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A GVAR Approach

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The Impact of the US Stock Market on the BRICS and G7: A GVAR Approach

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Abstract
Purpose – The authors investigate the impact of the US stock market on the economies of the BRICS and major industrialized economies (G7).
Design/methodology/approach – The authors construct the world economy and the vulnerability between economies using three economic integration variables: bilateral trade, bilateral direct investment and bilateral equity positions. Global vector autoregressive (GVAR) empirical studies usually adopt trade integration to estimate models. The authors complement these studies by using bilateral financial flows.
Findings – The authors summarize the results in four points: (1) financial integration variables increase the effect of the US stock market on the BRICS and G7, (2) the US shock produces similar responses in these groups regarding industrial production, stock markets and confidence but different responses regarding domestic currencies: in the BRICS, the authors detect appreciation of the currencies, while in the G7, the authors find depreciation, (3) G7 stock markets and policy rates are more sensitive to the US shock than the BRICS and (4) the estimates point out to heterogeneities such as the importance of industrial production to the transmission shock in Japan and China, the exchange rate to India, Japan and the UK, the interest rates to the Eurozone and the UK and confidence to Brazil, South Africa and Canada.
Research limitations/implications – The results reinforce the importance of taking into account different levels of economic development.
Originality/value – The authors construct the world economy and the vulnerability between economies using three economic integration variables: bilateral trade, bilateral direct investment and bilateral equity positions. GVAR empirical studies usually adopt trade integration to estimate models. The authors complement these studies by using bilateral financial flows.

Keywords Stock market, Financial flow, Bilateral trade, Transmission channel

JEL Classification — E37, F41, F47

1. Introduction

The latest events involving external shocks, like Covid-19 and the abrupt surge of oil prices, remind us how the international scenario can cause fluctuations in the domestic economies. BRICS, as a group of emerging market economies, is susceptible and vulnerable to volatility in these episodes. Besides external events, domestic shocks can also be a significant source of economic fluctuations, mainly when we consider markets highly sensitive to investors' uncertainty, such as the stock market. Although major industrialized economies (G7) have developed financial markets, they can also present persistent fluctuations to external financial shocks, such as the financial crisis of 2008.

This paper analyzes the impact of the U.S. stock market on the BRICS and G7. We evaluate how domestic stock markets, exchange rates, policy rates, confidence, and industrial production react to this shock. Additionally, we test the results using three proxies for economic integration: bilateral trade, bilateral direct investment, and bilateral equity positions. Thus, we can detect the importance of economic integration to financial shocks.

Following the approach of macro-econometric modeling with a global perspective (Pesaran and Smith, 2006), our strategy consists of a Global Vector Autoregressive (GVAR) model from 1999M1 to 2021M12. We construct a model with 24 developed and developing economies. We connect economies using bilateral trade and financial flow, which allows us to detect the transmission of shocks and simulate the world economy. Another characteristic of the GVAR is that we can analyze individually each economy instead of aggregations; thus, we can investigate how the domestic dynamics of Brazil, Russia, India, China, South Africa, Canada, Japan, the Eurozone, the U.K., and the U.S. respond to a local shock. Hence, we capture spillover effects and heterogeneities.

The results indicated that the economic integration variable is relevant to understand the impact of the U.S. stock market. We found that bilateral financial variables boost the effect of the U.S. shock. However, the fluctuations of the domestic variables do not change because of the integration variable. In other words, the impulse response functions show similar responses to the U.S. shock. The difference is in the influence of the U.S. stock market to explain domestic variables (variance decomposition).

Regarding the responses of the BRICS and G7, we detected that the stock markets and policy rates of G7 are more sensitive to the U.S. shock than the BRICS. Another difference is that the currencies of the BRICS appreciate in response to the shock while the currencies of the G7 depreciate. We also found similarities, such as the reactions of industrial production and confidence. The U.S. stock market shock promotes a global economic boom.

The literature about stock market shocks and fluctuations employs time series methods such as the GARCH and the VAR (Chuliá et al., 2017; Song et al., 2022). We implement the GVAR approach (Pesaran et al., 2004; Pesaran and Smith, 2006; Di Mauro and Pesaran, 2013; Chudik and Pesaran, 2016), a methodology that uses trade to connect economies (e.g., Bettendorf, 2018 and Pesaran et al., 2007). Soydemir (2000) concludes that trade had a relevant influence on the results of the interdependence between stock markets. However, the econometric approach used by the author (VAR) does not deal directly with trade. GVAR, on the other hand, by including explicitly bilateral trade as economic integration, addresses this point.

One of the main contributions of this paper is to provide a comparative analysis of the U.S. stock market shock using three alternative proxies of economic integration. Most GVAR studies employ bilateral trade. However, regarding financial shocks, we can raise the hypothesis that the main transmission channels are financial ones. Thus, our investigation tests bilateral financial flow. We provide results using bilateral trade and financial flow, which allows us to evaluate how economic integration affects the results.

Sevinc and Mata Flores (2021) analyze with a GVAR the diversity of responses between OECD regions showing the asymmetric impacts and degrees of relative vulnerability towards disturbances in international markets. Aggarwal and Raja (2019) examined the dependence between the stock markets of the BRICS using variance decomposition. Su (2020) includes, besides the BRICS, other relevant world economies, but its model only aggregates a specific measure of spillover coming from abroad. Tabak and Lima (2002) and Tabak (2006) investigated the Brazilian economy using a few trade partners and a reduced number of variables. Sharma et al. (2013) and Sui and Sun (2016) analyzed the influence of China on BRICS without considering bilateral trade. Our GVAR approach allows us to expand on both limitations. We compare the responses of two distinct groups due to economic development: BRICS, a group of emerging economies, and G7, a group of major industrialized economies. This distinction allows us to detect specific patterns due to economic development. Additionally, because GVAR considers the domestic dynamics, we evaluate each economy individually, providing more details to the analysis.

Chudik and Fratzscher (2011) analyzed the 2008 financial crisis and portrayed the effect of the U.S. stock market shock on developed and emerging economies. They concluded that the U.S. financial market provokes global fluctuations. However, this study used only financial variables: interest rates, stock markets, and the difference between the U.S. short-term money market and U.S. treasuries. We complement this study by constructing a broader system with real and financial variables: industrial production, stock market, interest rate, confidence, and exchange rate. Hence, our model provides real and financial responses to the U.S. stock market shock.

In this context, we elucidate the U.S. shock and the responses of domestic stock markets while discussing potential transmission channels. This contributes to the literature on understanding external stock market shocks and how they affect a set of economies through fluctuations in financial and real variables. Chudik and Fratzscher (2011) employed a limited set of domestic variables (money market rates and stock markets), preventing their study from advancing in this aspect. For instance, their model does not address the linkage between production and financial shocks. By incorporating industrial production and financial variables, we can explore connections between the financial and real sectors. Finally, we extend our analysis to three financial markets (credit, stock, and exchange markets) and incorporate uncertainty to better capture the sensitivity of economies to the U.S. shock.

The structure of the paper is as follows. Section 2 presents the methodology and data. Section 3 discusses the results and section 4 presents some concluding remarks. In the Online Appendix, we present a theoretical model which motivates our analysis.

2. Methodology and data

We use the Global Vector Autoregressive (GVAR). Equations (1) and (2) present the initial structure of the model. Equation (1) presents the vector of domestic variables of the region i in time t, x_{it}; the vector of foreign variables, x_{it}^{*}; the constant, a_{i0}; the trend, a_{i1}; the vectors of domestic and foreign variables lagged in one period; and the vector of idiosyncratic shocks, ε_{it}.

$$x_{it} = a_{i0} + a_{i1}t + \Phi_i x_{i,t-1} + \Lambda_{i0} x_{it}^{*} + \Lambda_{i1} x_{i,t-1}^{*} + \varepsilon_{it}. \quad (1)$$

$$x_{it}^{*} = \sum_{j=0}^{N} w_{ij} x_{jt}. \quad (2)$$

Equation (2) shows how we construct the foreign variables. Foreign variables simulate the world economy and the vulnerability between economies. The term w_{ij} illustrates the connection between economies. Most GVAR empirical studies utilize bilateral trade to connect economies (Pesaran et al., 2004; Dees et al., 2007; Attílio et al., 2023). However, as discussed in the introduction, this integration variable can omit relevant financial effects. Regarding real effects, bilateral trade, by representing the flow of goods, is a proper proxy for economic integration. As we analyze financial shocks, we test other two proxies for economic integration: bilateral direct investment and equity. In this case, w_{ij} is the financial flow between regions i and j. Consequently, in addition to connecting economies through bilateral trade, we establish connections using two alternative links: one involving bilateral financial investment and another centered on equities. We test our results using three integration variables: trade, financial investment, and equities. We construct three measures of w_{ij} for each of these variables.

One advantage of testing different integration linkages for our goal is that we can compare our results according to the type of integration, allowing us to evaluate the importance of financial and trade integration in the transmission of stock market shocks. This strategy was applied by Sevinc and Mata Flores (2021), who analyzed the impact of shocks on OECD economies using four integration approaches: financial, trade, migration, and geographical.

Table 1 presents the data. We use the industrial production index (2015 = 100) from the Organization for Economic Cooperation and Development (OECD) Main Economic Indicators. We seasonally adjusted this time series. We adopt the total industrial production, including construction and manufacturing. Due to missing values in the data, we use only construction production for China and manufacturing for Mexico, Indonesia, and South Africa.

We use share prices (2015 = 100) from the OECD Economic Outlook to represent stock market value. We deflated this time series using the consumer price index (CPI) from the OECD Economic Outlook. Additionally, we seasonally adjusted the stock market variable (q). Share prices could rise due to inflation. In this context, the increase in stock market value might reflect only higher inflation. To eliminate this nominal effect, we deflate the share prices by domestic inflation. Consequently, we focus on the real values of shares.

Table 1: Variables and sources

Variables	Definition	Sources
ip	Index of industrial production (2015 = 100)	OECD Main Economic Indicators
q	Real share prices (2015 = 100)	OECD Economic Outlook
e	Real exchange rate (domestic currency per U.S. dollar)	IFS/IMF, OECD Economic Outlook
r	3-month interest rate	FRED Economic Data

u	Composite leading indicator (CLI), proxy of confidence	OECD Main Economic Indicators
trade	Bilateral trade (goods)	DOTS/IMF
direct investment	Inward and outward direct investment positions	CDIS/IMF
equity	Inward and outward equity positions	CDIS/IMF

We collect the exchange rate (domestic currency per U.S. dollar) from the International Financial Statistics (IFS) of the International Monetary Fund (IMF). We use domestic inflation and U.S. inflation to deflate the exchange rates (we use CPI from the OECD Economic Outlook to deflate). We seasonally adjusted this variable.

We use the 3-month interest rates from the Federal Reserve Bank of St. Louis (FRED) Economic Data to represent short-term credit markets. For most economies, we use interbank rates. When we have missing values in the data, we use instead discount rates (Brazil and India) and call money (Chile, Japan, Switzerland, and Turkey).

We proxy confidence using the composite leading indicator (CLI) from the OECD Main Economic Indicators. The CLI shows the prediction that the current business cycle is changing. CLI measures changes in the short term. In this sense, CLI captures the feeling of the market to domestic and external fluctuations. We seasonally adjusted this time series. Table A, in the Online Appendix, presents the descriptive statistics of the variables.

