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KELLY SAMÁ LOPES DE VASCONCELOS

EXTERNAL SOURCES OF TRANSMISSION OF SHORT-RUN GROWTH SHOCKS IN BRAZIL

FORTALEZA
2025

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Tese apresentada ao Programa de Pós-Graduação em Economia da Universidade Federal do Ceará, como requisito parcial à obtenção do título de Doutora em Economia. Área de concentração: Métodos Quantitativos.

Orientador: Prof. Dr. Paulo Rogério Faustino Matos.
Coorientador: Prof. Dr. Cristiano da Costa da Silva.

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A Deus.

À minha família.

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RESUMO

Este trabalho contribui para a literatura empírica sobre os canais de transmissão do crescimento econômico e a decomposição de choques, com o objetivo de mensurar os efeitos de transbordamento da volatilidade do crescimento brasileiro decorrentes de choques em preços de commodities, bem como de variáveis macroeconômicas externas e domésticas. A metodologia adotada segue Gabauer e Gupta (2018), por meio da aplicação de um modelo Vetorial Autorregressivo com Parâmetros Variáveis no Tempo (TVP-VAR), com estruturas dinâmicas voltadas à modelagem da conectividade condicional. Essa abordagem permite estimar efeitos de transbordamento externos específicos no tempo, controlados por variáveis associadas às políticas fiscal, monetária, de crédito e de investimento. Com base no exercício empírico realizado entre abril de 2007 e setembro de 2024, estima-se o Índice Total de Conectividade (TCI), decomposto por grupos e frequências, identificando-se as variáveis que atuam como emissoras líquidas de choques ao crescimento. O estudo também oferece evidências sobre os canais internos de transmissão de volatilidade.

Palavras-chave: volatilidade do crescimento; choques externos; canais de transmissão; índices de commodities; integração comercial e financeira.

ABSTRACT

We contribute to the empirical literature on growth transmission channels and shock decomposition, aiming to measure the spillovers of Brazilian growth volatility from commodities, as well as open and domestic macroeconomic variables. We follow Gabauer and Gupta (2018) by using a Time-Varying Parameter Vector Autoregressive approach with dynamic structures to model the conditional connectedness. This technique enables us to measure time-specific external spillover effects that are controlled by variables associated with government fiscal, monetary, credit, and investment policies. Based on our empirical exercise from April 2007 to September 2024, we measure TCI decomposed by group and frequency, and identify which variables are net senders of shocks to growth. We also provide insights into the internal transmission channels.

Keywords: growth volatility spillover; external shocks; transmission channel; commodities indices; trade and financial integration.

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1 INTRODUCTION

Brazil is an emerging country with idiosyncratic and worrying characteristics that has usually appeared among the 10 largest economies in the world, according to the International Monetary Fund (IMF) ranking. This recent democracy experienced four periods of recession between 2007 and 2024, characterized by a fragile and unstable fiscal, monetary, and credit context. Regarding the fiscal side, there has been a history of growing primary deficits since 2014, except in 2022, in addition to a rise in net debt to GDP from 20% in 2014 to almost 55% during the pandemic. In monetary terms, only in the last decade, inflation was outside the tolerance range in five years, including 2024. The most recent (May 2025) benchmark SELIC interest rate was 14.75%. Concluding the analysis of the macroeconomic tripod, the country has had a stock of household credit higher than enterprise credit since 2016, as the federal government has adopted encouraging household consumption through a higher level of indebtedness as a public policy, even under unfavorable credit conditions. The default rate on the household non-earmarked credit, in the form of special checks, has remained above 11% since 2022.

These internal vulnerabilities, combined with external shocks such as commodity price volatility and global financial crises, help explain the fluctuations in Brazil's global economic position. Despite these challenges, its large domestic market, abundant natural resources, and integration into international trade continue to sustain its relevance. Nonetheless, maintaining or improving its status among the world's largest economies will require deep structural reforms, enhanced productivity, investment in human capital, and a commitment to consistent macroeconomic stability. The International Monetary Fund (2023), for instance, expresses concern over the implications of geopolitical tensions for macro-financial stability, particularly due to the financial fragmentation they may induce. In this context, Brazil's exposure to international capital flows, dependence on commodity exports, and structural fiscal fragilities may amplify the effects of such global disruptions, underscoring the urgency of advancing resilience-oriented economic policies.

Regarding economic growth, based on the variation in monthly real GDP per capita between April 2007 and September 2024, with 210 monthly observations, there was a negative variation in 105 months, exactly half of the observations. The average monthly real growth is positive, 0.18%. However, it is worrying to identify that the oscillation after the pandemic crisis has been greater than that recorded in the entire period analyzed and even higher than the volatility measured only during the four periods of crisis in that interstice. The weekly changes

in the Central Bank's Focus report forecasts, as well as the forecast errors of several institutions, corroborate the recent uncertainty about Brazilian economic growth and macroeconomic fundamentals.

Considering this scenario, we propose an empirical exercise to contribute to the discussion on short-term economic activity in Brazil by addressing the sources of growth volatility spillover. We measure the role of specific domestic macro variables (debt, primary balance, inflation, interest rate, stock capital, household and enterprise credit), open macro variables (export, import, foreign exchange, and foreign direct investment), as well as leading commodities indices (energy, beverage, fertilizers, food, metals & minerals, precious metals, and raw materials) in explaining time-varying short-run growth variation, through a connectedness framework.

Observing the recent literature on growth drivers in Brazil, Matos et al. (2025a) analyze the short-term comovements between real per capita GDP and macroeconomic variables in Brazil from 2004Q1 to 2022Q4 using wavelet techniques. Their findings reveal that the primary surplus positively leads the growth cycle outside of recessions, while inflation and household credit act in opposition. Corporate credit contributes positively during recessionary periods, whereas interest rates exert an adverse effect. The authors conclude that short-term fiscal balance can be achieved through a controlled increase in domestic debt, supported by credible primary surpluses, low inflation, and reduced interest rates, without undermining economic growth.

Here, we take a step further in this discussion by analyzing the role of external sources in transmitting short-term growth shocks in the same emerging country, using a different technique.

First, let us motivate our paper. Although some of the first neoclassical models assume that economies are independent and have not interacted with each other over the last 60 years, one of the traditional stylized facts about growth is that national growth rates depend on external determinants. Considering globalization, liberalization, and integration among all economies over the last decades, the closed economy assumption may be revised, and we need to study the sources and the role of external sources of growth spillover. According to the World Bank, to illustrate the strong momentum behind the growth in trade and financial globalization, the world's trade-to-GDP ratio has increased from 25.8% in 1970 to 62.5% in 2022.

Theoretically, the concept of spillover has been studied primarily within the framework of endogenous growth models, as illustrated in Aghion and Howitt (1992) and Howitt (2000). Empirically, one of the most developed strands of literature usually employs an

extended version of a neoclassical model, with an interest in one or more channels through which growth fluctuations in one country or external variables are transmitted to other countries. This route of discussion proposes an integrated theoretical and empirical framework to gauge the effect of the main channels of transmission of growth spillovers, including technological interactions, industrial structure, specialization of production, financial integration, trade agreements, geopolitical relationships, currency unions, and even the distance between countries. For instance, Klenow and Rodriguez-Clare (2005) present stylized facts reflecting worldwide interdependence and the role of cross-country externalities. Considering this broad set of possible channels, we examine the role played by trade and financial integration as sources of external spillover by modeling the impact of exports, imports, foreign exchange, foreign direct investment, and commodities. We follow Ho et al. (2013), who extend the Solow growth model with a spatial autoregressive term and a time lag term. Based on an estimation of this model using a sample of 26 OECD countries over the period 1971–2005, they find that bilateral export and import flows are key drivers in transmitting growth across countries. Regarding the other channel, Kose et al. (2003) find that financially open developing economies have synchronized cycles with the G7 countries, while Imbs (2006) finds that more financially integrated countries are more synchronous.

Concerning the methodology, we employ the conditional connectedness approach outlined by Gabauer and Gupta (2018), extending the Diebold and Yilmaz model (2009, 2012, 2014, 2015). This approach incorporates a Time-Varying Parameter Vector Autoregressive (TVP-VAR) model with dynamic structures to accommodate pattern changes and minimize the influence of outliers across periods. This technique highlights both quantitative (levels) and qualitative (roles and directions) time-specific changes in connectedness due to commodities, domestic and open macro variables, and their unusual behavior through static and dynamic analyses of connectedness indices. In this connectedness-based debate on transmission channels, Costa et al. (2021) provide insights into the pass-through of sectoral index volatility in the U.S. before and after the pandemic. Regarding discussions based on this approach, we highlight Karkowska and Urjasz (2021) and Pham and Sala (2021). The former examines the connectedness structures of sovereign bond markets in Central and Eastern Europe. The latter explores this concept in the context of monthly inflation and unemployment, focusing on the G7 economies, as well as Spain. More recently, Wang et al. (2024) utilize connectedness to analyze quantile spillovers between the U.S. yield curve spread, the U.S. dollar, and the gold price, while Matos et al. (2025b) employ the same framework to measure growth spillovers from G-10 countries to the U.S.

