-0.8%	0.4%	-1.1%	Belgium	-0.1%	-0.2%	-0.3%	0.2%	-0.3%
Denmark	-0.1%	-0.4%	0.1%	-0.1%	-0.9%	Denmark	0.0%	-0.2%	0.0%	0.0%	-0.3%
India	-0.1%	-1.0%	0.2%	-0.1%	-0.1%	India	0.0%	-0.5%	0.1%	0.0%	0.0%
Paraguay	0.0%	-2.5%	-2.8%	0.8%	-1.9%	Paraguay	0.0%	-1.2%	-1.2%	0.3%	-0.6%
Turkey	0.0%	0.0%	1.0%	0.0%	0.0%	Turkey	0.0%	0.0%	0.4%	0.0%	0.0%
South Africa	0.0%	-0.5%	2.2%	0.1%	-0.2%	South Africa	0.0%	-0.2%	0.9%	0.1%	-0.1%
Switzerland	0.1%	-1.2%	-0.2%	0.0%	0.1%	Switzerland	0.0%	-0.5%	-0.1%	0.0%	0.0%
Brazil	0.1%	-1.2%	-0.1%	0.5%	-0.7%	Brazil	0.0%	-0.6%	0.0%	0.2%	-0.2%
Korea	0.2%	-0.2%	-4.4%	0.1%	0.0%	Korea	0.1%	-0.1%	-1.9%	0.0%	0.0%
Netherlands	0.4%	-0.4%	-0.1%	0.9%	-0.2%	Netherlands	0.2%	-0.2%	-0.1%	0.4%	-0.1%
Ireland	0.9%	0.4%	0.3%	0.9%	0.9%	Ireland	0.4%	0.2%	0.1%	0.4%	0.3%
Spain	1.3%	0.5%	0.2%	2.5%	0.4%	Spain	0.6%	0.2%	0.1%	1.1%	0.1%
United States	1.7%	2.3%	1.6%	1.2%	2.9%	United States	0.8%	1.1%	0.7%	0.5%	0.9%
Greece	1.8%	4.5%	2.0%	3.4%	5.6%	Greece	0.8%	2.1%	0.9%	1.5%	1.7%
Chile	2.1%	-7.4%	1.4%	1.7%	0.3%	Chile	0.9%	-3.5%	0.6%	0.7%	0.1%
China	2.1%	0.0%	2.2%	2.2%	0.5%	China	0.9%	0.0%	0.9%	0.9%	0.2%
Australia	2.5%	1.7%	2.5%	2.2%	3.8%	Australia	1.1%	0.8%	1.0%	1.0%	1.2%
Canada	3.0%	2.1%	1.5%	2.7%	4.7%	Canada	1.3%	1.0%	0.6%	1.2%	1.4%
United Kingdom	3.3%	1.6%	3.1%	3.1%	4.8%	United Kingdom	1.5%	0.7%	1.3%	1.3%	1.5%
Sweden	3.3%	2.5%	4.1%	3.8%	0.7%	Sweden	1.5%	1.2%	1.7%	1.7%	0.2%
Finland	4.0%	1.6%	5.6%	5.3%	-1.4%	Finland	1.8%	0.8%	2.4%	2.3%	-0.4%
New Zealand	4.5%	4.2%	4.5%	4.1%	7.0%	New Zealand	2.0%	1.9%	1.9%	1.8%	2.2%
Uruguay	4.8%	0.6%	5.1%	6.2%	3.9%	Uruguay	2.1%	0.3%	2.2%	2.7%	1.2%

Table 3  
Robustness check and alternative specifications for China simulations.