Our sample is composed of 24 economies, encompassing developed and developing economies: Austria (AUT), Belgium (BEL), Brazil (BRA), Canada (CAN), Chile (CHL), China (CHN), Finland (FIN), France (FRA), Germany (GER), India (IND), Indonesia (IDN), Italy (ITA), Japan (JPN), Korea (KOR), Mexico (MEX), the Netherlands (NTH), Norway (NOR), Russia (RUS), South Africa (SOU), Spain (SPN), Sweden (SWE), Turkey (TUR), the United Kingdom (U.K.), and the United States (U.S.). We follow Dees et al. (2007) and Attílio et al. (2023) and aggregate Austria, Belgium, Finland, France, Germany, Italy, the Netherlands, and Spain to give rise to the Eurozone (EUR). Our period of analysis is from 1999M1 to 2021M12.

We included as many countries as possible in our model. In GVAR empirical studies, authors try to improve the representativeness of the world economy (see Equations 18 and 19). One of the strategies is to incorporate many economies in the model (Dees et al., 2007; Attílio et al., 2023). Thus, besides the BRICS and the major industrialized economies, our sample has relevant economies such as Indonesia, Mexico, Norway, and Sweden. We chose the economies based on the availability of data from the sources described in Table 1. We extend our period until 2021M12 due to Russian data. Otherwise, if we surpass this period, we would have to exclude this economy.

Equation (3) presents the vectors of domestic and foreign variables:

$$x_{it} = (q_{it}, ip_{it}, e_{it}, r_{it}, u_{it})$$
$$x_{it}^* = (q_{it}^*, ip_{it}^*, r_{it}^*, u_{it}^*), \text{ for all economies except the U.S.}$$

$$x_{it} = (q_{it}, ip_{it}, r_{it}, u_{it})$$
$$x_{it}^* = (e_{it}^*), \text{ for the U.S.} \quad (3)$$

Equation (3) demonstrates the interconnectedness of economies through international stock markets (q_{it}^*), credit markets (r_{it}^*), the real sector (industrial production, ip_{it}^*), and uncertainty (u_{it}^*). We employ the hypothesis of weak exogeneity. According to Dees et al. (2007), economies can influence foreign variables in the short term. However, in the long term, this influence disappears, as foreign variables constrain the fluctuations of domestic variables. This scenario aligns with the framework of open macroeconomics, where small open economies adapt to external shocks (Attílio et al., 2023). We apply this hypothesis to all economies, with the exception of the U.S.

We follow Pesaran et al. (2004), Dees et al. (2007), and Attílio et al. (2023) by restricting the inclusion of foreign variables in the U.S. model. Given the global significance of the U.S. economy, the application of weak exogeneity poses potential challenges. Consequently, we limit the foreign variables in the U.S. model to include only the exchange rate. Because the exchange rate is the ratio of domestic currency per U.S. dollar, we do not include this variable as a domestic variable in the U.S. model. Subsequently, in this section, we delve into the weak exogeneity test to reinforce our model configuration.

We use Generalized Impulse Response Function (GIRF) and Generalized Forecast Error Variance Decomposition (GFEVD) in the empirical analysis. GIRF shows how local shocks affect the whole system, suggesting transmission channels; however, GIRF does not identify shocks. We use the Structural GIRF (SGIRF) to reinforce the results from the GIRFs. SGIRF identifies the shocks in one economy. In our case, we identify the shock in the U.S.

GFEVD measures the influence of domestic and external variables on the decomposition of domestic variables. We normalize the lines in the GFEVD to a sum of 100%. We are especially interested in examining the influence of the U.S. stock market on the domestic markets of the BRICS and the major industrialized economies. Besides, GFEVD complements the analysis of the GIRFs by estimating the influence between variables.

As shown in Equation (2), we connect economies and construct their vulnerability using economic integration variables. Most GVAR studies adopt bilateral trade (Dees et al., 2007; Attílio et al., 2023). As we investigate a financial shock, we use two financial integration variables. The first is the sum of inward and outward direct investment positions, and the second is the inward and outward equity positions. We collected both variables from the Coordinated Direct Investment Survey (CDIS) of the IMF. We adopt the average of the years 2019-2021. The last three lines in Table 1 presents the integration variables.

We compare these financial integration variables with bilateral trade from the Direction of Trade Statistics (DOTS) of the IMF. Because the times series of bilateral trade are longer than the financial times series, we use time-varying bilateral trade to accommodate structural changes in trade integration. This is recommended in our case since our sample has emerging economies. Thus, we use bilateral trade from 1997 to 2022. In GVAR, we can employ either fixed or time-varying bilateral trade. Fixed bilateral trade utilizes an average of years of bilateral trade to estimate and solve the model. The construction of foreign variables is based on this average. On the other hand, time-varying bilateral trade involves using moving averages of bilateral trade over the years. Given that our domestic and foreign variables span from 1999 to 2021 and bilateral trade from 1997 to 2022, the model accommodates structural changes by calculating the external scenario (foreign variables) in response to changes in trade integration. For instance, in the year 1999, the foreign variable is constructed using the average of bilateral trade from 1997 to 1999.The financial and trade integration variables allow us to compare and evaluate how the treatment of economic integration affects the results.

In the Online Appendix, Tables B and C show the results of the unit root tests. The results indicated that some time series have unit roots. However, we found stationarity when the time series are in the first differences. Consequently, Table D presents the existence of cointegrating relationships (besides showing the lags of the VARXs). We use the GVAR in the error correction form to accommodate these results.

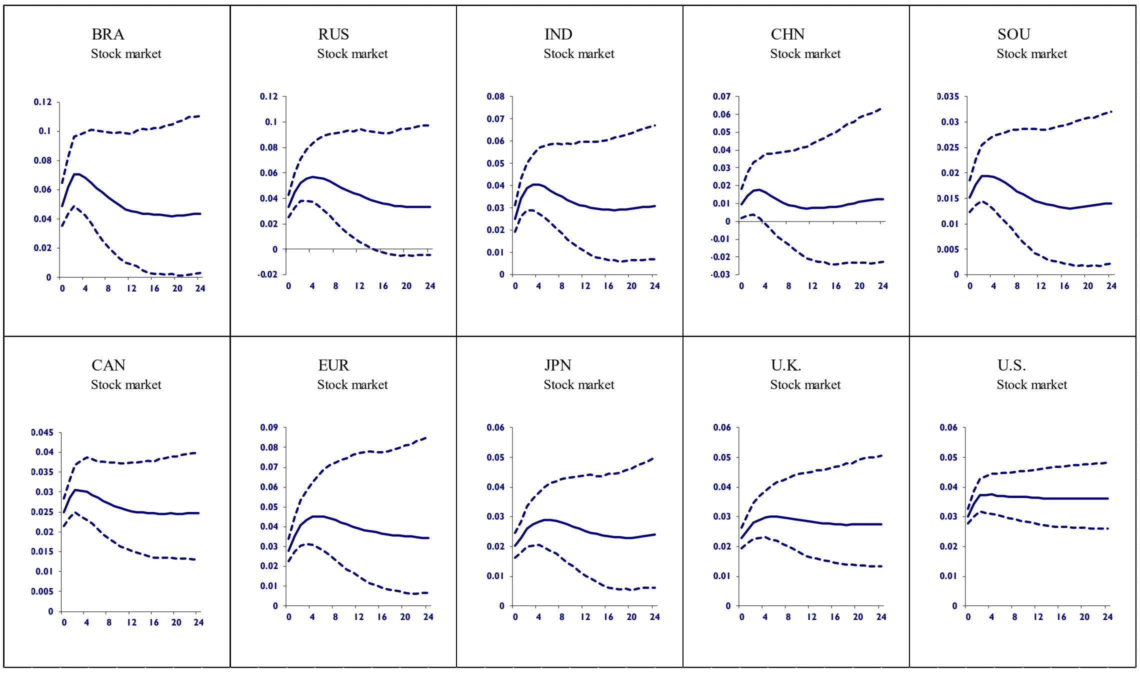
Finally, Table E presents the results of the weak exogeneity test. As discussed, foreign variables serve as proxies of the world economy, shaping the external scenario for domestic economies. Table E indicates the validity of this hypothesis for the majority of economies. Of particular interest are large economies, such as China and the Eurozone. The estimates reveal that the hypothesis is valid for these economies. The test rejected the null hypothesis of weak exogeneity in some cases. However, we chose to retain these variables. This decision stems from the understanding that, despite these rejections, the stability of the model remained unaffected. Excluding these variables could reduce the information in the estimations.

3. Results

3.1 Comparing economic integration variables

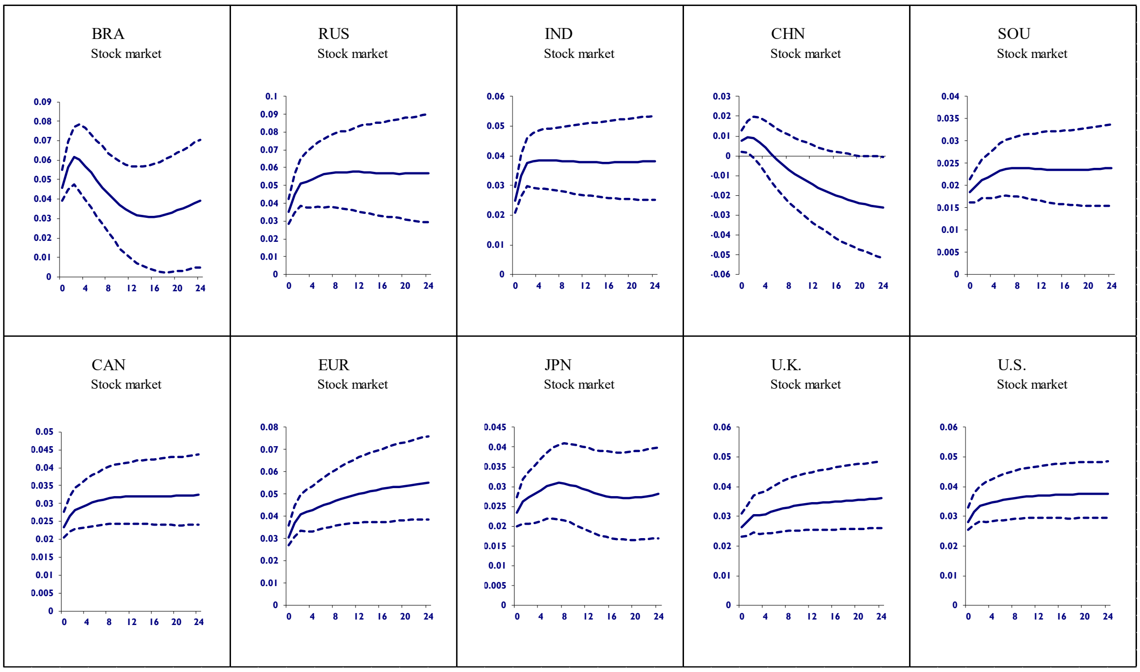
We start our investigation by using three variables to connect economies: i) bilateral trade, ii) direct investment positions, and iii) equity positions. In each of the following figures, we use a distinct w_{ij} term to estimate and solve the model. Figure 1 uses time-varying bilateral trade, Figure 2 uses direct investment positions, and Figure 3 uses equity positions. In all these figures, we analyze the U.S. stock market shock and the responses of domestic stock markets of the BRICS and G7. Our purpose is twofold: i) to analyze the responses of domestic stock markets to shocks in the U.S. stock market, and ii) to assess whether these responses are sensitive to trade and financial linkages.