The paper proceeds as follows. In Section 2, we provide an explanation of economic modeling. In Section 3, we describe the methodology, while the related literature is addressed in Section 4. We analyze data in Section 5. In Section 6, we report the results. In Section 7, we offer concluding remarks.

2 ECONOMIC THEORY AND RELATED EMPIRICAL FINDINGS: THE SPECIFICATION OF THE MODEL

2.1. Initial remarks

We employ a conditional connectedness framework to conduct an empirical exercise examining the macroeconomic transmission channels of growth shock decomposition in Brazil. However, we do not follow a specific theoretical framework that has already been developed. Instead, this paper's thesis follows the purpose of Hodrick and Prescott (1997) by assuming that studying the co-movements of aggregate economic variables using an efficient and replicable technique can provide insights into the features of the economy that an equilibrium theory should incorporate. From a normative perspective, the relationship proposed between economic activity and external sources, filtered by a relevant and parsimonious set of domestic variables, can be useful for modeling and better understanding the dynamics of growth volatility spillover.

This section serves as a survey, featuring theoretical and empirical papers on the role of the variables used in this study. First, domestic macro variables. In the following subsections, we discuss the choice of external sources of spillover, specifically open macro variables and commodities. In subsection 2.5, we describe the complete set of variables.

2.2 Domestic source of spillover

Regarding domestic drivers, some related contributions are based on the extensions of the neoclassical approach developed in the 1950s and 1960s, including other sources of cross-economy variation, such as variables associated with government policies. In contrast, other extensions have suggested broadening the definition of capital, enabling this agenda to include human capital or productivity. Considering our purpose of modeling short-run spillover using available monthly series, we must limit our analysis to government decisions. We follow the growth and business cycle literature by defining a set of determinants or drivers, rather than adhering to a specific theoretical model or utilizing all existing economic variables. It is helpful to highlight some key papers in the extensive theoretical and empirical literature on identifying transmission mechanisms involving most of the fiscal, monetary, and credit variables, as well as their effects on growth.

Concerning the relationship between debt, interest rates, and growth, according to Reinhart et al. (2003), debt has a nonlinear effect on growth related to a response of market interest rates as economies reach debt tolerance limits. According to them, as countries reach debt tolerance limits, sharply rising interest rates, in turn, force a painful fiscal adjustment in the form of tax hikes, spending cuts, or outright default. This pass-through is even more complex, as it may depend on the term structure of the interest rate, the maturity of the debt, and its solvency, i.e., its relationship with the flow of surplus or deficits.

Regarding the transmission channel involving inflation, interest rates, credit, and growth, it is customary for the Central Bank to manage monetary policy, aiming to control inflation by adjusting benchmark interest rates. These rates affect long-term interest rates and mortgage, loan, and other rates that consumers and business borrowers face. Lower interest rates drive higher demand, which in turn reduces slack in markets. The pass-through effect depends on the credit market. Eventually, these tighter markets put upward pressure on prices and wages, increasing inflation. Higher rates have the opposite effect. On this topic, Rossi Júnior et al. (2019) analyze the role played by the different components of wealth, public debt, the stock market, and housing, in the transmission channels of monetary policy in Brazil, using a Bayesian approach.

Regarding the role of inflation and debt, according to recent fiscal theory explored in Cochrane (2023), the key reason severe inflation often comes with serious economic difficulties is straightforward: Inflation is a form of sovereign default. Paying off bonds with a currency worth half as much as used is like defaulting on half of the debt. Moreover, sovereign default does not typically occur in boom times, but rather when economies and governments are in financial trouble. This mechanism related to interest rates is also helpful in understanding the role played by inflation in GDP, a classic research agenda in monetary economics, as illustrated in a highly informative survey by Lucas (2000).

Reinhart and Rogoff (2010) study the longer-term implications of higher public debt using a simple exercise with a multi-country historical dataset in this related empirical literature. They find that median growth rates for countries with public debt exceeding 90% of GDP are approximately one percentage point lower than otherwise, and they report that in emerging market countries, high public debt levels are associated with higher inflation.

Regarding the role of credit, Beck et al. (2012) propose addressing the roles played by enterprise and household credit. They find that the role played by enterprise credit in GDP is positive and higher than the elasticity of household credit growth for a sample of forty-five developed and developing countries. Chen et al. (2012) are among the rare papers that address

frequency-varying co-movements between the credit market and macrofinance. They employ a multivariate analysis that accounts for the phase shift mechanism to identify causality between financial and business cycles, even with raw data at different frequencies.

Finally, extensive literature addresses the role of public investment measured by its impact on macroeconomic variables, such as economic growth. We begin by mentioning Barro (1990), a landmark in this literature. He assumes that tax-financed public services and goods are inputs to private production and are incorporated into the household's utility functions. Regarding the role of capital stock, we must remember that the discussion of the economic effects of public investment encompasses three key issues: efficiency, the marginal productivity of capital, and the crowding-in or crowding-out response. According to Berg et al. (2015), the marginal contribution of an additional dollar of investment spending to output can be broken down into the amount of capital installed (efficiency) and the marginal productivity of that capital. According to the IMF (2014), if the efficiency of the public investment process is low, then project selection and execution could be better, and only a fraction of the amount invested is converted into productive capital stock. Low investment efficiency implies that less than a dollar of capital is invested per dollar of revenue generated. Therefore, raising capital stock is a relevant growth driver.

To summarize, we follow some relevant and recent empirical studies – Adrian et al. (2010), Azariadis (2018), Matos et al. (2024), and Matos et al. (2025a) – by studying the role played by domestic macro variables, based on the monetary, fiscal, credit, and investment decisions.

2.3 External source of spillover: open macro variables

Brazil has undergone significant transformations over the past few decades. In the 1990s, the implementation of the Washington Consensus introduced market-oriented policies aimed at fostering economic development. While various policy shifts have taken place since then, Ban and Blyth (2013) argue that the dominant economic framework still reflects key principles of the liberal model, particularly those associated with the Post-Washington Consensus. The role of foreign direct investment (FDI) in the Brazilian economy has undergone significant evolution over time. Before World War II, FDI was primarily concentrated on public utilities, such as transportation, as well as in the export-oriented primary goods sector and banking, with only a small share directed toward manufacturing. Following a pattern similar to

that of Argentina, post-war FDI shifted toward the manufacturing sector as part of an import substitution industrialization strategy. However, in the 1990s, the role of FDI underwent a substantial change. Brazil implemented a series of institutional and macroeconomic reforms to attract greater FDI inflows (Treviño and Mixon Jr., 2004).

The 1999 depreciation of the Brazilian Real led to only a modest trade balance adjustment, US$6 billion between 1998 and 2000, despite a 30% decline in the real effective exchange rate and stable growth relative to trade partners. This limited response fueled concerns over structural rigidities and reinforced perceptions of low trade elasticity, suggesting that greater depreciation might be required to sustain external balance under adverse conditions (Paiva, 2003).

Bulmer-Thomas (1999) analyzes the repercussions of the 1997 Asian crisis as it extended to Latin America in the subsequent year. The Brazilian currency devaluation of January 1999 highlighted the susceptibility of Latin America's largest economy to external shocks and the underlying issues of fiscal imbalance. This article examines the factors contributing to devaluation and identifies the conditions under which it could potentially improve economic performance. It further assesses the repercussions of the devaluation on Brazil's MERCOSUR partners, with particular emphasis on Argentina. Additionally, the study examines the broader implications of the Brazilian case for reforming the global financial architecture, particularly in the context of capital flow volatility in emerging markets. He concludes that the primary effects of the devaluation will manifest within Brazil itself and that achieving a positive outcome will necessitate comprehensive economic and political reforms beyond those implemented by the Cardoso administration.

Rocha et al. (2022) employ a structural vector autoregression (SVAR) model to assess the influence of external factors, namely commodity prices and U.S. GDP, on the dynamics of credit and key domestic variables in Brazil (GDP, inflation, interest rate, and exchange rate). The findings suggest that interest rate shocks have a significant impact on credit, while commodity price shocks gain relevance over longer time horizons. A positive interest rate shock reduces GDP, whereas a credit shock produces a short-lived increase in GDP. In the long run, commodity price shocks explain a substantial portion of the variance in domestic variables, particularly GDP (67%) and credit (47%), underscoring their importance in Brazil's macroeconomic dynamics.

Lasco-Pereira et al. (2024) empirically examine the impact of the real exchange rate (RER) on investment across 81 manufacturing sectors in Brazil from 2007 to 2018. Using a highly disaggregated dataset, the study identifies two opposing channels through which a

competitive RER affects investment: positively via export growth and negatively through higher input costs. The RER effect is more pronounced in low-markup sectors, where export revenues help offset limited internal financing. Additionally, evidence supports an import substitution channel, whereby a competitive RER boosts investment as domestic goods replace imports.