Country	2.5 S.D. shock on China GDP per Capita Growth					−2 p.p. slowdown on China GDP per capita growth					
	Baseline	China as dominant	OIL	20 years	Dummy	Baseline	China as Dominant	OIL	20 years	Dummy	
Uruguay	−7.6%	−7.8%	−8.0%	−4.3%	−7.0%	Uruguay	−2.2%	−2.2%	−2.2%	−1.2%	−2.0%
Peru	−7.5%	−7.4%	−7.4%	−4.8%	−4.2%	Peru	−2.1%	−2.1%	−2.1%	−1.4%	−1.2%
China	−7.0%	−7.1%	−7.2%	−6.9%	−6.8%	China	−2.0%	−2.0%	−2.0%	−2.0%	−2.0%
Argentina	−4.9%	−5.3%	−4.9%	−2.4%	−3.9%	Argentina	−1.4%	−1.5%	−1.4%	−0.7%	−1.1%
Indonesia	−4.3%	−1.5%	−5.2%	−2.9%	−0.9%	Indonesia	−1.2%	−0.4%	−1.4%	−0.8%	−0.3%
Finland	−3.8%	−1.7%	−2.8%	−2.1%	−2.8%	Finland	−1.1%	−0.5%	−0.8%	−0.6%	−0.8%
Paraguay	−3.2%	−3.5%	−1.0%	−1.6%	−3.6%	Paraguay	−0.9%	−1.0%	−0.3%	−0.5%	−1.0%
Venezuela	−2.6%	−4.6%	−3.5%	−2.9%	−1.5%	Venezuela	−0.7%	−1.3%	−1.0%	−0.8%	−0.4%
Brazil	−2.3%	−2.3%	−2.3%	−1.2%	−1.7%	Brazil	−0.7%	−0.7%	−0.6%	−0.4%	−0.5%
Korea	−1.7%	0.9%	1.4%	−1.6%	−1.0%	Korea	−0.5%	0.2%	0.4%	−0.5%	−0.3%
Spain	−1.6%	0.6%	−2.9%	−0.6%	−1.2%	Spain	−0.5%	0.2%	−0.8%	−0.2%	−0.4%
Colombia	−1.6%	−1.8%	−0.3%	−1.1%	−0.6%	Colombia	−0.4%	−0.5%	−0.1%	−0.3%	−0.2%
Singapore	−1.3%	1.0%	−2.8%	−0.9%	−0.8%	Singapore	−0.4%	0.3%	−0.8%	−0.3%	−0.2%
Italy	−1.1%	1.3%	−1.4%	−0.1%	−0.7%	Italy	−0.3%	0.4%	−0.4%	0.0%	−0.2%
Sweden	−1.1%	−0.2%	−1.2%	−0.6%	−0.8%	Sweden	−0.3%	−0.1%	−0.3%	−0.2%	−0.2%
South Africa	−1.0%	−0.7%	−1.1%	−0.6%	−0.9%	South Africa	−0.3%	−0.2%	−0.3%	−0.2%	−0.3%
Belgium	−0.9%	1.0%	−1.4%	−0.4%	−0.7%	Belgium	−0.3%	0.3%	−0.4%	−0.1%	−0.2%
Chile	−0.8%	−5.7%	−0.5%	1.2%	−1.2%	Chile	−0.2%	−1.6%	−0.1%	0.3%	−0.4%
Netherlands	−0.6%	−0.3%	−0.9%	−0.2%	−0.4%	Netherlands	−0.2%	−0.1%	−0.3%	−0.1%	−0.1%
Japan	−0.5%	0.6%	−0.1%	−0.5%	−0.4%	Japan	−0.1%	0.2%	0.0%	−0.1%	−0.1%
France	−0.4%	1.4%	−1.1%	−0.1%	−0.2%	France	−0.1%	0.4%	−0.3%	0.0%	−0.1%
Portugal	−0.3%	0.9%	−2.4%	0.5%	−0.5%	Portugal	−0.1%	0.2%	−0.7%	0.2%	−0.1%
Denmark	−0.2%	0.1%	−0.2%	−0.1%	−0.1%	Denmark	−0.1%	0.0%	−0.1%	0.0%	0.0%
Austria	−0.1%	1.2%	0.0%	0.0%	0.2%	Austria	0.0%	0.3%	0.0%	0.0%	0.1%
Turkey	0.0%	0.0%	1.0%	0.0%	0.0%	Turkey	0.0%	0.0%	0.3%	0.0%	0.0%
Ireland	0.1%	1.0%	−0.1%	0.2%	0.1%	Ireland	0.0%	0.3%	0.0%	0.1%	0.0%
Mexico	0.3%	0.0%	0.4%	0.2%	0.7%	Mexico	0.1%	0.0%	0.1%	0.1%	0.2%
Switzerland	0.4%	−0.5%	0.4%	0.3%	0.4%	Switzerland	0.1%	−0.1%	0.1%	0.1%	0.1%
Norway	0.4%	0.3%	1.3%	0.2%	0.9%	Norway	0.1%	0.1%	0.4%	0.1%	0.3%
India	0.4%	−3.5%	0.5%	0.2%	0.4%	India	0.1%	−1.0%	0.1%	0.1%	0.1%
Germany	0.5%	0.4%	0.9%	0.3%	1.1%	Germany	0.1%	0.1%	0.2%	0.1%	0.3%
Australia	0.8%	0.3%	0.7%	0.4%	0.3%	Australia	0.2%	0.1%	0.2%	0.1%	0.1%
United Kingdom	0.9%	0.8%	0.7%	0.5%	0.3%	United Kingdom	0.2%	0.2%	0.2%	0.2%	0.1%
Canada	1.2%	1.0%	1.3%	1.0%	0.6%	Canada	0.3%	0.3%	0.4%	0.3%	0.2%
Hong Kong	1.2%	−0.1%	1.5%	0.7%	1.4%	Hong Kong	0.4%	0.0%	0.4%	0.2%	0.4%
New Zealand	1.3%	−1.2%	1.2%	0.8%	0.5%	New Zealand	0.4%	−0.3%	0.3%	0.2%	0.1%
United States	1.6%	1.3%	1.7%	0.9%	1.1%	United States	0.4%	0.4%	0.5%	0.3%	0.3%
Greece	1.6%	1.3%	2.1%	0.9%	2.1%	Greece	0.5%	0.4%	0.6%	0.3%	0.6%