Figure 1: GIRF of a U.S. stock market shock and responses of stock markets (time-varying bilateral trade)



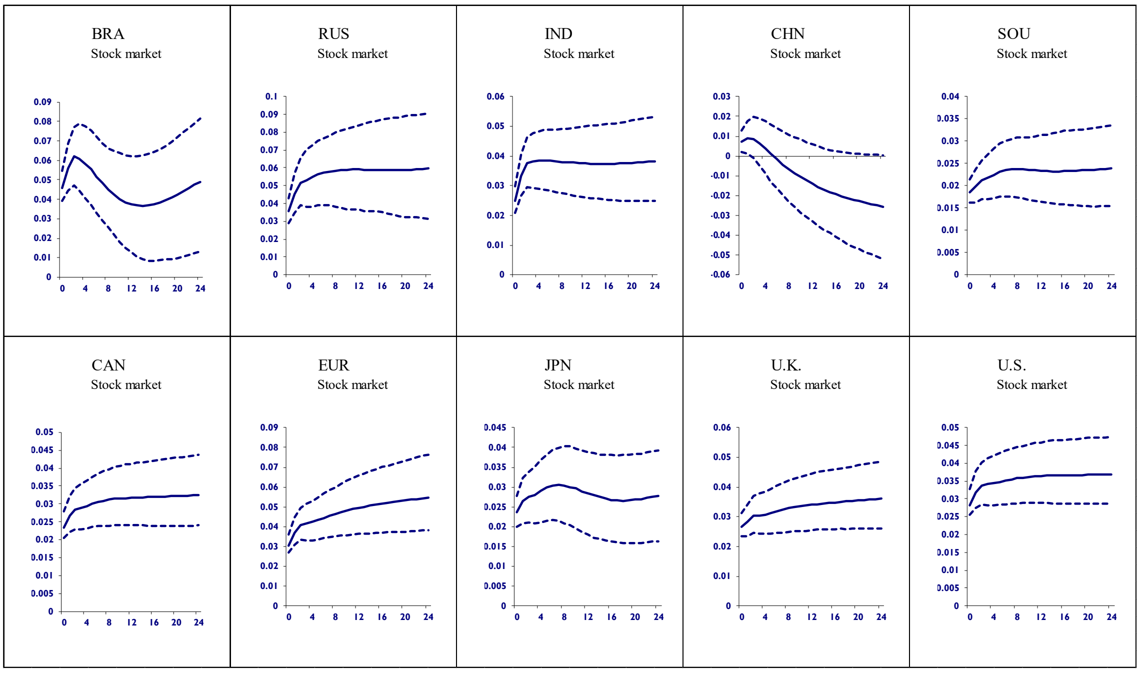
Source: Authors' own calculations.

Figure 2: GIRF of a U.S. stock market shock and responses of stock markets (direct investment positions)



Source: Authors' own calculations.

Figure 3: GIRF of a U.S. stock market shock and responses of stock markets (equity positions)



Source: Authors' own calculations.

Figures 1-3 show that most economies respond positively to the U.S. financial shock independently of the economic integration variable. In Figure 1, the response of the Russian stock market loses statistical significance in the second year of the shock. However, when we use financial integration variables (Figures 2 and 3), the Russian response becomes statistically significant for the entire period. We detect another distinct pattern for China; in Figure 1, the response of China is statistically significant for four months. In Figures 2 and 3, the Chinese response varies from positive to negative values. Besides these economies, the BRICS and G7 show similar responses to the U.S. shock, except that, when using financial integration variables (Figures 2 and 3), the statistically significant responses of the BRICs last longer than when using bilateral trade (Figure 1). Regarding the G7, its responses do not change according to the economic integration variable.

An economic interpretation of the sensitivity difference between the stock markets of the G7 and the BRICS is that the financial markets of the G7 are developed, while those of the BRICS are underdeveloped. Consequently, underdeveloped financial markets exhibit a lesser response to changes in the economic scenario. Blanchard and Fischer (1989) posit that underdeveloped financial markets experience credit rationing, which hampers the connections between external shocks or changes in the macroeconomic landscape and responses in the financial markets.

Another noteworthy point is that the confidence intervals in Figures 2 and 3 are narrower compared to Figure 1. Across all figures, we employed confidence intervals at 90% of statistical significance calculated by bootstrap. The reduced range of the confidence intervals in Figures 2 and 3 suggests that the estimates and the model exhibit greater precision when incorporating financial linkages rather than trade linkages. This provides additional support for the argument that financial integration variables offer a more accurate representation of stock market shocks.

Figures 1-3 confirm the study of Chudik and Fratzscher (2011), who argued that the U.S. financial market influences the domestic financial markets of developed and emerging economies. In particular, Chudik and Fratzscher (2011) investigated the transmission channels of the 2008 financial crisis.

Another test to compare the relevance of the economic integration variable is to measure the effect of the U.S. stock market on domestic variables. Table 2 provides the GFEVD of the stock markets of the BRICS and G7. This table decomposes stock markets into domestic variables and the U.S. stock market (last column).

We can draw four conclusions from Table 2. The first is that the U.S. stock market is a notorious external source of domestic fluctuation; in most economies, the U.S. stock market is the principal or the second most important factor explaining stock market fluctuations. The exception to this statement is the Chinese economy, where the U.S. influence is reduced (this is our second conclusion). The third is that the U.S. stock market causes more fluctuation in the G7 than in the BRICs. In this sense, Canada and U.K. are especially sensitive to the U.S. stock market. The last conclusion is that there are heterogeneities among the economies: industrial production is relevant for Brazil, China, South Africa, and the Eurozone; the exchange rate for China, Canada, the Eurozone, Japan, and the U.K.; interest rates for Russia, South Africa, Japan, and the U.S.; and confidence for all economies except Canada and Japan. Later, we explore transmission channels using these heterogeneities.

We can construct two tables similar to Table 2, changing only the economic integration variable to compare the impact of the U.S. stock market. If the influence of the U.S. stock market changes according to the economic integration variable, we have evidence that the integration variable is relevant to understand the U.S. shock transmission. Thus, for space and to avoid repetition, we united the influence of the U.S. stock market under the three integration variables in Table 3. Table 3 shows how the U.S. stock market affects domestic stock markets using bilateral trade (Table 2), direct investment, and equity positions. We show only the U.S. influence because of space (notice that the column bilateral trade has the same values as Table 2). Table 2 illustrated the potential transmission channels of the U.S. stock market on domestic stock markets, a topic we explore further in Section 4.3. In contrast, Table 3 specifically addresses the quantitative impact of the U.S. stock market on domestic economies under three integration variables.

Table 2: GFEVD of stock markets to domestic variables and the U.S. stock market (time-varying bilateral trade)

	Brazil					U.S.
	q	ip	e	r	u	
1	57.68	8.55	0.08	3.62	6.55	23.52
24	57.94	4.12	3.16	2.08	3.76	28.95

	Russia					U.S.
	q	ip	e	r	u	
1	58.75	1.75	0.65	12.03	4.60	22.23
24	71.88	3.50	3.27	3.76	6.48	11.11

	India					U.S.
	q	ip	e	r	u	
1	51.63	4.08	5.15	0.48	2.53	36.12
24	56.36	4.87	3.16	0.04	9.63	25.95

	China					U.S.
	q	ip	e	r	u	
1	83.91	5.92	6.37	0.82	1.28	1.70
24	58.99	9.11	1.63	0.35	28.26	1.66

	South Africa					U.S.
	q	ip	e	r	u	
1	37.76	1.38	0.13	0.65	7.30	52.78
24	25.49	21.56	0.31	9.75	27.53	15.36

	Canada					U.S.
	q	ip	e	r	u	
1	29.72	0.24	0.08	0.03	3.34	66.59
24	9.69	2.47	6.03	2.43	1.03	78.35

	Eurozone					U.S.
	q	ip	e	r	u	
1	30.09	1.13	9.69	1.89	16.01	41.19
24	39.86	16.72	8.81	1.76	4.30	28.56

	Japan					U.S.
	q	ip	e	r	u	
1	54.12	0.43	10.91	1.39	0.05	33.11
24	61.60	2.12	7.65	4.41	2.41	21.81

	U.K.					U.S.
	q	ip	e	r	u	
1	32.18	0.18	2.32	0.52	0.64	64.15
24	37.56	5.13	5.31	1.96	9.89	40.14

	U.S.					U.S.
	q	ip	e	r	u	
1	85.51	0.14		2.74	11.61	
24	82.58	0.11		4.12	13.19	

Source: Authors' own calculations.

Table 3: GFEVD of domestic stock markets to the U.S. stock market in three configurations

	Brazil				Canada		
	bilateral trade	direct investment	equity		bilateral trade	direct investment	equity
1	23.52	51.71	50.70	1	66.59	67.83	68.41
24	28.95	35.08	39.36	24	78.35	69.82	70.05
	Russia				**Eurozone**		
	bilateral trade	direct investment	equity		bilateral trade	direct investment	equity
1	22.23	29.39	29.46	1	41.19	76.73	76.43
24	11.11	31.04	32.24	24	28.56	82.52	81.92
	India				**Japan**		
	bilateral trade	direct investment	equity		bilateral trade	direct investment	equity
1	36.12	41.86	42.02	1	33.11	46.41	46.74
24	25.95	49.68	49.74	24	21.81	48.09	47.48
	China				**U.K.**		
	bilateral trade	direct investment	equity		bilateral trade	direct investment	equity
1	1.70	2.41	2.33	1	64.15	68.92	68.79
24	1.66	5.74	5.20	24	40.14	68.94	68.81
	South Africa						
	bilateral trade	direct investment	equity				
1	52.78	54.47	54.40				
24	15.36	58.45	58.47				

Source: Authors' own calculations.

We find that changing the integration variable from bilateral trade to bilateral financial stock/flow increases the impact of the U.S. stock market on domestic stock markets. Even in China, where Table 2 shows that the U.S. influence is minor, the influence of the U.S. increased as we adopted financial integration variables. These estimates suggest that the results do not change profoundly when connecting economies through direct investment or equity variables; however, there is a quantitative difference in the results when using bilateral trade to connect economies. In other words, the critical change is from trade to financial integration variable.