In addition to its role in foreign exchange, trade is also a significant driver of growth. In the 1980s, Feder (1983) contributed to this debate by finding a positive relationship between exports and GDP growth, while Barro (1991) proposed assessing the roles of government spending and human capital stock on countries' economic development. These studies find that both variables are statistically significant, even using different proxy variables for human capital. Levine and Renelt (1992) try to shed light on this discussion by incorporating investment, trade, fiscal, and monetary variables into the model. Using Extreme Bounds Analysis, they find a positive impact of investment on GDP, human capital, and the trade-to-GDP ratio. Matos and Albuquerque (2020) contribute to the literature on financial systems and development by proposing an empirical exercise to understand better the channels through which credit drivers can promote economic growth. They estimate an extended version of Barro-style growth panel regression in difference, considering the role of household credit, enterprise credit, and government credit, as well as exports, imports, years of schooling, government capital, and current expenditures. They find that exports and imports play a significant and divergent role.

Although exporter survival rates in Brazil remained relatively high between 2003 and 2009, this outcome primarily reflects a low and declining rate of firm entry into export markets. Brazil already exhibited a limited entry rate compared to peer economies, which has further deteriorated in recent years. Favorable geographic and sectoral composition effects largely supported export performance during this period. However, once these factors are controlled for, the underlying, or "pure," export performance remains positive but appears considerably weaker, particularly in comparison to other major emerging economies.

Additionally, there has been a marked decline in export sophistication, characterized by an increasing concentration of primary and resource-based goods and a significant reduction in the share of high-technology products. This trend suggests underperformance in technologically intensive sectors, rather than being solely attributable to expanding commodity exports (Canuto et al., 2013).

2.4 External source of spillover: commodity-driven economic cycles in Brazil

Between 2004 and 2008, Brazil's economic performance emerged as the most remarkable within the period spanning from 1960 to 2016, underpinned by a favorable international environment, most notably through the appreciation of commodities. This interval was characterized by fiscal and current account surpluses, robust real GDP per capita growth, an expansion in international trade, a reduction in public external debt, the accumulation of global reserves, and the consolidation of an inflation-targeting framework.[1]

Observing the last decades, the Brazilian economic growth model of the 2000s, heavily reliant on commodity exports, domestic consumption expansion, an overvalued exchange rate, and high interest rates, imposed significant constraints on national development and Brazil's consolidation as a regional power. The so-called neo-developmental model, supported by state-led incentives aimed at promoting natural resource exports and attracting foreign investment, revealed internal contradictions by simultaneously endorsing policies in support of family farming while also advancing the interests of large agribusiness conglomerates and Brazilian multinationals across the continent. This ambiguity is reflected in the tension between the rhetoric of a national development project and the reality of deindustrialization and dependence on commodity-based surpluses. Drawing on aggregate data and secondary sources, the article examines these contradictions and the limitations of Brazil's strategy for asserting itself as a regional power during the Lula (2003–2010) and Rousseff (2011–2016) administrations (Sauer et al., 2017).

Céspedes and Velasco (2014) argue that, in recent decades, the fiscal policy of commodity-exporting countries has become progressively less procyclical in response to fluctuations in commodity prices. The authors observe that during the commodity boom in the 1970s, fiscal policy was predominantly anticyclical or procyclical, i.e., it tended to follow the economic expansion driven by high prices. However, during the price upcycle between 2003 and 2008, a shift occurred toward a more countercyclical stance. This transition reflects greater institutional maturity and a growing recognition of the need to mitigate the impact of external shocks on domestic economic conditions.

Regarding the macroeconomic effects of oil price shocks in the United States and Brazil, Cavalcanti and Jalles (2013) find that such shocks account for only a modest share of Brazil's output growth volatility. In contrast, in the United States, not only has growth volatility

[1] A very interesting discussion of the history of Brazil can be seen in Kehoe and Nicolini (2021).

declined over time, but the influence of oil shocks on that volatility has also become less pronounced. This contrast highlights the Brazilian economy's greater structural vulnerability to fluctuations in international commodity prices, despite its status as a net oil exporter. Although Brazil has been a net oil-exporting economy since 2008, its long-term growth performance has remained below its potential.

Arbache and Sarquis (2018) argue that this underwhelming performance is mainly attributable to the high volatility of economic growth, which undermines both the predictability and sustainability of development. Despite the strategic importance of oil to the Brazilian economy, the country has struggled to transform this resource into a consistent driver of economic growth. According to them, increases in international oil prices, rather than yielding lasting benefits, have been associated with episodes of macroeconomic instability. They also emphasize that such price increases contribute to the outbreak of external debt crises, which are often accompanied by severe fiscal crises that curtail the public sector's investment capacity. This scenario illustrates how commodity dependence can exacerbate structural vulnerabilities, rather than fostering balanced and sustainable economic growth.

Complementarily, Cavalcanti et al. (2019) analyze the effects of natural resource extraction on Brazil's economic growth and observed that, although oil discoveries generated positive impacts on local output, economic development, and urbanization in specific areas, these effects did not translate into aggregate benefits for the country as a whole. At the national level, the impacts were adverse, possibly due to displacement effects, resource misallocation, or the so-called "natural resource curse," which can undermine institutional and macroeconomic efficiency over the long term.

Mohaddes and Raissi (2017) investigate the impact of volatility in commodity terms of trade (CToT) on long-term economic growth in 69 commodity-dependent countries from 1981 to 2014. Using the CS-ARDL estimation method, they find that CToT volatility has a negative impact on growth, reducing physical capital accumulation and total factor productivity (TFP). However, the adverse effects are significantly mitigated in countries with Sovereign Wealth Funds (SWFs) and higher institutional quality, contributing to more stable government spending. Additionally, improving the functioning of financial markets is a crucial step, as it enables firms and households to hedge against shocks, reduce uncertainty, and mitigate the adverse effects of volatility on investment and economic growth.

The study by Kang et al. (2017) demonstrates that the Global Financial Crisis significantly altered the risk spillover dynamics between different commodity markets. Specifically, the crisis episode intensified the interdependency between assets such as gold,

silver, crude oil, rice, and wheat, revealing that shocks in one market began to have a more pronounced influence on others.

Fernández et al. (2018) investigate the hypothesis that fluctuations in commodity prices play a central role in driving business cycles in small emerging market economies (EMEs). The authors provide empirical evidence of strong comovements between commodity prices and key macroeconomic variables throughout the business cycles of these economies, identifying a common factor that explains a significant portion of the time-series behavior of commodity prices. Based on these stylized facts, they incorporate a commodity sector into a dynamic, stochastic, multi-country business cycle model, in which exogenous shocks to commodity prices coexist with other macroeconomic disturbances. In this framework, commodity prices follow a standard dynamic factor structure. When estimated using EME data, the model attributes a substantial share, over one-third of the variance in real output across countries, to shocks in commodity prices, particularly those linked to the common factor. The model also effectively captures other empirical features of business cycles. Furthermore, it highlights an amplification mechanism through which commodity price shocks influence interest rates. Notably, in certain instances, positive commodity price shocks have mitigated the impact of adverse domestic shocks, such as during the rapid post-crisis recovery following the global financial crisis.

Global commodity markets are profoundly impacted by disruptive factors, including the COVID-19 pandemic, the war in Ukraine, and climate change, resulting in a structural reconfiguration with potential long-lasting implications for developing economies. These events impact trade flows, supply and demand, and alter prices and value chains, particularly in countries that rely heavily on natural resource exports. As a result, adaptation policies are required to address the emerging challenges in the global landscape.

Moreover, according to Baffes and Nagle (2022), commodity price shocks affect exporting countries in a heterogeneous manner, requiring public policies tailored to national specificities. The study highlights three main areas of action: i) strengthening fiscal, monetary, and regulatory frameworks through the accumulation of reserves during periods of prosperity, flexible exchange rate regimes, and the prevention of risks such as external debt; ii) adopting more efficient instruments to smooth economic cycles, preferring market-based mechanisms over subsidies and trade barriers, which tend to be costly and ineffective; and iii) promoting economic diversification, with a focus on reducing dependence on fossil fuels or agricultural products, through reforms aimed at strengthening human capital, competitiveness, and institutions.

Flechtner and Middelanis (2024) analyze the effects of the 2003–2013 commodity price boom on public social spending in 16 Latin American countries from 1990 to 2019 using structural VARs and local projections. Their findings reveal significant heterogeneity in country responses: only Argentina and Ecuador experienced sustained increases in social spending, while Brazil and Mexico saw temporary rises, Chile displayed mixed dynamics, and countries like Bolivia, Colombia, and Peru showed no significant response. The study finds no consistent pattern across countries or spending categories and concludes that the commodity boom was neither a necessary nor sufficient condition for social policy expansion. Explanatory factors such as political orientation, fiscal frameworks, sovereign wealth funds, and economic diversification help explain individual cases but do not establish generalizable trends. The authors emphasize the need for country-specific analyses and better longitudinal data to advance development research.

2.5 Specification of the model

Remember what we said at the beginning of this section. The empirical literature on growth drivers has evolved by proposing extensions of a specific theoretical model already developed, including other sources of cross-country variation, such as variables associated with government policies. Moreover, the empirical discussion on growth transmission channels and shock decomposition also seems to follow this same strategy.