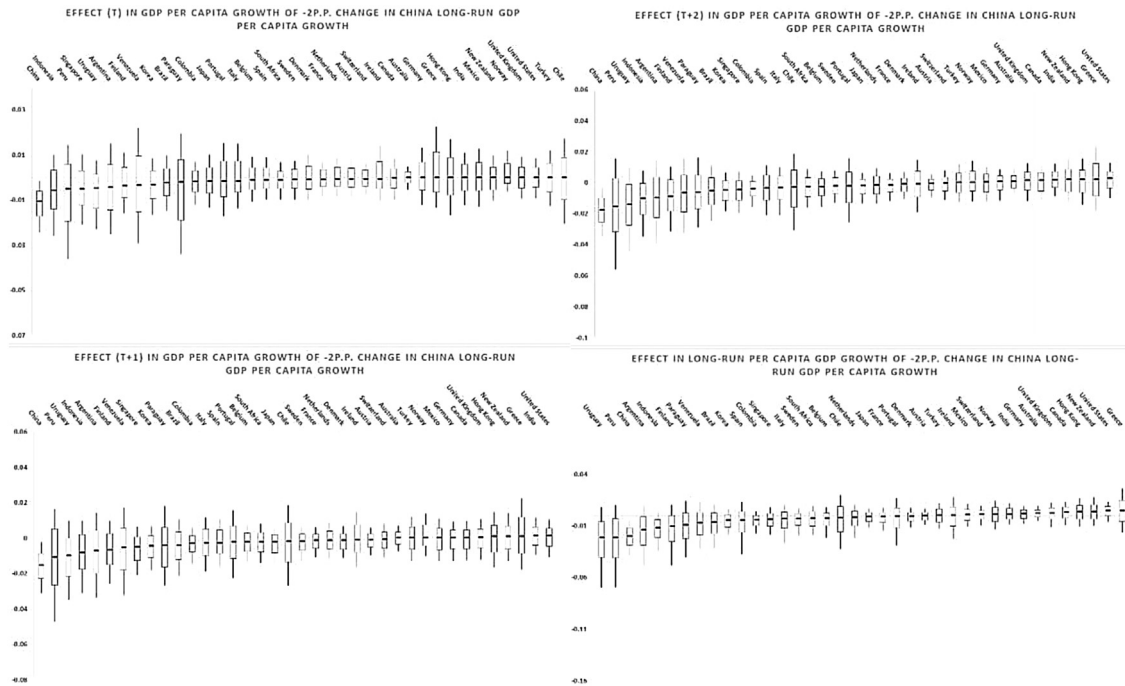


Fig. 7. Cumulative effect in T, T+1, T+2 and in steady-state of a 2 p.p. slowdown in China GDP per capita.