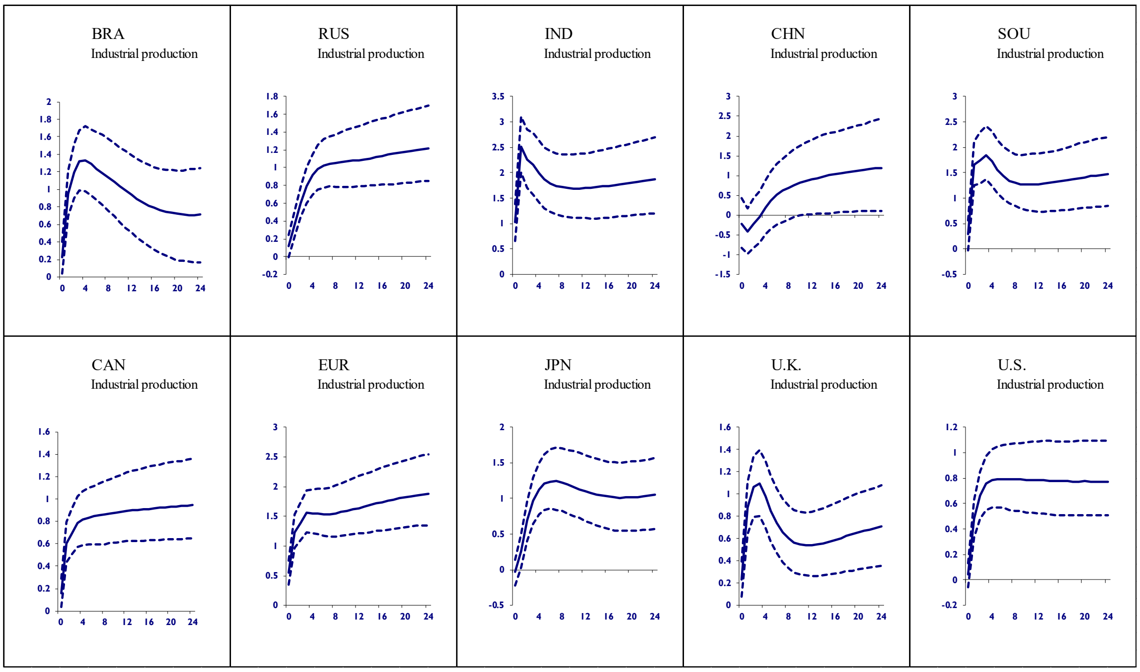
Our results indicate that the study of the U.S. stock market shocks (or, in a broader context, the U.S. financial shocks) is sensitive to the integration variable. Our paper challenges other investigations that examined the U.S. financial influence without considering the kind of economic integration (Chuliá et al., 2017; Aggarwal and Raja, 2019; Song et al., 2022). Exceptions in analyzing U.S. financial shocks include Chudik and Fratzscher (2011) and Eickmeier and Ng (2015), who employed financial and trade variables to connect economies. However, these authors did not compare the relative importance of these linkages in relation to the results. Consequently, their studies do not indicate how these linkages contribute to the main findings. A similar gap is observed in Sevinc and Mata Flores (2021) in their investigation of shocks in OECD economies. Although the authors utilized four integration variables, they did not conduct a comparative analysis through variance decomposition to demonstrate the quantitative importance of each integration variable to the results. We address these gaps by quantitatively illustrating the differences generated in the results by the integration variables. In particular, we detect that the direction of reactions of the BRICS and G7 to the U.S. stock market is unaltered (Figures 1-3) whether we consider alternative integration variables. However, Table 3 demonstrates that the effect of the U.S. stock market is sensitive to financial integration: empirical works that omit this information can undervalue the impact of the U.S. stock market on the world economy.

3.2 U.S. stock market shock

This section presents the reactions of the variables of BRICS and G7 to a U.S. stock market shock. Because we concluded that financial integration variables increase the impact of this shock on domestic economies, we use direct investment positions to connect economies. The responses of the variables are quite similar when using bilateral trade or bilateral equity positions, as discussed earlier; the main difference is quantitative. Thus, we present the figures using direct investment. Another justification is that direct investment is a broader measure of financial integration, encompassing equity[1]. Figures 4, 5, 6, and 7 show the responses of industrial production, exchange rates, interest rates, and confidence.

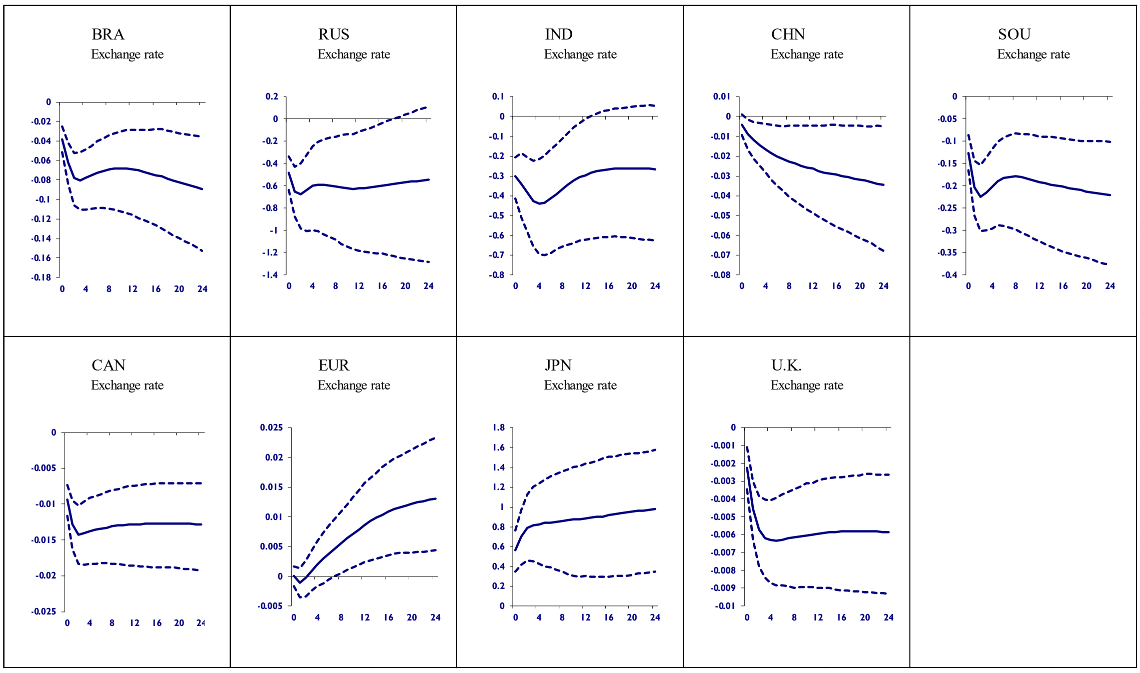
[1] The results of the model using bilateral trade and equity positions are available upon request.

Figure 4: GIRF of a U.S. stock market shock and responses of industrial production (direct investment positions)



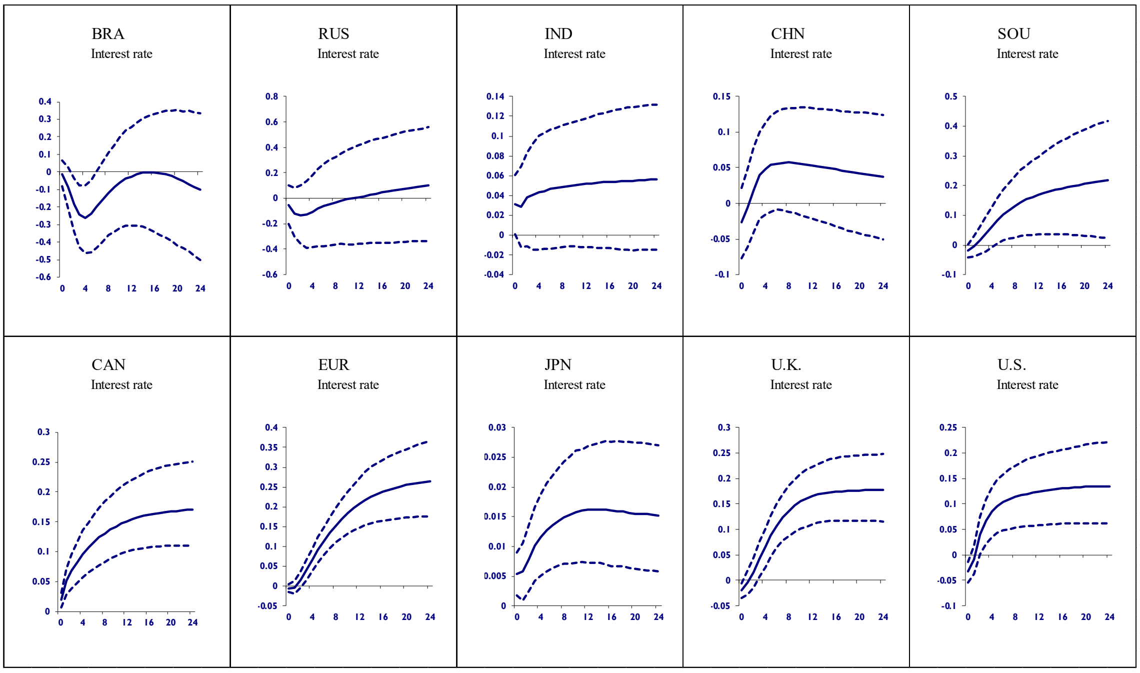
Source: Authors' own calculations.

Figure 5: GIRF of a U.S. stock market shock and responses of exchange rates (direct investment positions)



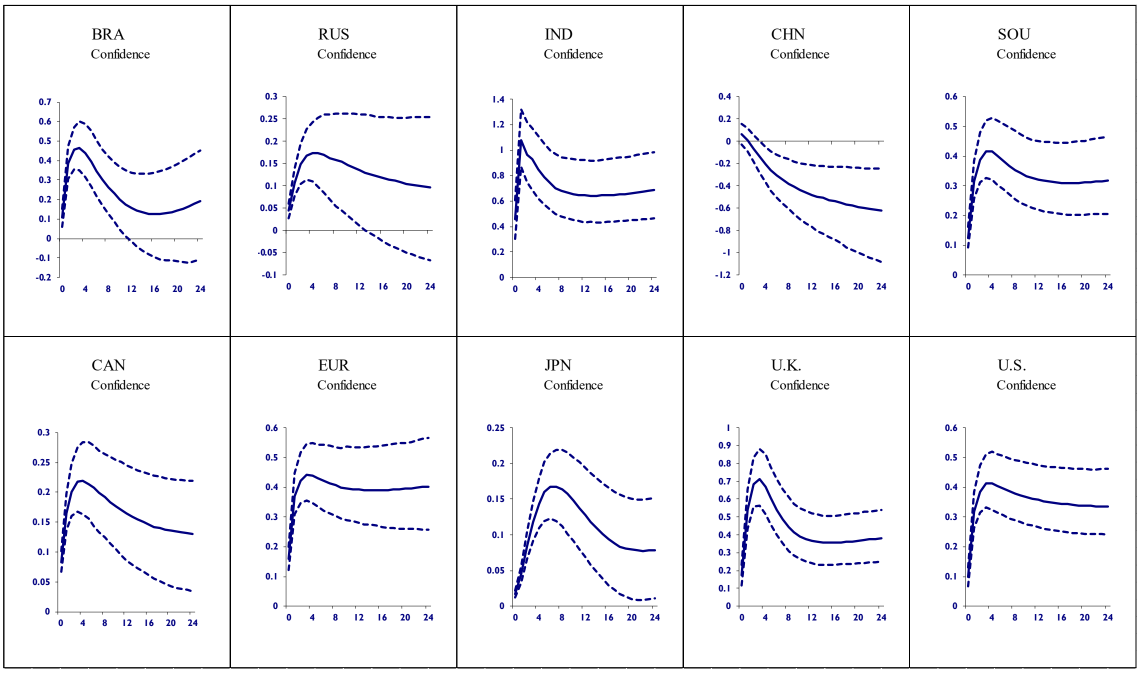
Source: Authors' own calculations.

Figure 6: GIRF of a U.S. stock market shock and responses of interest rates (direct investment positions)



Source: Authors' own calculations.

Figure 7: GIRF of a U.S. stock market shock and responses of confidence (direct investment positions)



Source: Authors' own calculations.

Figure 2 shows that a positive U.S. stock market promotes increasing share prices in developed and developing economies. Figure 4 indicates that the U.S. shock causes an international boom, with industrial production increasing in all economies.

Again, all economies present statistically significant responses in the exchange rate markets (Figure 5). One difference is that in the BRICS, we detect appreciations of the currencies to the shock, while in the major industrialized economies, the currencies of the Eurozone and Japan depreciate (Canada and the U.K. had appreciations of their currencies).