Considering the availability of Brazilian monthly data and our purpose of modeling short-run spillovers, we have chosen to limit our analysis to government decisions. In addition to the domestic and open macro variables, we also explore the role of commodity indices.

Thus, upon reviewing the literature survey mentioned in this section, we are convinced of the relevance of the variables reported in most of these papers, which motivates us to measure the role of the specific set of variables (Table 1) used here in explaining time-varying short-run growth variation. We also report the source of each variable, along with its abbreviation.

Table 1. Description of the main variables

Variable	Abbreviation	Source
Real per capita GDP (R$ sep/24)	GDP	Central Bank of Brazil
Domestic macroeconomic variables		
Real per capita household credit balance (R$ sep/24)	Household credit	Central Bank of Brazil
Real per capita enterprise credit balance (R$ sep/24)	Enterprise credit	Central Bank of Brazil
Public sector net debt of the federal government to GDP	Public debt	Central Bank of Brazil
Primary balance (without exchange devaluation) of the federal government to GDP	Primary balance	Central Bank of Brazil
Average interest rate practiced i'n repo operations with federal public bonds with a maturity of one business day (SELIC) % per month	SELIC rate	Central Bank of Brazil
Oficial inflation (Broad consumer price index -IPCA) % per month	Inflation	Central Bank of Brazil
Real per capita Fixed capital stock (R$ jul/24)	Capital stock	Institute of Applied Economic Research (IPEA)
Commodities		
Energy commodity monthly index based on R$ (2010=100 US$)	Energy	World Bank Commodity Price Data
Beverage commodity monthly index based on R$ (2010=100 US$)	Beverage	World Bank Commodity Price Data
Food commodity monthly index based on R$ (2010=100 US$)	Food	World Bank Commodity Price Data
Raw materials commodity monthly index based on R$ (2010=100 US$)	Raw materials	World Bank Commodity Price Data
Fertilizers commodity monthly index based on R$ (2010=100 US$)	Fertilizers	World Bank Commodity Price Data
Metals & minerals commodity monthly index based on R$ (2010=100 US$)	Metals & minerals	World Bank Commodity Price Data
Precious metals commodity monthly index based on R$ (2010=100 US$)	Precious metals	World Bank Commodity Price Data
Open macro variables		
Foreign exchange (US$ to R$)	Foreign exchange	Central Bank of Brazil
Foreign Direct Investment to GDP	FDI	Central Bank of Brazil
Export to GDP	Export	Ministry of Development, Industry, Trade and Services (COMEX STAT/MDIC)
Import to GDP	Import	Ministry of Development, Industry, Trade and Services (COMEX STAT/MDIC)

3 METHODOLOGY

3.1. The choice of the approach

We aim to measure the short-run spillover between growth, domestic, and open macroeconomic variables. Theoretically, we address this spillover by extending a classic economic framework guided by extensive literature on growth transmission channels and shock decomposition. In practice, we intend to model internal and external transmission of shocks across macroeconomic variables and growth from April 2007 to September 2024. Considering the short-run behavior of growth, fiscal, credit, monetary, capital, commodity, trade, and other open macroeconomic variables over almost 17 years, we believe it is essential to determine whether these spillover relationships remain stable over time. Methodologically, Diebold and Yılmaz (2012) can be seen as significant work for examining dynamic network spillovers. This technique enables us to fulfill our primary purpose—to highlight both quantitative (levels) and qualitative (roles and directions) changes in growth connectedness that occurred, as well as any unusual behavior of specific countries, using static and dynamic analyses of the proper connectedness indices.

More specifically, Diebold and Yilmaz (2009) formulate and examine precise and separate measures of return and volatility spillovers. This facilitates the study of non-crisis and crisis episodes, including trends and spillover bursts. Diebold and Yilmaz (2012) use a generalized vector autoregressive framework in which forecast-error variance decompositions are invariant to the variable ordering, and they propose measures of both the total and directional volatility spillovers. According to Corbet et al. (2020), this model has some advantages, such as allowing bilateral spillovers. It also allows displaying the strength of spillovers and enables proper comparisons among alternative model configurations and variable sets. This methodology is more suitable than concurrent correlation-based methods, such as Wavelet analysis and the multivariate GARCH models, since it can clearly and compactly infer the direction of spillovers for many simultaneously interacting variables. Due to the connectedness approach's popularity, numerous extensions address different issues, such as asymmetry, frequency, and time-varying parameters, among others. [2] We follow the framework developed by Gabauer and Gupta (2018), which introduces the segmentation of connectedness measures at both the sectoral and country level. To our context, we adapt this approach to

[2] One can see Gabauer et al. (2023) for a summary of such extensions.

distinguish spillovers effects between domestic variables versus open macroeconomic variables and commodities within a TVP-VAR model. This adaptation enables us to provide a detailed analysis of the spillover dynamics between internal and external factors in the Brazilian economy.

3.2 Theoretical review of this technique

Gabauer and Gupta (2018) introduce a significant methodological advancement by developing sector- and country-specific measures of connectedness. This approach facilitates the design of a large-scale unified network encompassing multiple markets, such as the energy and agricultural commodity markets. A key advantage of this method lies in its ability to disentangle intra-sector contagion effects (i.e., within the energy market or the agricultural market) from inter-sector contagion effects occurring across distinct markets. Consequently, this methodology supports a more granular and precise analysis of systemic interdependencies.

In parallel, Demirer et al. (2018) employ a LASSO-VAR (Least Absolute Shrinkage and Selection Operator Vector Autoregression) model to perform dimensionality reduction, variable selection, and network estimation in high-dimensional settings. This approach mitigates the challenges associated with high-dimensional data by applying penalization techniques that remove negligible connections, thereby emphasizing the most relevant interactions within the network. The LASSO-VAR model, in this context, is regarded as a specific case of the elastic net approach subsequently proposed by Gabauer et al. (2024), which combines both LASSO- and Ridge-type penalties. Depending on the tuning of its parameters, the elastic net constraint may produce estimators that are equivalent to either the LASSO or the Ridge regression formulations.

Antonakakis et al. (2019) propose the application of a time-varying parameter factor-augmented VAR (TVP-FAVAR) model as a solution to the "curse of dimensionality" frequently encountered in empirical studies involving large sets of variables. The central idea is to synthesize information from a large set of variables through latent factors, which form the basis for modeling the dynamic interconnections among system components. This enables the monitoring of evolving interdependencies across markets, even within highly complex networks. Antonakakis et al. (2020) enhance the analysis of market interdependence by developing a TVP-VAR model that overcomes the limitations of traditional methods, providing greater flexibility and robustness in measuring dynamic connectedness. Chatziantoniou and

Gabauer (2021), in turn, apply this model to the context of Eurozone sovereign bonds, demonstrating its utility in identifying financial fragmentation and systemic risks over time. Baruník and Krehlík (2018) introduce an innovative framework for quantifying connectedness among financial variables based on the spectral decomposition of variance decompositions. This methodology captures dynamic interactions across multiple time horizons, short, medium, and long term, thereby enabling the analysis of how shocks propagate through markets at different frequencies and allowing for the distinction between transitory disturbances and persistent structural effects.

This framework was later integrated into the dynamic TVP-VAR approach, as applied by Chatziantoniou and Gabauer (2021), thereby enabling the decomposition of market connectedness in both temporal and persistence dimensions. This allows for the identification, for instance, of whether systemic risk within a monetary union arises from transient disturbances or structural shocks, thus broadening the analytical capacity of the original model. Adekoya et al. (2022) explicitly demonstrate the impact of return asymmetry on the connectedness between oil prices and Islamic sectoral stock prices. To this end, the authors employ an extension of the TVP-VAR model that estimates dynamic connectedness asymmetrically, distinguishing between the effects induced by positive and negative market shocks.

Wan et al. (2024) highlight those traditional approaches to dynamic connectedness analysis, such as those proposed by Diebold and Yılmaz (DY) and Baruník and Krehlík (BK), typically rely on rolling-window VAR models, which lead to the loss of initial observations. Given these limitations, recent literature has increasingly adopted the time-varying parameter vector autoregressive (TVP-VAR) model as a more robust methodological alternative. Among the primary advantages of the TVP-VAR model lies in its ability to eliminate the use of arbitrarily defined rolling windows, thereby preserving the entirety of the sample observations. Furthermore, this methodology demonstrates reduced sensitivity to outliers and greater accuracy in identifying structural changes in model parameters over time, as documented by Antonakakis et al. (2020) and Chatziantoniou et al. (2023). These authors further emphasize that, taken together, these methodologies represent significant advances in the measurement and understanding of connectedness in large-scale financial and economic systems. They not only enable effective statistical handling of dense and dynamic networks but also expand analytical capacity by incorporating distinctions across sectors, countries, and temporal effects. Such tools are essential for identifying sources of systemic risk and for formulating more effective macroprudential policies in response to global or regional shocks.