## References

- Andritzky, J., Kassner, B., Reuter, W.H., 2019. Propagation of changes in demand through international trade: a case study of china. *World Econ.* 42 (4), 1259–1285.
- Bagliano, F.C., Morana, C., 2012. The great recession: US dynamics and spillovers to the world economy. *J. Bank. Finance* 36 (1), 1–13.
- Baldwin, R., Teulings, C., 2014. *Secular Stagnation: Facts, Causes and Cures*. Centre for Economic Policy Research-CEPR, London.
- Bataa, E., Osborn, D.R., Sensier, M., 2018. China's increasing global influence: changes in international growth linkages. *Econ. Model.* 74, 194–206.
- Bems, R., Johnson, R.C., Yi, K.-M., 2010. Demand spillovers and the collapse of trade in the global recession. *IMF Econ. Rev.* 58 (2), 295–326.
- Blanchard, O.J., Das, M., Faruqee, H., 2010. The initial impact of the crisis on emerging market countries. *Brook. Papers Econ. Act.* 1.
- Bussiere, M., Chudik, A., Sestieri, G., 2009. Modelling Global Trade Flows: Results From a Gvar Model.
- Castle, J.L., Hendry, D.F., 2014. Model selection in under-specified equations facing breaks. *J. Econom.* 178, 286–293.
- Cerra, V., Saxena, S.C., 2008. Growth dynamics: the myth of economic recovery. *Am. Econ. Rev.* 98 (1), 439–457.
- Cesa-Bianchi, A., Pesaran, M.H., Rebucci, A., Xu, T., Chang, R., 2012. China's emergence in the world economy and business cycles in Latin America. *EconomiA* 12 (2), 1–75.
- Chudik, A., Smith, V., 2013. *The GVAR Approach and the Dominance of the US Economy*. Federal Reserve Bank of Dallas, Technical Report.
- Diebold, F.X., Yilmaz, K., 2015. Measuring the dynamics of global business cycle connectedness. In: *Unobserved Components and Time Series Econometrics*. Oxford University Press, pp. 45–70.
- Doyle, B.M., Faust, J., 2005. Breaks in the variability and comovement of g-7 economic growth. *Rev. Econ. Stat.* 87 (4), 721–740.
- Eaton, J., Kortum, S., Neiman, B., Romalis, J., 2016. Trade and the global recession. *Am. Econ. Rev.* 106 (11), 3401–3438.
- Eickmeier, S., Kühnlenz, M., 2018. China's role in global inflation dynamics. *Macroecon. Dyn.* 22 (2), 225–254.
- Feldkircher, M., Korhonen, I., 2014. The rise of china and its implications for the global economy: evidence from a global vector autoregressive model. *Pac. Econ. Rev.* 19 (1), 61–89.
- Gauvin, L., Rebillard, C.C., 2018. Towards recoupling? Assessing the global impact of a chinese hard landing through trade and commodity price channels. *World Econ.* 41 (12), 3379–3415.
- Han, L., Qi, M., Yin, L., 2016. Macroeconomic policy uncertainty shocks on the chinese economy: a GVAR analysis. *Appl. Econ.* 48 (51), 4907–4921.
- Hendry, D.F., 2011. Empirical model discovery and theory evaluation. *Ration. Mark. Morals* 2.
- Hendry, D.F., Doornik, J.A., 2014. *Empirical Model Discovery and Theory Evaluation: Automatic Selection Methods in Econometrics*. MIT Press.
- Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. *J. Econom.* 74 (1), 119–147.
- Kose, M.A., Loungani, P., Terrones, M.E., 2013. From the global to the national cycle: an intricate liaison. *Pac. Econ. Rev.* 18 (3), 370–402.
- Kose, M.A., Otrok, C., Whiteman, C.H., 2003. International business cycles: world, region, and country-specific factors. *Am. Econ. Rev.* 93 (4), 1216–1239.
- Montinari, L., Stracca, L., 2016. Trade, finance or policies: what drives the cross-border spill-over of business cycles? *J. Macroecon.* 49, 131–148.
- Osborn, D.R., Vehbi, T., 2015. Growth in china and the us: effects on a small commodity exporter economy. *Econ. Model.* 45, 268–277.

- Pentecote, J.-S., Rondeau, F., 2018. Withstanding financial crises: would trade partners help or hurt? *Appl. Econ.* 50 (11), 1254–1267.
- Pesaran, H.H., Shin, Y., 1998. Generalized impulse response analysis in linear multivariate models. *Econ. Lett.* 58 (1), 17–29.
- Pesaran, M.H., Schuermann, T., Weiner, S.M., 2004. Modeling regional interdependencies using a global error-correcting macroeconomic model. *J. Bus. Econ. Stat.* 22 (2), 129–162.
- Summers, L.H., 2015. Demand side secular stagnation. *Am. Econ. Rev.* 105 (5), 60–65.
- Sun, Y., Heinz, F., Ho, G., 2013. Cross-Country Linkages in Europe: A Global VAR Analysis., pp. 2, IMF Working Paper.
- Zhang, D., Lei, L., Ji, Q., Kutan, A.M., 2019. Economic policy uncertainty in the US and china and their impact on the global markets. *Econ. Model.* 79, 47–56.