Figure 6 elucidates another distinction between the BRICS and the major industrialized economies. In the BRICS, the interest rates of Russia, India, and China are not statistically significant to the shock. Brazil presents statistically significant values in the beginning, but they lose statistical significance. In contrast, all interest rates of the major industrialized economies increased to the shock. In this sense, we have evidence that the central banks of these economies are more vigilant to possible spikes in domestic inflation because of the boom promoted by the U.S. stock market.

Figure 7 shows that global confidence increases, except in China. Thus, Figures 4-7 present similar co-movements between the BRICS and the major industrialized economies, such as the boom in the industrial sector, and distinctions, such as the higher sensitiveness of the policy rates of the major industrialized economies than in the BRICS.

One possible explanation for these responses is that the U.S. stock market generates global optimism, causing increasing confidence, which attracts capital to the domestic stock markets. This capital inflow presses the domestic currencies, a movement more intense in the BRICS than in the major industrialized economies. These movements help to understand increasing stock market values and the appreciation of domestic currencies. This pool of available capital reduces the cost of investment and production, allowing companies to increase industrial production. We explained in the methodology that GIRFs do not identify shocks (we tested a Structural GIRF to identify the U.S. shock, and the results were similar; see Section 3.4); GIRFs portray the transmission of shocks over the system. We delve into the channels of shock diffusion using the GFEVD.

An economic rationale for Figures 4-7 is provided by the discussion in Section 3.1, highlighting that the economies of the G7 are more responsive to U.S. fluctuations compared to the BRICS due to their developed financial markets. While the responses of the BRICS are statistically significant in many cases, the G7's responses remain statistically significant for a more extended period than those of the BRICS. In essence, the impact of the U.S. shock lasts longer in the G7.

Chudik and Fratzscher (2011) concluded that the U.S. stock market shock affects economies through financial linkages. Figures 1-7 support this statement since domestic stock markets, credit markets, and currency markets responded to the shock. However, we need to decompose the domestic variables to properly evaluate the transmission of the U.S. shock. That is our next task.

3.3 Transmission channels of the U.S. stock market shock

In Section 3.1, we concluded that the effect of the U.S. stock market on domestic stock markets is boosted if we use financial integration variables. Section 4.2 showed how the system reacts to the U.S. stock market. We advance our investigation by exploring transmission channels of the U.S. shock. We use GFEVD of domestic variables to measure the influence of the U.S. stock market as well as to detect heterogeneities and peculiarities in each economy. Tables 4-8 present the GFEVDs. We normalized each row to a sum of 100%. We present only periods 1 and 24 for each economy. We acknowledge that this approach does not depict the entire temporal evolution of variables, but the analysis remains consistent whether we use periods 1 and 24 or the entire period[2].

Table 4 shows that, except in China, the U.S. stock market explains large fluctuations in domestic stock markets, with values around 29-82%. As discussed in the last section, major industrialized economies are more susceptible to U.S. influence. Besides the stock markets, i) industrial production is important in China and Japan, ii) exchange rates in India, Japan, and the U.K., iii) interest rates are relevant in Russia, China, the Eurozone, the U.K., and the U.S., and iv) confidence in Brazil, South Africa, Canada, and the U.S. These observations demonstrate heterogeneities about how sensitive domestic stock markets are to other economic segments. Furthermore, we can comprehend other (indirect) channels through which the U.S. stock market impacts these economies.

Table 5 presents the decomposition of industrial production. Again, we found that the U.S. stock market is a notorious influence on these economies. We can connect Tables 4 and 5 to indicate indirect transmission channels of the U.S. stock market. Table 4 revealed that industrial production is relevant in China and Japan to explain fluctuations

[2] Full tables are available upon request.

in their stock markets. Table 5 shows that the U.S. stock market affects the industrial production of these two economies. Consequently, we can state that the U.S. stock market indirectly affects the stock markets of China and Japan by causing changes in their industrial production.

Table 6 indicates that the U.S. stock market provokes changes in domestic exchange rates. We follow the same procedure to find indirect transmission channels. In Table 4, we detected that the exchange rates of India, Japan, and the U.K. are relevant to explain domestic stock market fluctuations. Table 6 portrays that the U.S. stock market affects the currencies of these economies. Thus, the U.S. stock market indirectly affects the domestic stock markets of these economies by causing changes in their currencies.

Table 4: GFEVD of stock markets to domestic variables and the U.S. stock market (direct investment positions)

	Brazil					U.S.
	q	ip	e	r	u	
1	43.54	0.68	2.23	0.03	1.81	51.71
24	56.64	0.40	3.00	0.08	4.80	35.08

	Russia					U.S.
	q	ip	e	r	u	
1	65.94	0.10	0.35	2.04	2.19	29.39
24	60.57	0.03	0.82	5.59	1.93	31.04

	India					U.S.
	q	ip	e	r	u	
1	51.26	1.01	5.50	0.08	0.29	41.86
24	43.64	0.70	5.48	0.10	0.39	49.68

	China					U.S.
	q	ip	e	r	u	
1	94.14	1.00	0.93	1.06	0.46	2.41
24	57.42	15.67	0.94	19.84	0.39	5.74

	South Africa					U.S.
	q	ip	e	r	u	
1	44.11	0.17	0.02	0.62	0.61	54.47
24	29.53	3.39	0.70	3.79	4.14	58.45

	Canada					U.S.
	q	ip	e	r	u	
1	26.93	0.07	0.16	0.10	4.91	67.83
24	21.55	0.01	0.06	0.28	8.28	69.82

	Eurozone					U.S.
	q	ip	e	r	u	
1	19.22	0.61	2.36	0.26	0.82	76.73
24	4.82	3.15	2.28	5.79	1.44	82.52

	Japan					U.S.
	q	ip	e	r	u	
1	46.09	0.10	6.56	0.34	0.49	46.41
24	33.42	8.71	7.73	1.44	0.60	48.09

	U.K.					U.S.
	q	ip	e	r	u	
1	22.17	0.01	4.63	4.23	0.04	68.92
24	19.59	0.11	5.40	5.92	0.05	68.94

	U.S.					U.S.
	q	ip	e	r	u	
1	82.73	0.09		4.78	12.41	
24	67.35	2.30		4.38	25.97	

Source: Authors' own calculations.

Table 5: GFEVD of industrial production to domestic variables and the U.S. stock market (direct investment positions)

	Brazil					U.S.
	q	ip	e	r	u	
1	1.67	71.23	2.23	0.25	0.22	24.40
24	21.73	16.05	18.95	0.46	4.01	38.81
	Russia					U.S.
	q	ip	e	r	u	
1	1.72	81.91	1.49	0.97	6.17	7.75
24	12.67	5.77	0.14	5.37	8.85	67.19
	India					U.S.
	q	ip	e	r	u	
1	1.04	40.13	0.13	0.31	10.94	47.46
24	1.19	36.57	0.15	0.41	14.07	47.62
	China					U.S.
	q	ip	e	r	u	
1	0.78	95.89	0.08	0.11	2.87	0.28
24	1.20	70.15	6.63	1.34	12.91	7.77
	South Africa					U.S.
	q	ip	e	r	u	
1	2.93	55.64	0.86	0.95	3.44	36.19
24	14.02	16.07	0.93	0.11	17.03	51.83
	Canada					U.S.
	q	ip	e	r	u	
1	0.23	73.34	2.29	0.03	2.95	21.17
24	0.34	42.49	2.42	0.12	3.87	50.76
	Eurozone					U.S.
	q	ip	e	r	u	
1	0.50	39.05	1.19	1.09	9.08	49.08
24	3.88	8.27	1.26	0.81	2.98	82.80
	Japan					U.S.
	q	ip	e	r	u	
1	0.69	95.71	0.17	0.33	1.64	1.45
24	9.90	38.39	0.02	1.15	1.90	48.64
	U.K.					U.S.
	q	ip	e	r	u	
1	0.14	69.19	0.03	0.01	2.41	28.23
24	1.47	44.45	0.04	3.69	5.06	45.30
	U.S.					U.S.
	q	ip	e	r	u	
1	6.99	54.45		0.67	37.89	
24	21.28	35.19		1.17	42.35	

Source: Authors' own calculations.

Table 6: GFEVD of exchange rates to domestic variables and the U.S. stock market (direct investment positions)

	Brazil					U.S.
	q	ip	e	r	u	
1	3.82	1.65	77.00	0.49	2.56	14.48
24	3.44	3.88	57.70	5.42	1.54	28.02
	Russia					**U.S.**
	q	ip	e	r	u	
1	1.77	0.56	80.02	7.46	0.13	10.05
24	7.33	0.20	50.60	31.54	3.67	6.66
	India					**U.S.**
	q	ip	e	r	u	
1	6.24	0.35	84.65	0.41	0.15	8.20
24	4.50	0.57	86.44	1.08	0.42	7.00
	China					**U.S.**
	q	ip	e	r	u	
1	0.45	0.12	93.43	1.35	2.96	1.69
24	8.34	3.66	62.94	13.46	1.16	10.44
	South Africa					**U.S.**
	q	ip	e	r	u	
1	0.10	1.52	82.91	0.13	0.46	14.88
24	1.07	4.52	73.49	0.20	0.64	20.08
	Canada					**U.S.**
	q	ip	e	r	u	
1	1.51	0.62	63.78	9.18	0.03	24.88
24	2.42	0.73	58.33	12.61	0.02	25.88
	Eurozone					**U.S.**
	q	ip	e	r	u	
1	4.07	0.47	94.46	0.70	0.12	0.19
24	0.82	6.38	60.96	17.80	0.02	14.01
	Japan					**U.S.**
	q	ip	e	r	u	
1	9.12	0.91	80.96	0.19	0.56	8.26
24	6.96	2.87	76.98	0.43	0.14	12.62
	U.K.					**U.S.**
	q	ip	e	r	u	
1	10.49	0.20	77.98	3.57	0.30	7.47
24	7.62	0.75	73.35	1.31	0.22	16.74

Source: Authors' own calculations.

Table 7: GFEVD of interest rates to domestic variables and the U.S. stock market (direct investment positions)

	Brazil					U.S.
	q	ip	e	r	u	
1	0.17	0.37	2.72	91.31	5.02	0.41
24	1.41	3.38	31.95	34.92	24.92	3.43

	Russia					U.S.
	q	ip	e	r	u	
1	4.58	0.69	2.80	87.93	3.65	0.35
24	9.73	8.09	0.77	55.08	26.11	0.23

	India					U.S.
	q	ip	e	r	u	
1	0.40	0.19	0.21	98.04	0.10	1.05
24	0.96	0.14	0.14	95.40	0.27	3.09

	China					U.S.
	q	ip	e	r	u	
1	0.84	0.13	1.37	93.17	4.27	0.21
24	6.37	1.01	7.09	60.30	23.06	2.17

	South Africa					U.S.
	q	ip	e	r	u	
1	0.06	4.69	0.93	93.19	0.78	0.36
24	1.53	25.65	33.04	12.42	14.07	13.29

	Canada					U.S.
	q	ip	e	r	u	
1	0.13	0.00	9.05	81.06	0.06	9.71
24	0.00	0.00	4.83	46.25	0.04	48.87

	Eurozone					U.S.
	q	ip	e	r	u	
1	2.63	0.49	0.92	95.83	0.00	0.13
24	2.07	6.75	0.52	10.97	0.12	79.57

	Japan					U.S.
	q	ip	e	r	u	
1	1.08	0.05	2.35	92.81	0.96	2.74
24	2.02	0.20	4.03	74.53	4.60	14.63

	U.K.					U.S.
	q	ip	e	r	u	
1	7.46	0.71	6.86	82.73	1.58	0.66
24	1.32	4.77	4.78	44.26	0.27	44.59

	U.S.					U.S.
	q	ip	e	r	u	
1	1.28	0.83		95.13	2.76	
24	14.00	5.65		50.80	29.55	

Source: Authors' own calculations.