3.3 The specification of the technique

In this subsection, we describe the network topology based on the dynamic connectedness framework grounded in the time-varying parameter vector autoregressive model (TVP-VAR, hereafter), as developed by Antonakakis and Gabauer (2017). This methodology constitutes an extension of the framework originally proposed by Diebold and Yilmaz (2009, 2012, 2014), enabling the modeling of interdependencies among time series in relation to variance spillovers without the need for arbitrarily defined rolling windows. This feature provides enhanced flexibility and accuracy in analyzing connectedness over time.

The connectedness measure means the variance decomposition of the H-step ahead forecast. One can view the Connectedness from a variable j to another variable i as the share that shocks in j have on the complete variance of i, or when measuring the influence that i has on k, analyzing which share of the variance of k that i is responsible for. In this paper, we use an extension of the original work of Diebold and Yilmaz (2009, 2012, 2014, 2015), devised by Gabauer and Gupta (2018), which considers a Time-Varying Parameter Vector Autoregression (TVP-VAR) with a lag length of one as suggested by the Akaike Criteria (AIC), which is defined as:

$$\boldsymbol{z_t = B_t z_{t-1} + u_t} \qquad \boldsymbol{u_t | F_{t-1} \sim N(0, S_t)} \tag{1}$$

$$vec(\boldsymbol{B_t}) = vec(\boldsymbol{B_{t-1}}) + \boldsymbol{v_t} \qquad \boldsymbol{v_t | F_{t-1} \sim N(0, R_t)} \tag{2}$$

where $\boldsymbol{z_t}$ and $\boldsymbol{z_{t-1}}$ are $k\ x\ 1$ dimensional vectors of endogenous variables in t and $t-1$, respectively. $\boldsymbol{B_t}$ is a $k\ x\ k$ dimensional time-varying parameter, $\boldsymbol{u_t}$ denotes the $k\ x\ 1$ dimensional vector of error term and $\boldsymbol{S_t}$ are $k\ x\ k$ dimensional variance-covariance matrices, $vec(\boldsymbol{B_t})$ and $\boldsymbol{v_t}$ are $k^2 x\ 1$ dimensional vectors and $\boldsymbol{R_t}$ represents the $k^2\ x\ k^2$ dimensional parameter variance-covariance matrix. The variance-covariance matrices vary via a stochastic volatility Kalman Filter estimation with forgetting factors.

To compute Generalized Impulse Response Functions (GIRF) and Generalized Forecast Error Variance Decomposition (GFEVD), it is necessary to use the transformation of TVP-VAR into Time-Varying Parameter Vector Moving Average (TVP-VMA) via the Wold representation theorem:

$$\boldsymbol{z_t} = \sum_{i=1}^{p} \boldsymbol{B_{it}\, z_{t-i} + u_t} = \sum_{j=0}^{\infty} \boldsymbol{A_{jt}\, u_{t-j}} \tag{3}$$

The GIRFs illustrate the responses of all variables following a shock in variable i. Given the absence of a structural representation of shocks, GFEVD is applied. The difference is attributed to the shock in variable i, which is given by:

$$GIRF_t(J, \delta_{j,t}, \boldsymbol{F}_{t-1}) = E(\boldsymbol{Y}_{t+j} | \boldsymbol{u}_{j,t} = \delta_{j,t}, \boldsymbol{F_{t-1}}) - E(\boldsymbol{Y}_{t+j} | \boldsymbol{F_{t-1}}) \quad (4)$$

$$\boldsymbol{\Psi}_{\mathrm{j,t}}(J) = \frac{\boldsymbol{A}_{j,t}\boldsymbol{S}_t\boldsymbol{u}_{j,t}}{\sqrt{S_{jj,t}}} \frac{\delta_{j,t}}{\sqrt{S_{jj,t}}} \qquad \delta_{j,t} = \sqrt{S_{jj,t}} \quad (5)$$

$$\boldsymbol{\Psi}^{g}_{\mathrm{j,t}}(J) = S^{-\frac{1}{2}}_{jj,t}\boldsymbol{A}_{j,t}\boldsymbol{S}_t\boldsymbol{u}_{j,t} \quad (6)$$

where $\boldsymbol{\Psi}^{g}_{\mathrm{j,t}}(J)$ represent the GIRFs of variable j, J is the forecast horizon, $\delta_{j,t}$ is the vector with one on the jth position and zero otherwise, and $\boldsymbol{F}_{t-1}$ the information set until $t-1$. GFEVD means the variance share one variable has on others, and it is given by:

$$\tilde{\phi}^{g}_{ij,t}(J) = \frac{\sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}}{\sum_{i=1}^{N}\sum_{t=1}^{J-1} \Psi^{2,g}_{ij,t}} \quad (7)$$

where $\sum_{j=1}^{N} \tilde{\phi}^{g}_{jj,t}(J) = 1$ and $\sum_{i,j=1}^{N} \tilde{\phi}^{N}_{jj,t}(J) = N$.

Based on this framework, all connectedness measures presented below are computed dynamically at each t and correspond to the chosen forecast horizon (J). Thus, the results reflect the evolving structure of spillovers and interdependencies in the system over time. The *total connectedness index* (TCI) quantifies the overall degree of interconnectedness within the system by measuring the average spillover of shocks across all variables. It reflects the degree of network interconnectedness and is formally expressed as follows:

$$C^{g}_{t}(J) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}^{g}_{ij,t}(J)}{\sum_{i,j=1}^{N} \tilde{\phi}^{g}_{ij,t}(J)} * 100 \quad (8)$$

The *total directional connectedness to others* measures the extent to which variable i transmits spillovers to all other j variables in the system. This metric is denoted as:

$$C^{g}_{i\rightarrow j,t}(J) = \frac{\sum_{i,j=1, i\neq j}^{N} \tilde{\phi}^{g}_{ji,t}(J)}{\sum_{j=1}^{N} \tilde{\phi}^{g}_{ij,t}(J)} * 100 \quad (9)$$

Conversely, the *total directional connectedness from others* quantifies the extent to which variable i receives spillovers from all other variables in the system. This measure is represented as:

$$C^{g}_{i\leftarrow j,t}(J) = \sum_{\boldsymbol{j=1,i\neq j}}^{\boldsymbol{k}} \tilde{\phi}^{g}_{ij,t}(H) \tag{10}$$

The difference between the *total directional connectedness to others* (equation 9) and the *total directional connectedness from others* (equation 10) yields the net total bidirectional connectedness for variable i.

$$C^{g}_{i\leftarrow j,t}(J) = C^{g}_{i\rightarrow j,t}(J) - C^{g}_{i\leftarrow j,t}(J) \tag{11}$$

A positive value of this measure indicates that variable i is a net transmitter of shocks within the network, while a negative value implies that it is a net receiver of shocks from the system.

In addition, we construct the *net pairwise directional connectedness* (NPDC), which indicates whether variable i acts as a driver or is driven by variable j. Positive NPDC means that variable i is a net transmitter of shocks to variable j, whereas a negative value means that variable i is a net receiver of shocks from variable j.

$$NPDC_{ij}(J) = \frac{\tilde{\phi}^{g}_{ji,t}(J) - \tilde{\phi}^{g}_{ij,t}(J)}{T} * 100 \tag{12}$$

Given that our primary objective is to evaluate the influence of both internal (*domestic variables*) and external (*open macroeconomic variables*) components on Brazil's economic dynamics, a natural extension of the connectedness framework is to distinguish the extent to which spillovers among domestic variables are generated by internal sources as opposed to being driven by external macroeconomic factors. To this end, we group the variables into two distinct sets: the first (*domestic variables*) comprises growth per capita, household credit, enterprise credit, inflation, the SELIC rate, public debt, primary balance, and stock capital; the second (*open macroeconomic variables*) includes FDI, exports, imports, foreign exchange, and commodity prices. Adapting the methodology proposed by Gabauer and Gupta (2018), the decomposition of the set of domestic variables and open macroeconomic variables can be written as follows:

$$\Phi(J) = \left[\tilde{\phi}^{g}\right]_{ij,t}(J) = \begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix} \quad (13)$$

where C_{11} includes the internal spillovers among domestic variables, while C_{22} reflects spillovers among open macroeconomic variables and commodities. C_{12} represents the spillovers of the open macroeconomic variables to domestic variables, and C_{21} denotes the reverse direction. To compute the internal and external spillovers, we set $diag(C_{ii}) = 0$ and proceed with the following calculations:

$$TO_{ij} = \sum_{n=1}^{2} \mathrm{C_{ij,nm}} \quad (14)$$

$$FROM_{ij} = \sum_{n=1}^{2} \mathrm{C_{ji,nm}} \quad (15)$$

$$NET_{ij} = \mathrm{TO_{ij}} - FROM_{ij} \quad (16)$$

$$NE_{ij} = \sum_{n=1}^{2} \sum_{m=1}^{2} \mathrm{C_{ij,nm}} - \sum_{n=1}^{2} \sum_{m=1}^{2} \mathrm{C_{ji,nm}} \quad (17)$$

where TO_{ij} denotes the total connectedness of domestic variables to others, $FROM_{ij}$ is the total connectedness from other variables to the domestic set, NET_{ij}represents the net total domestic connectedness. In our framework, NE_{ij} represents the *net external total connectedness of the domestic variables*. This measure captures the difference between the total spillovers transmitted from the domestic variables to the set of open macroeconomic variables and commodities and the total spillovers received by the domestic set. A positive value indicates that domestic variables are net transmitters of shocks to the external sector, while a negative value signifies that domestic variables are net recipients of shocks originating from the external sector. Given Brazil's position as an emerging economy and the role of the commodity sector in its economic structure, domestic variables are expected to be net recipients of shocks from open macroeconomic variables and commodity prices.

4 LITERATURE ON CONNECTEDNESS, OPEN MACRO VARIABLES, AND COMMODITIES

Let us present the most recent empirical papers that utilize connectedness to examine the role of some of the open macro variables and commodities discussed here.

Chen et al. (2021) examine the interdependence structure among commodity sectors in China by employing daily data from August 2004 to April 2019 and a dynamic connectedness approach. The findings indicate that a substantial portion of the variation in commodity prices can be attributed to sectoral connectedness, which intensifies during periods of instability. Net connectedness indices suggest that sectors dynamically alternate between net transmitters and shock receivers. Furthermore, the study provides evidence of a contemporaneous causal structure among sectors, with important implications for portfolio diversification strategies and economic policy formulation.

Balcilar et al. (2021) employ an extended joint connectedness approach based on the TVP-VAR model to examine the dynamic interdependence between crude oil futures and 11 agricultural commodities from July 2005 to May 2020. The results reveal that systemic connectedness among these markets fluctuates over time and intensifies during major economic events such as the Global Financial Crisis, the European Debt Crisis, and the COVID-19 pandemic. Crude oil, alongside commodities such as grains, sugar, soybean oil, and livestock, is a key transmitter of shocks, while corn, lean hogs, soybeans, cattle, and wheat are primary receivers. The analysis highlights the strong interconnectedness of oil with other markets, both as a source and a recipient of innovations. The study also highlights the methodological importance of model normalization, with practical implications for investors in portfolio strategy formulation, risk management, and hedging.

The study by Mishra and Kumar (2021) explores the dynamic connectivity and volatility spillovers among five agricultural commodities (cotton, corn, wheat, barley, and soybeans) from 2005 to 2019, using both VAR and TVP-VAR models. The results show that, before the implementation of India's pan-national electronic trading platform (eNAM), commodity prices were less susceptible to volatility shocks, with cotton displaying immunity to spillovers. Following the introduction of eNAM, volatility spillovers increased, particularly in commodity prices; however, overall connectedness among commodities declined. Network analysis reveals stronger price associations within individual markets, indicating that volatility is primarily concentrated within specific markets, with minimal spillovers between distinct markets.

The study by Mishra and Ghate (2022) analyzes the dynamic return and volatility connectedness among base metal markets in India, utilizing the TVP-VAR and DCC-GARCH models from March 1, 2011, to March 20, 2020. The results indicate that zinc, lead, and nickel are the main transmitters of return shocks across metals, whereas copper and tin act as primary recipients. Regarding volatility, tin, aluminum, and zinc emerge as the dominant shock transmitters, with nickel and lead as the main recipients. The analysis demonstrates strong interconnectedness in the base metals market, suggesting that portfolio diversification involving these metals may offer limited benefits due to heightened systemic risk. The findings provide meaningful guidance for policymakers and risk managers in emerging markets.

Gong and Xu (2022) investigate the spillover effects among five categories of commodity markets (energy, precious metals, industrial metals, agricultural products, and livestock) from 2008 to 2020. Their findings indicate that the energy, precious metals, and industrial metals markets act primarily as net transmitters of shocks. In contrast, the agricultural and livestock markets predominantly serve as net receivers of such effects.

Alam et al. (2022) assess the impact of Russia's invasion of Ukraine on the dynamic connectedness among five commodities and the stock markets of the G7 and BRIC countries from September 1, 2021, to March 24, 2022. The authors use Bloomberg daily data and the TVP-VAR model to identify strong interconnectedness among the analyzed assets. The findings indicate that gold, silver, and the stock markets of the United States, Canada, China, and Brazil predominantly acted as receivers of financial shocks during the conflict, highlighting the high degree of interdependence between commodities and global markets in times of crisis.

Guo and Tanaka (2022) examine the effects of biofuel production and financial speculation on food prices in Africa between January 2001 and July 2021, using monthly FAOSTAT data and the TVP-VAR model with extended joint connectedness. The results indicate that external factors such as U.S. biofuel production and the volume of food commodity futures contracts (wheat, rice, corn, and soybeans) significantly influence African food prices, particularly during global shock periods such as the 2008 commodity boom and the COVID-19 pandemic. Speculation and arbitrage transactions impacted prices from 2001 to 2012, while the influence of biofuels persisted throughout the study period. The study highlights the structural vulnerability of African food markets to external shocks and advocates for implementing policy measures designed to mitigate exposure to these risks.

Agyei and Bossman (2023) investigate, through the TVP-VAR model, the dynamic connectedness between 12 commodity classes and African stock markets using daily data from February 2010 to February 2022. The results reveal low average spillover transmission,

primarily driven by idiosyncratic shocks, yet highlight significant contagion episodes during periods of financial stress. The study concludes that these markets are not immune to global shocks, underscoring the importance of volatility management and the implementation of dynamic risk mitigation strategies.

Cagli et al. (2023), using daily data from August 11, 2005, to November 4, 2022, and the extended joint connectedness methodology based on the TVP-VAR model, analyze volatility interdependence between the stock prices of the ten largest agribusiness companies in the United States and various agricultural commodities—including wheat, corn, soybeans, coffee, sugar, cocoa, cotton, and live cattle. The findings suggest that agribusiness companies function as net transmitters of volatility, while commodities predominantly act as receivers. These results provide valuable insights for investors and policymakers interested in risk dynamics and price formation in the agri-food sector.

Furuoka et al. (2023) examine the short- and long-term connectedness between agricultural and energy commodities by employing the Frequency TVP-VAR model, an extension of the standard TVP-VAR framework incorporating frequency decomposition. The study uses daily data from August 2017 to August 2022 to explore the dynamic interrelations between oil and natural gas prices, as proxies for energy commodities, and the prices of corn, wheat, oats, flour, and rice. The findings reveal that risk transmission from energy to agricultural markets is relatively limited, amounting to 32.52% for oil and 31.38% for gas. Notably, the degree of connectedness declined during the COVID-19 pandemic but rose markedly amid the Russia–Ukraine conflict. The analysis identifies corn, wheat, and flour as net transmitters of risk, with a powerful linkage between wheat and flour, and it also uncovers asymmetries in these interconnections. Portfolio simulations further indicate that minimal allocation to energy assets is sufficient to enhance returns and mitigate risk in agricultural and energy commodities portfolios.

The study by Mishra et al. (2023) investigates the dynamic connectivity among commodity futures contracts in India during the COVID-19 pandemic using the extended joint connectedness TVP-VAR framework. Drawing on daily data from January 1, 2018, to December 31, 2021, the results reveal that systemic connectivity fluctuated over time, peaking during the global health crisis. Crude oil and zinc were identified as the main net transmitters of shocks, while gold and silver served as net recipients. Aluminum exhibited variation in its role, alternating between transmitter and recipient of shocks. Pairwise analysis highlights that zinc, copper, nickel, and crude oil significantly influenced gold price movements, while silver also substantially impacted gold. The study further notes that, compared to natural gas, gold

showed lower sensitivity to market shocks, offering insights for risk mitigation strategies in volatile markets.

Polat et al. (2023) investigate the dynamic connectivity between agricultural commodities and geopolitical risk using the TVP-VAR model and data from 2020 to 2023. Time and frequency domain analyses reveal that the interconnectedness between these markets strengthens during periods of geopolitical tension, particularly following Russia's invasion of Ukraine in 2022. Wheat and the Geopolitical Risk Index (GPRD) emerge as key transmitters of volatility shocks with persistent and widespread effects. These findings underscore the importance of monitoring geopolitical risks for portfolio management and agricultural market policymaking.

Aliu et al. (2024) investigate the impact of the Russia–Ukraine conflict and the COVID-19 pandemic on the interconnectedness between European currencies and energy and agricultural commodities from January 1, 2022, to September 1, 2023. Employing the TVP-VAR model and daily data from the Bank for International Settlements, the study finds that geopolitical factors, particularly Europe's dependence on Russian gas, had a pronounced influence on exchange rate dynamics. Although fluctuations in commodity prices exerted a moderate direct effect, policy decisions concerning the Russian ruble and broader energy security considerations played a pivotal role. The findings underscore the complexity of the effects of non-economic shocks on currency markets and highlight the importance of incorporating global geopolitical and public health risks into analyses of volatility and interdependence between currencies and commodities.

The study by Karkowska and Urjasz (2024) examines the volatility structure among biofuel, crude oil, and grain markets from 2013 to 2023, employing the Frequency Decomposed TVP-VAR model. The findings suggest that the increasing interdependence between biofuels, such as ethanol, and agricultural commodities, including corn, soybeans, wheat, rapeseed, and palm oil, amplifies market vulnerability to external shocks, with the Russia–Ukraine conflict exerting a particularly pronounced and enduring influence. The study reveals that shocks originating in the agricultural sector have a significant influence on energy markets, particularly during periods of geopolitical tension. Based on these results, the authors propose strategies to mitigate volatility transmission between the energy and food sectors, aiming to enhance stability for investors and policymakers.