Table 8: GFEVD of confidence to domestic variables and the U.S. stock market (direct investment positions)

	Brazil					U.S.
	q	ip	e	r	u	
1	3.46	0.22	0.55	3.00	19.61	73.15
24	10.16	18.24	5.73	2.17	15.67	48.03

	Russia					U.S.
	q	ip	e	r	u	
1	7.59	1.66	0.15	2.56	73.91	14.13
24	22.01	4.93	10.73	12.14	41.61	8.58

	India					U.S.
	q	ip	e	r	u	
1	0.06	2.93	0.18	0.13	25.18	71.51
24	0.04	2.93	0.26	0.23	30.73	65.82

	China					U.S.
	q	ip	e	r	u	
1	1.59	11.07	2.50	1.49	83.08	0.27
24	2.42	39.10	4.32	0.53	32.01	21.62

	South Africa					U.S.
	q	ip	e	r	u	
1	1.99	0.08	0.03	0.30	25.03	72.56
24	2.37	0.20	2.78	0.72	19.72	74.21

	Canada					U.S.
	q	ip	e	r	u	
1	4.32	0.65	0.00	0.17	50.08	44.76
24	5.73	0.05	0.01	2.90	61.14	30.17

	Eurozone					U.S.
	q	ip	e	r	u	
1	0.18	7.87	0.10	0.00	23.95	67.90
24	1.82	1.38	0.04	9.91	11.85	74.99

	Japan					U.S.
	q	ip	e	r	u	
1	1.09	0.06	0.29	0.63	73.33	24.59
24	5.61	36.99	0.02	3.54	19.64	34.20

	U.K.					U.S.
	q	ip	e	r	u	
1	0.34	0.21	0.22	2.18	27.38	69.67
24	0.16	7.85	0.36	3.19	7.02	81.43

	U.S.					U.S.
	q	ip	e	r	u	
1	24.85	22.85		2.87	49.44	
24	50.84	7.62		8.82	32.71	

Source: Authors' own calculations.

Table 7 shows an important distinction regarding the effect of the U.S. stock market on interest rates. Similarly to the domestic stock markets, the interest rates of the BRICS are less sensitive to the U.S. stock market than the major industrialized economies. Except in South Africa, the Brazilian, Russian, Indian, and Chinese credit markets do not seem to be vulnerable to the U.S. stock market. The major industrialized economies, on the other hand, are vulnerable to the U.S. Concerning indirect transmission channels, Table 4 indicated five possible candidates: Russia, China, the Eurozone, the U.K., and the U.S. However, because the influence of the U.S. stock market on Russia and China is minor, we exclude these economies from this analysis. Table 7 shows that the U.S. stock market indirectly affects domestic stock markets through credit markets in the Eurozone, the U.K., and the U.S.

The last table reinforces the prominent influence of the U.S. stock market; domestic confidence is highly sensitive to the U.S. Our indirect analysis of transmission channels suggests that Brazil, South Africa, Canada, and the U.S. are vulnerable to the U.S. stock market through fluctuations in domestic confidence.

In short, this section provided three conclusions. The first is that the U.S. stock market affects domestic stock markets directly and indirectly. We derive the second conclusion from this last point: the indirect channels suggest heterogeneities of U.S. influence. Further studies can break these relationships and offer more insights. Finally, we found that the financial markets (stock market and credit market) of the major industrialized economies are more sensitive to the U.S. stock market than the BRICS. This last observation shows the importance of studying groups of countries separated by economic development.

3.4 Additional checks

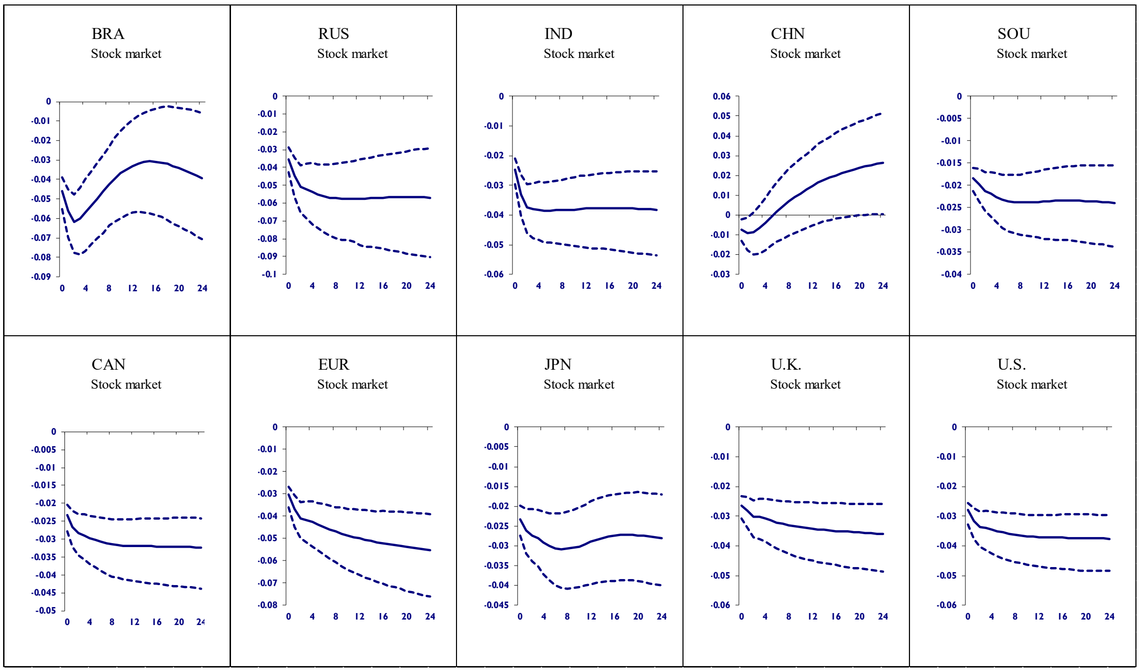
We test in Figure 8 if there are asymmetries in the U.S. stock market. In the entire article, we analyzed positive U.S. stock market shocks. Figure 8 changes this pattern, portraying a negative U.S. stock market shock.

The estimates reinforce the influence of the U.S. stock market on domestic stock markets, with economies presenting statistically significant responses. All domestic stock markets decline to the shock. Thus, we find little evidence of significant asymmetries between positive and negative U.S. stock market shocks.

Figure 9 identifies the U.S. shock using the order: (q, u, ip, r). This order means that stock market fluctuations affect confidence, promoting a boom in economic activity.

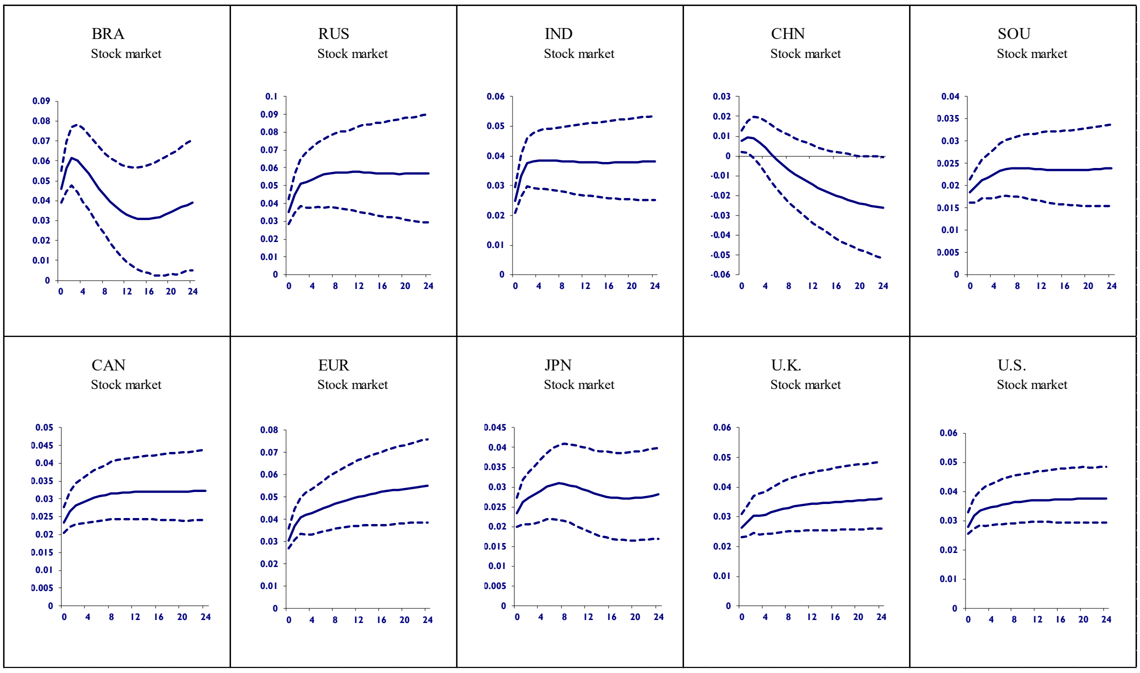
Subsequently, central banks respond by increasing the interest rate to curb domestic prices. Figure 9 shows the Structural Generalized Impulse Response Function (SGIRF).

Figure 8: GIRF of a negative U.S. stock market shock and responses of stock markets (direct investment positions)



Source: Authors' own calculations.

Figure 9: SGIRF of a U.S. stock market shock and responses of stock markets (direct investment positions)



Source: Authors' own calculations.

The results are similar to the GIRFs we used in Figures 1-3, suggesting that the identification of the shock does not profoundly change the results (we portray only the responses of domestic stock markets due to space; results of the other variables are available upon request).

4. Conclusion

We analyze a U.S. stock market shock on the BRICS and G7. We find that the effect of the shock increases if we adopt financial linkages instead of trade linkages. Regarding the two blocs, the central banks of the G7 are more vigilant to the effects of the U.S. shock than the monetary authorities of the BRICS. We also found co-movements between these blocs, such as increases in industrial production, stock markets, and confidence. The U.S. stock market shock promotes a global economic boom. This shock also generates distinct responses, such as the appreciation of the currencies of the BRICS and the depreciation of the currencies of the G7.

Our research contributes to this literature in at least two significant ways. Firstly, we use the GVAR model to detect transmission channels and assess the impact of U.S. stock market shocks on the stock markets of domestic economies. This connection is established through trade and financial variables, allowing us to simulate the global economy. While other studies, such as Chudik and Fratzscher (2011) and Sevinc and Mata Flores (2021), explored linkages between economies using financial and trade variables, they relied on a limited set of domestic variables for investigating transmission channels. Furthermore, these studies did not conduct a comparative analysis to indicate how the results may vary based on different integration variables. Secondly, we incorporate financial (credit, stock, and exchange markets), uncertainty, and real variables (industrial production) to illustrate how a U.S. stock market shock impacts domestic economies. This comprehensive approach enables us to generate a global picture of an external financial shock, facilitating a discussion on potential transmission channels and spillover effects of U.S. shocks in both financial and real markets.