Ozcelebi and Kang (2024) examine extreme connectivity between the S&P 500 index and commodity futures markets across different market regimes (bearish, standard, and bullish) using TVP-VAR and Quantile VAR models. The findings reveal asymmetric and

heightened connectedness during crises, with the S&P 500 acting as a net shock transmitter, particularly during the COVID-19 pandemic. Total connectedness intensifies under extreme conditions, limiting the effectiveness of portfolio diversification. The VIX index is identified as the most effective hedging instrument against S&P 500-related risks.

Vo and Tran (2024) examine the impact of uncertainty related to the Russia–Ukraine war on volatility spillovers between energy markets, specifically gasoline, natural gas, and oil, and agricultural markets, including corn, wheat, soybeans, sugar, cotton, and coffee. The analysis employs the TVP-VAR model, with Google Trends data as a proxy for geopolitical uncertainty. The study finds that cross-sector volatility rose significantly during the conflict, especially in response to events like G7/EU sanctions. However, the widespread dissemination of information regarding geopolitical risks helped to partially attenuate these effects, suggesting an important moderating role of informational transparency.

Vuba and Qabhobho (2024) examine risk connectedness among exchange rates, energy commodities, and agricultural commodities across SADC countries from 2007 to 2022 using the TVP-VAR model. The study identifies energy commodities (oil and heating oil) and the South African rand as primary net transmitters of shocks. In contrast, currencies such as the Malawian kwacha (MWK), Mozambican metical (MZN), natural gas, and corn emerge as primary recipients. Connectivity varied substantially during crises such as the 2008 financial crash and the COVID-19 pandemic, with strong evidence that energy shocks directly affect agricultural and currency prices in the region, particularly impacting the most vulnerable economies.

Xiang and Borjigin (2024) explore volatility spillovers between the U.S. Economic Policy Uncertainty (EPU) index and commodity futures markets, employing an extended joint connectedness TVP-VAR model. Using data from 2001 to 2023, the study constructs separate networks for high- and low-volatility regimes, showing that spillovers are more intense during high-volatility periods; in contrast, the low-volatility network demonstrates more efficient and predictive risk transmission. The EPU index functions as a transmitter and recipient of shocks, highlighting its central role in shaping interactions with commodity markets.

5 DATA

In Table 1, we have already described every variable used in this empirical exercise, as well as the respective abbreviation and source. Considering our purpose to study short-term shocks and the availability of monthly data, we employ the conditional TVP-VAR-based connectedness approach to time series from April 2007 to September 2024. According to the OECD, [3] there have been four recessions during this period.

The first crisis lasted 11 months and is associated with the subprime mortgage crisis in the United States. The second crisis between 2011 and 2012 lasted 9 months, while the third recession was the longest, lasting 31 months. This recession occurred from 2014 to 2016 and resulted from internal fiscal imbalances. The most recent crisis lasted 4 months in the first half of 2020, and although it was the shortest, it was the one that generated the most significant drop in GDP per capita. The monthly real GDP per capita variation in February 2020 was 10.4%. It is also important to highlight the accumulated drop in the 31 months of the fiscal recession that began in 2014 of almost 9.2%. These extreme negative variations can be seen in Fig. 1, in which we report the time series of real GDP per capita and other domestic macro variables at the level used in this paper. In all graphics, the shaded areas correspond to OECD recession periods (56 monthly observations). As expected, considering all these observations, the average growth is -0.06%. During non-recession periods (154 monthly observations), we find expected growth of 0.26%. The volatility in both periods is quite similar, close to 3.8%.

In Fig. 1, we show the evolution of credit, fiscal, and monetary variables, and capital stock. The growth trajectory of household credit throughout the period is noteworthy, except for the fiscal crisis from 2014 to 2016. This profile differs from enterprise credit, which fell sharply after the same crisis and only recovered as a public policy instrument to combat the pandemic. Since 2016, the stock of household credit has exceeded the stock of enterprise credit.

In the fiscal scenario, net debt to GDP remained below 30% until the 2014 crisis, but it grew worryingly until it surpassed the 50% level during the pandemic. The most recent ratio exceeded 55%, equivalent to a net debt of almost R$6.7 trillion. Unlike the behavior observed in the first two crises, in the fiscal crisis of 2014 to 2016, net debt to GDP grew from 20.7% to 33.4%, while during the pandemic, it went from 47.2% to 50.6%.

We complement the fiscal analysis by seeing the behavior of the primary result in the context of current fiscal rules. Brazil set a primary surplus target in 1999 – a critical

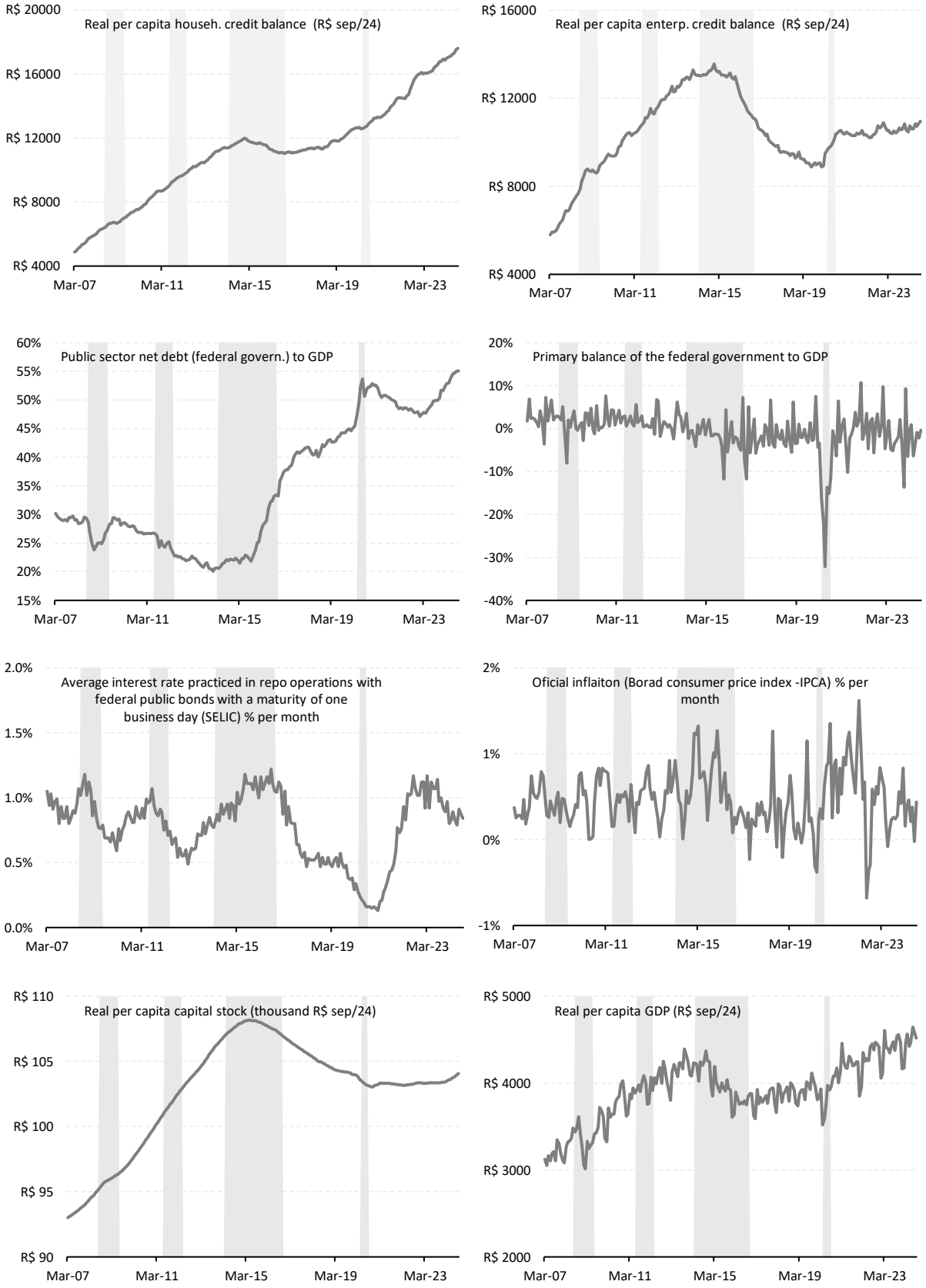
[3] Organization for Economic Co-operation and Development based recession monthly and binary indicator for Brazil, available in the database of Federal Reserve Economic Data (FRED/FED).

condition for repairing the damage to public accounts in the first years of the Real Plan. The healthy trajectory of public accounts was reinforced the following year with the Fiscal Responsibility Law that imposed some rules on the federal, state, and municipal governments. Observing the period between 2004 and 2013, there was a negative primary result in only three quarters: 2008q4, 2009q3, and 2013q3. In 2013, the federal government again recorded a primary surplus but did not reach the planned primary surplus target this time.