Our investigation opens avenues for future research. One direction is to delve into the identification of the U.S. stock market shock in a set of financial and real variables. In the context of open economies, this task poses a significant challenge due to the identification of a shock in a sample with multiple economies and numerous variables. The GVAR model provides two tools to address this issue: the GIRF and Structural GIRF (SGIRF). However, GIRF does not identify shocks, and SGIRF identifies the shock only in one economy, with the other economies responding to the shock. While we demonstrated potential directions of the influence of the U.S. shock on domestic markets, a more formal assessment is warranted. The identification of U.S. shocks in a large system of economies could further strengthen our discussion regarding potential transmission channels.

Given the global impact of U.S. stock market shocks, policymakers should possess tools to mitigate the effects of external shocks on domestic markets. Specifically, our findings demonstrate that a U.S. shock triggers an economic boom, leading to increased industrial production and stock market. Other financial markets also respond, exhibiting fluctuations in exchange rates and interest rates. Additionally, domestic confidence changes in response to this shock. All these domestic fluctuations can potentially generate additional effects in other markets. Thus, our results highlight the importance for policymakers to recognize the pervasive and influential effects of U.S. stock market shocks on domestic economies. The stability of domestic economies is influenced not only by their own variables but also by external stock market shocks.

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The Impact of the U.S. Stock Market on the BRICS and G7: A GVAR Approach

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Online Appendix

Appendix A

Table A: Descriptive statistics

q	Mean	Maximum	Minimum	Std. dev.	r	Mean	Maximum	Minimum	Std. dev.
BRA	1.23	2.12	0.38	0.43	BRA	18.86	46.00	8.01	5.87
CAN	0.91	1.30	0.54	0.17	CAN	2.21	5.92	0.18	1.59
CHL	0.90	1.46	0.31	0.31	CHL	4.04	14.24	0.30	2.56
CHN	0.75	1.97	0.37	0.23	CHN	3.32	6.96	1.09	1.18
EUR	0.97	1.49	0.58	0.20	EUR	1.55	5.11	-0.58	1.78
IDN	0.73	1.18	0.18	0.34	IDN	8.97	45.50	3.75	5.28
IND	0.83	1.63	0.27	0.32	IND	6.67	10.25	4.25	1.31
JPN	0.85	1.30	0.49	0.21	JPN	0.31	0.75	0.10	0.17
KOR	0.87	1.50	0.36	0.26	KOR	3.39	7.54	0.63	1.78
MEX	0.72	1.10	0.18	0.30	MEX	7.91	35.45	3.30	4.91
NOR	0.79	1.68	0.20	0.37	NOR	3.07	7.72	0.20	2.23
RUS	1.12	2.27	0.18	0.44	RUS	9.27	43.90	4.20	4.80
SOU	0.70	1.04	0.26	0.25	SOU	7.62	16.40	3.45	2.42
SWE	0.77	1.74	0.30	0.30	SWE	1.47	4.49	-0.79	1.71
TUR	0.87	1.60	0.32	0.25	TUR	22.08	400.27	1.50	31.70
U.K.	1.00	1.39	0.65	0.14	U.K.	2.54	6.65	0.03	2.28
U.S.	0.90	1.38	0.50	0.18	U.S.	1.99	6.73	0.09	1.99

ip	Mean	Maximum	Minimum	Std. dev.	u	Mean	Maximum	Minimum	Std. dev.
BRA	98.25	115.32	72.72	10.08	BRA	100.19	105.73	94.56	2.08
CAN	97.82	112.42	82.73	5.87	CAN	99.83	102.78	95.66	1.23
CHL	89.91	103.75	64.91	11.23	CHL				
CHN	78.07	142.75	13.98	39.33	CHN	99.78	105.02	84.24	2.27
EUR	101.64	115.18	73.15	4.88	EUR	100.09	102.81	91.78	1.62
IDN	83.25	129.36	44.24	19.40	IDN	99.75	103.14	93.52	1.65
IND	80.79	123.38	39.21	25.60	IND	99.92	104.18	71.38	2.64
JPN	102.34	120.65	80.52	6.98	JPN	100.05	101.65	96.32	1.03

KOR	83.38	121.02	37.57	22.43	KOR	100.33	105.50	96.63	1.64
MEX	91.67	109.37	71.56	9.16	MEX	100.36	104.17	86.24	2.27
NOR	107.92	127.45	90.43	9.10	NOR	100.10	102.81	95.82	1.27
RUS	86.51	121.08	50.95	18.43	RUS	100.94	104.10	95.28	1.52
SOU	95.41	109.83	48.61	6.95	SOU	99.90	103.30	92.33	1.58
SWE	104.86	120.56	90.92	6.79	SWE	99.94	104.20	95.29	1.61
TUR	78.48	142.09	38.65	28.12	TUR	99.89	107.14	77.70	3.18
U.K.	101.68	118.43	87.62	6.09	U.K.	100.00	103.29	87.96	2.01
U.S.	95.35	102.97	83.89	4.95	U.S.	99.81	102.14	93.00	1.46

e	Mean	Maximum	Minimum	Std. dev.
BRA	3.35	6.25	1.95	0.90
CAN	1.23	1.55	0.96	0.16
CHL	641.83	861.42	492.71	83.18
CHN	7.50	9.07	6.10	1.05
EUR	0.84	1.12	0.64	0.11
IDN	13966.34	22646.07	10307.75	2511.80
IND	72.94	94.74	57.68	11.40
JPN	99.06	131.76	74.80	14.40
KOR	1172.99	1483.40	966.71	108.37
MEX	14.80	21.87	11.77	2.20
NOR	7.20	10.09	5.31	1.13
RUS	60.14	107.85	35.06	18.67
SOU	11.23	17.69	8.01	1.99
SWE	7.61	10.12	5.67	1.15
TUR	2.92	6.18	1.81	0.80
U.K.	0.66	0.81	0.51	0.08
U.S.				

Sources: Data sources described in Table 1.

Table B: Unit root test (Weighted Symmetric) for domestic variables at 5% of statistical significance

	C.V.	BRA	CAN	CHL	CHN	EUR	IDN	IND	JPN	KOR
q (with trend)	-3.24	-2.40	-3.61	-1.36	-4.37	-2.30	-2.77	-3.13	-2.30	-3.98
q (no trend)	-2.55	-1.66	-1.47	-0.77	-4.19	-2.30	-0.94	-1.03	-1.93	-1.38
Dq	-2.55	-10.69	-8.06	-10.03	-5.72	-5.74	-7.09	-7.76	-9.76	-7.59
ip (with trend)	-3.24	-1.70	-2.46	-1.31	-0.93	-2.99	-3.86	-3.73	-3.14	-2.27
ip (no trend)	-2.55	-1.46	-1.59	0.66	0.04	-3.00	0.42	-0.13	-2.98	1.51
Dip	-2.55	-11.17	-13.10	-13.20	-11.11	-14.62	-11.62	-11.44	-10.40	-13.10
e (with trend)	-3.24	-1.65	-1.38	-1.46	-1.12	-1.82	-1.61	-1.99	-2.21	-2.92
e (no trend)	-2.55	-1.83	-1.31	-1.57	-1.16	-1.86	-1.08	-1.19	-0.67	-2.87
De	-2.55	-6.57	-10.67	-9.85	-5.79	-10.24	-9.45	-5.95	-9.40	-6.73
r (with trend)	-3.24	-3.58	-2.63	-2.13	-3.25	-3.24	1.24	-1.42	-2.31	-3.00
r (no trend)	-2.55	-1.74	-1.17	-1.11	-3.22	-1.51	2.45	-1.11	-2.31	-0.46
Dr	-2.55	-5.24	-5.92	-10.50	-12.75	-5.89	2.34	-13.03	-10.06	-7.37
u (with trend)	-3.24	-3.67	-6.11		-3.72	-3.49	-4.18	-4.78	-4.46	-4.80
u (no trend)	-2.55	-3.52	-6.13		-3.73	-3.50	-4.23	-4.65	-4.52	-4.90
Du	-2.55	-7.78	-5.40		-12.22	-5.62	-5.40	-15.98	-5.75	-6.86

	C.V.	MEX	NOR	RUS	SOU	SWE	TUR	U.K.	U.S.
q (with trend)	-3.24	-1.53	-2.78	-2.16	-2.35	-1.13	-2.86	-2.38	-2.28
q (no trend)	-2.55	-0.53	-0.01	-1.50	-0.32	0.70	-2.65	-2.13	-1.34
Dq	-2.55	-10.68	-10.92	-9.49	-10.96	-8.14	-9.84	-8.91	-11.30
ip (with trend)	-3.24	-3.95	-1.95	-2.78	-2.76	-2.49	-2.29	-1.54	-2.47
ip (no trend)	-2.55	-1.51	-1.39	1.49	-2.40	-2.20	1.31	-1.41	-1.56
Dip	-2.55	-9.93	-11.24	-8.09	-13.99	-13.76	-13.19	-13.07	-13.33
e (with trend)	-3.24	-2.17	-1.86	-0.20	-2.50	-2.18	0.23	-2.28	
e (no trend)	-2.55	-1.29	-1.68	0.35	-2.15	-1.64	0.59	-1.47	
De	-2.55	-13.08	-10.80	-6.67	-10.01	-7.25	-9.17	-7.70	
r (with trend)	-3.24	2.04	-3.08	-0.40	-2.47	-3.55	-4.52	-2.27	-2.40
r (no trend)	-2.55	3.21	-1.03	0.28	-0.52	-1.51	-3.14	-0.72	-1.62
Dr	-2.55	-3.79	-4.25	-6.05	-4.55	-6.29	-10.33	-8.32	-9.06
u (with trend)	-3.24	-3.79	-3.90	-4.34	-2.72	-4.61	-4.49	-3.73	-3.50
u (no trend)	-2.55	-3.79	-3.95	-4.35	-2.77	-3.93	-4.51	-3.69	-3.50
Du	-2.55	-8.97	-6.23	-7.32	-5.82	-5.32	-13.99	-14.72	-10.09

Source: Authors' own calculations.

Table C: Unit root test (Weighted Symmetric) for foreign variables at 5% of statistical significance

	C.V.	BRA	CAN	CHL	CHN	EUR	IDN	IND	JPN	KOR
q* (with trend)	-3.24	-2.41	-2.49	-2.80	-2.38	-2.84	-2.54	-2.30	-2.70	-2.73
q* (no trend)	-2.55	-2.24	-1.87	-2.41	-1.82	-1.95	-2.32	-2.17	-2.07	-2.11
Dq*	-2.55	-10.72	-11.07	-10.86	-8.07	-11.00	-9.61	-10.95	-10.51	-9.64
ip* (with trend)	-3.24	-2.84	-2.73	-2.97	-3.06	-3.08	-2.48	-2.88	-2.85	-2.39
ip* (no trend)	-2.55	-2.41	-1.58	-2.40	-1.87	-0.99	-0.69	-2.32	-0.48	-0.46
Dip*	-2.55	-13.89	-13.65	-14.14	-11.41	-13.82	-13.56	-13.25	-13.57	-14.58
e* (with trend)	-3.24	-1.67	-1.43	-1.30	-1.54	-1.41	-2.65	-2.13	-1.59	-1.57
e* (no trend)	-2.55	-1.74	-1.38	-0.37	-1.22	-1.16	-2.60	-2.13	-1.09	-1.11
De*	-2.55	-10.18	-10.38	-9.72	-10.88	-7.00	-6.88	-7.09	-9.25	-9.42
r* (with trend)	-3.24	-2.40	-2.08	-2.80	-2.52	-1.67	-2.85	-2.28	-1.90	-2.05
r* (no trend)	-2.55	-0.77	-0.79	-0.55	-0.19	0.15	-1.33	-0.84	-0.20	-0.14
Dr*	-2.55	-7.46	-8.58	-6.25	-5.87	-7.40	-9.02	-8.01	-8.76	-7.78
u* (with trend)	-3.24	-3.85	-3.96	-4.09	-4.15	-4.01	-3.67	-3.88	-4.07	-3.79
u* (no trend)	-2.55	-3.86	-3.96	-4.11	-4.17	-4.01	-3.68	-3.88	-4.07	-3.80
Du*	-2.55	-7.84	-10.98	-7.81	-6.84	-11.44	-5.23	-8.57	-7.16	-5.52

	C.V.	MEX	NOR	RUS	SOU	SWE	TUR	U.K.	U.S.
q* (with trend)	-3.24	-2.41	-2.26	-2.38	-2.34	-2.45	-2.51	-2.34	-2.47
q* (no trend)	-2.55	-2.17	-1.68	-2.39	-2.35	-2.21	-2.49	-1.99	-2.38
Dq*	-2.55	-10.89	-10.83	-8.06	-8.12	-10.73	-7.98	-10.75	-8.05
ip* (with trend)	-3.24	-2.81	-2.86	-3.07	-3.02	-2.87	-2.91	-2.82	-3.00
ip* (no trend)	-2.55	-2.29	-2.33	-2.52	-2.66	-2.48	-1.87	-2.15	-2.38
Dip*	-2.55	-13.95	-12.82	-14.38	-14.33	-14.17	-13.95	-13.62	-13.33
e* (with trend)	-3.24	-2.29	-1.47	-2.75	-1.57	-1.35	-1.13	-1.49	-1.45
e* (no trend)	-2.55	-2.35	-1.45	-2.76	-1.47	-1.48	-0.76	-1.15	-1.39
De*	-2.55	-6.45	-6.32	-6.65	-10.59	-6.20	-6.92	-9.18	-10.44
r* (with trend)	-3.24	-2.69	-3.13	-3.18	-2.98	-2.88	-1.99	-2.52	-3.13
r* (no trend)	-2.55	-0.92	-0.99	-1.27	-1.14	-0.90	0.28	-0.98	-0.82
Dr*	-2.55	-7.19	-6.48	-11.01	-6.33	-6.50	-5.95	-6.94	-5.89
u* (with trend)	-3.24	-3.81	-3.83	-3.75	-3.73	-3.76	-3.74	-3.78	-3.90
u* (no trend)	-2.55	-3.82	-3.81	-3.77	-3.73	-3.77	-3.76	-3.79	-3.91
Du*	-2.55	-8.08	-7.68	-8.52	-8.54	-8.24	-8.18	-8.06	-7.91

Source: Authors' own calculations.

Table D: VARXs order and number of cointegrating relationships

	VARX (p,q)		cointegrating relationships
	p	q	
BRA	2	2	3
CAN	2	2	0
CHL	2	1	1
CHN	2	1	2
EUR	2	2	2
IDN	2	2	2
IND	2	2	0
JPN	2	2	1
KOR	2	2	2
MEX	2	2	1
NOR	2	2	2
RUS	2	1	2
SOU	2	2	2
SWE	2	2	1
TUR	2	2	2
U.K.	2	1	1
U.S.	2	1	1

Source: Authors' own calculations.

Table E: Weak Exogeneity Test at 5% of Statistical Significance

	Critical value	q*	ip*	e*	r*	u*
BRA	3.03	1.52	2.97		0.15	0.23
CAN	3.88	3.49	0.98		0.22	0.28
CHL	3.88	0.10	0.56		3.94	0.27
CHN	2.64	1.43	0.86		0.89	0.82
EUR	3.03	1.37	0.60		1.09	2.21
IDN	3.03	1.72	2.26		1.42	1.35
IND	3.88	1.20	0.47		0.40	6.87
JPN	3.88	5.80	0.76		3.15	6.02
KOR	3.03	0.23	0.54		1.72	0.13
MEX	3.88	0.01	0.25		0.06	7.06
NOR	3.03	1.17	1.17		3.13	0.97
RUS	3.03	0.01	0.09		2.19	1.01
SOU	2.64	2.38	1.14		1.82	0.61
SWE	3.88	2.21	0.37		4.36	0.46
TUR	3.88	0.02	2.07		0.36	9.59
U.K.	3.88	0.03	0.98		2.73	4.09
U.S.	3.88			0.01		

Source: Authors' own calculations.

Appendix B - Theoretical Model

There are several theoretical and empirical models of GDP, investment and the stock market, e.g., Blanchard (1981), Fama (1981, 1990), and Barro (1990) to name a few. In the model that follows, we adapt and extend Blanchard (1981) dynamic IS-LM model for a small open economy, given its simplicity and flexibility, to unveil the contagion and transmission of its stock market shocks to the rest of the economy, and how interconnected the domestic stock market is to other world stock markets that will be estimated through GVAR[3].

The dynamic IS-LM are given by the following equations:

$$\dot{y} = \sigma(aq + g + NX(\bar{y}, E) - by) \quad \text{(A1)}$$

$$i = cy - h(m - p) \quad \text{(A2)}$$

In Eq. A1 output adjusts to spending over time. Where σ, *a* and *b* are positive constants; q is the stock market value, *NX* is the trade balance (exports minus imports), which is an increasing function of the world income, $\bar{y}$, and a decreasing function of the real exchange rate, *E; y* is domestic income. All variables are in real terms. Equation A2 represents the financial markets, where *c* and *h* are positive constants, *i* denotes the short-term nominal rate, m and p are the logs of nominal money and domestic price level, respectively.

The short-term expected real rate of interest, r^*, is defined as:

$$r^* = i - \dot{p}^* \quad \text{(A3)}$$

where asterisks denote expectations; and $\dot{p}^*$ is the expected rate of inflation.

Let *e* be the nominal exchange rate (foreign currency in terms of domestic currency), *P* is the domestic price level, and $\bar{P}$ the foreign price level (measured in its own currency), then the real exchange rate *E* is

$$E = e\frac{P}{\bar{P}} \quad \text{(A4)}$$

Assuming the uncovered nominal-interest parity (e.g., Walsh, 1998, p.252):

$$\dot{e} = i - \bar{\imath} + \theta \quad \text{(A5)}$$

Where θ captures the risk premia that would lead to divergences between real returns in the two countries, and $\bar{\imath}$ is the foreign interest rate. Linearizing Eq. A4, differentiating it

[3] The basic open economy extension of the IS-LM model is only partially adequate for large economies like the US, the Euro-zone and China. These economies can influence the world financial markets, and capital may not be perfectly mobile across countries. However, our framework is the best available for our objective because it explicitly considers the stock market.

with respect to time and introducing Eq. A5 yields a dynamic equation for the real exchange rate:

$$\dot{E} = i - \bar{\iota} + \theta + \dot{P} - \frac{d\bar{P}}{dt} \quad \text{(A4')}$$

The long-term bonds in this economy are consols with yield *I* and price 1/*I*. The expected short-term nominal rate of return from holding consols is the sum of the yield and the expected nominal capital gain. Arbitrage between short and long bond implies

$$i = I - \frac{\dot{I}^*}{I} \quad \text{(A6)}$$

Following the same logic of Eq. A6 we define the long-term rate *R*:

$$r^* = R - \frac{\dot{R}^*}{R} \quad \text{(A7)}$$

As q is the real stock market value, the expected real rate of return on holding shares is $\frac{\dot{q}^*}{q} + \frac{ב}{q}$, where ב is real profit. Real profit is assumed to be a function of domestic income *y,* and *q*,

$$ב = \alpha_0 + \alpha_1 y + \alpha_2 (q - 1) \quad \text{(A8)}$$

where α_0, α_1, and α_2 are positive constants and $q>1$ increases investments and profits. Eq. A8 adds to the basic Blanchard (1981) framework a channel between stock markets and profitability. When Tobin's q is greater than one, q>1, the firm invests and accumulates capital which increases profits.

Arbitrage between short-term bonds and shares implies:

$$\frac{\dot{q}^*}{q} + \frac{ב}{q} = r^* \quad \text{(A9)}$$

The system of equations (A1)-(A9) characterize output, the stock market, interest and exchange rates as functions of policy variables *m* and *g*, expectations $\dot{q}^*$and $\dot{p}^*$ and the price levels P and $\bar{P}$. The system is block recursive: short and long rates are determined by equation A6 and A7 yielding $r = i$.

Assuming rational expectations the model is reduced to this system of equations:

$$\dot{y} = \sigma(aq + g + NX\left(\bar{y}, e\frac{P}{\bar{P}}\right) - by) \quad \text{(A10)}$$

$$r = cy - h(m - p) \quad \text{(A11)}$$

$$\dot{E} = r - \bar{\iota} + \theta + \dot{P} - \frac{d\bar{P}}{dt} \quad \text{(A12)}$$

$$\frac{\dot{q}^*}{q} + \frac{\alpha_0 + \alpha_1 y + \alpha_2 (q-1)}{q} = r \quad \text{(A13)}$$

In the steady-state with fixed prices we have from Eq. A12, $\dot{E} = 0$:

$$r = i = \bar{\iota} - \theta \quad \text{(A14)}$$

The domestic real interest rate, which is equal to domestic nominal interest rate, and which depends on the world's nominal interest rate and risk premia.

The steady-state values of two endogenous variables of our interest, y and q, are:

$$y_{ss} = \left(b - \frac{a\alpha_1}{\bar{\iota}-\theta-\alpha_2}\right)^{-1}\left[\frac{a(\alpha_0-\alpha_2)}{\bar{\iota}-\theta-\alpha_2} + g + NX\left(\bar{y}, e\frac{P}{\bar{P}}\right)\right] \quad \text{(A15)}$$

$$q_{ss} = \frac{\alpha_0+\alpha_1 y_{ss}-\alpha_2}{\bar{\iota}-\theta-\alpha_2} \quad \text{(A16)}$$

Eqs. A15 and A16 are the core of the model. They show that the steady-state equilibrium output and stock market of a given country depend critically on the open economy variables such as world interest rate, risk premia, trade balance and on the real exchange rate (or, alternatively, on the nominal exchange rate and price levels, domestic and foreign) as well as on fiscal and monetary policies.

The system (A10)-(A13) linearized around the steady state equilibrium Eqs. A15 and A16 yields the following Jacobian:

$$J = \begin{bmatrix} \frac{\partial \dot{y}}{\partial y} & \frac{\partial \dot{y}}{\partial q} \\ \frac{\partial \dot{q}}{\partial y} & \frac{\partial \dot{q}}{\partial q} \end{bmatrix}_{y_{ss}, q_{ss}} = \begin{bmatrix} -b\sigma & a\sigma \\ cq_{ss} - \alpha_1 & \bar{\iota} - \theta \end{bmatrix} \quad \text{(A17)}$$

As long as $cq_{ss} > \alpha_1$, and $\bar{\iota} > \theta$, the determinant of the Jacobian, Eq. A17, is negative and the steady-state equilibrium is a saddle point.

In this paper, we estimate through GVAR the main results of the theoretical model given by Eqs. A15 and A16, namely, we estimate stock market shocks to the rest of the world, showing the interconnection of the domestic stock market to other world stock markets. Therefore, we estimate the contagion and transmission of the economies of the BRICS and major industrialized economies (G7).