At the end of 2013, the National Congress approved a project that exempts the federal government from offsetting primary surplus targets not achieved by states, the Federal District, and municipalities. In practice, the proposal reduces the federal government's primary surplus target from R$155.8 billion to R$108 billion because the federal government would no longer be obliged to cover the part of the economy of states and municipalities. In 2016, via Constitutional Amendment, the country began to adopt a new fiscal rule, “the spending upper bound,” aiming to limit the growth of primary expenditure to the variation in inflation registered in the previous year. As a result of this new fiscal rule, a succession of primary deficits has occurred, with a record deficit of 23.57% in Q2 2020 (the height of the pandemic). After nine years, in 2022, Brazil reported a positive annual primary result: R$54 billion.

Regarding the evolution of the primary deficit in the quarter before and after each recession, the Brazilian government adopted the same fiscal policy characterized by financing via debt increases and reduction (increase) of primary surplus (deficit). More precisely, observing the average primary result in a 12-month moving window, in the month preceding the entry into the recession and the last month of recession, we observe the following variations, respectively, in the four recessions: i) from 2.7% to 1.0%, ii) from 2.7% to 2.2%, iii) from 1.2% to -2.2%, and iv) from -2.6% to -8.9%.

Fig. 1. Real GDP per capita and main domestic macroeconomic variables at the level.



Notes: Monthly series from March 2007 to September 2024. Shaded areas correspond to OECD recession periods. The original series of capital stock available in IPEADATA was in R$2010. We show the values in R$ September 2024) via IPCA.

In the monetary scenario, annualized SELIC interest rates, ranging between 6% and 15% in the first years of the sample, are observable before the onset of the fiscal crisis. [4] This benchmark interest rate reached its peak of 15.7% in June 2016 and its lowest level, below 3% per year, in 2020, during the pandemic. Observing the interest rate before and after each recession, except for the fiscal recession from 2014 to 2016, the interest rate was reduced in the other crises.

Concerning IPCA, since 1999, when the Central Bank implemented the inflation targeting system in Brazil, the tolerance limits have not been respected in seven (out of 24 years). Only in 2017 was the annual inflation (2.95%) lower than the target lower bound (4.5% - 1.5%), while in 2001, 2002, 2003, 2015, 2021, and 2022, the official inflation was higher than the respective upper bound. For instance, according to IBGE, in 2022, IPCA exceeded the target upper bound (3.5% + 1.5%); the annual result was almost 5.8%. With a few exceptions, 12-month accumulated inflation has remained above 4% over the past two years. Except for the increase in inflation during the fiscal recession, from 6.2% to 7.9%, annualized inflation has usually dropped in the most recent crises.

The real per capita capital stock grew linearly between 2007 and the middle of the fiscal crisis at the end of 2014, going from R$93 thousand to almost R$110 thousand. From then on, it began to fall to R$103 thousand, stagnating at that level until 2024. However, the scenario is worrying when this stock is analyzed as a ratio of annual GDP. In 2007, the capital stock to GDP ratio was close to 265%, reaching less than 200% by September 2024. In Fig. 2, we present the monthly series of commodity indices extracted from the World Bank Commodity Price Data, adjusted for the R$/US$ exchange rate. Initially, based on the correlations between the index, all linear relationships suggest phasic co-movements. In addition to being positive, correlations assume lower values when associated with energy, raw materials, and beverage indices. The food index presents the highest correlations with the other commodities. Regarding the behavior of the seven indices during the four recessions, there is heterogeneity in the downward or upward trend during the crisis period, as well as in terms of volatility during the economic turbulence in Brazil. Based on the accumulated gain between March 2007 and September 2024, there is approximately no variation in the raw materials and metals & minerals indices. The variations of 178% and 246% in the beverage and precision

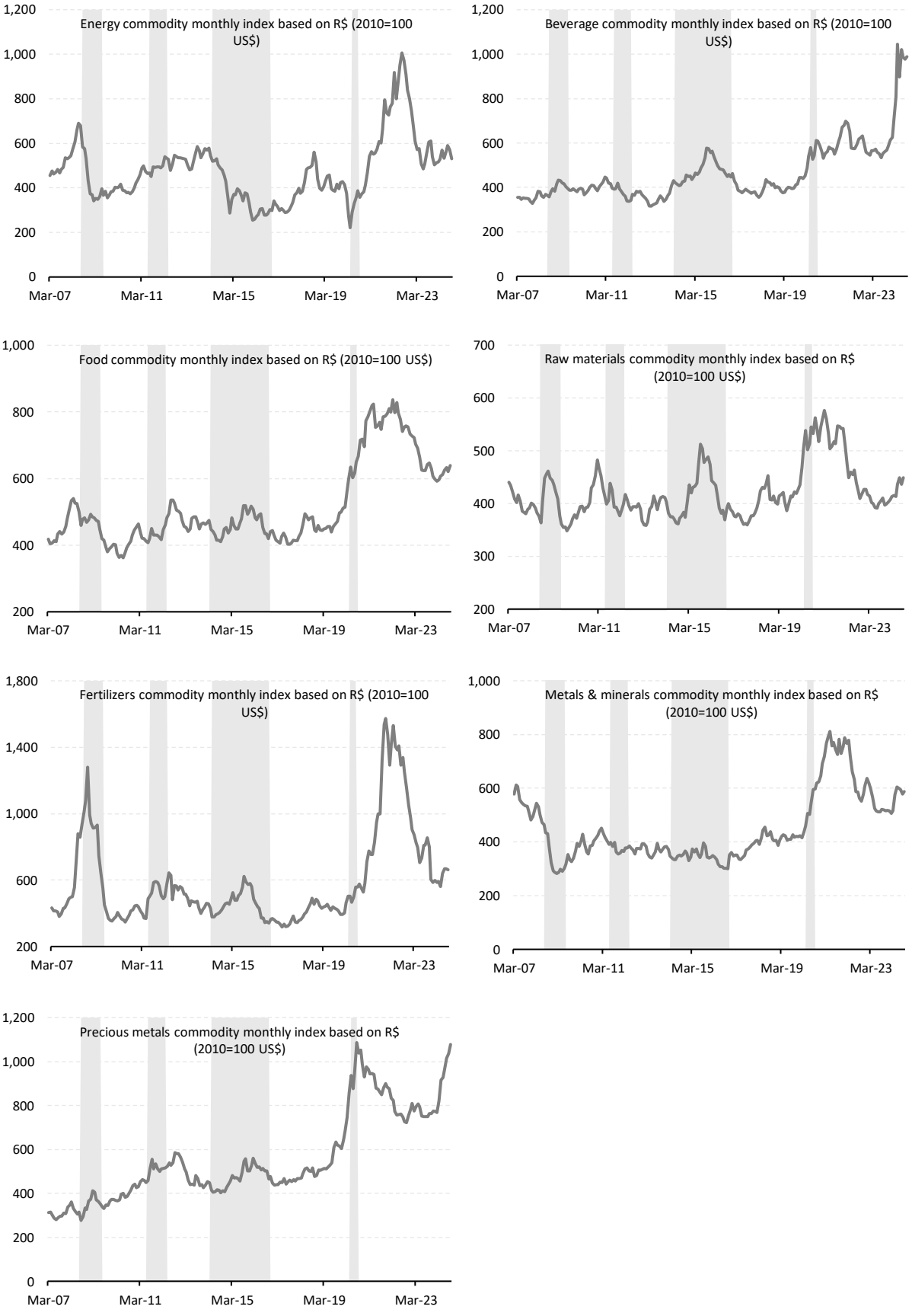
[4] SELIC is the rate used as a benchmark for interest in the Brazilian economy. It sets the boundaries of the reserve exchanges between financial institutions and is considered by the market to be the main indicator of the government's monetary policy. This rate safeguards all the bonds issued by the Central Bank of Brazil, the National Treasury, and various states and municipalities, as well as inter-financial deposits held by many banks.

materials indices are the largest. This heterogeneous behavior may be crucial in explaining the transmission of shocks to short-term Brazilian economic growth in various economic scenarios over the past 14 years.

Fig. 3 reports the open macro series, including the R$/US$ exchange rate, FDI to GDP, exports to GDP, and imports to GDP. The US dollar ranged between R$1.56 and R$2.31 until the fiscal crisis, when its levels changed definitively. At the end of this crisis, it was already above R$3.00. There was a new period of increases between the fiscal crisis and the pandemic, surpassing R$5.50. Since then, the exchange rate has ranged between R$4.76 and R$5.53. The high volatility after the pandemic is also noteworthy. Regarding FDI, there was a negative flow in only five of the 211 months, with a concentration of these net capital outflows after the pandemic. The extreme volatility of this variable is visible. During recessions, the average FDI to GDP was 3.5%, while in periods without recession, this average was 3.3%. However, volatility is higher precisely in these periods of economic calm, with a standard deviation of 2.1%, compared to the deviation observed in recessions, 1.7%.

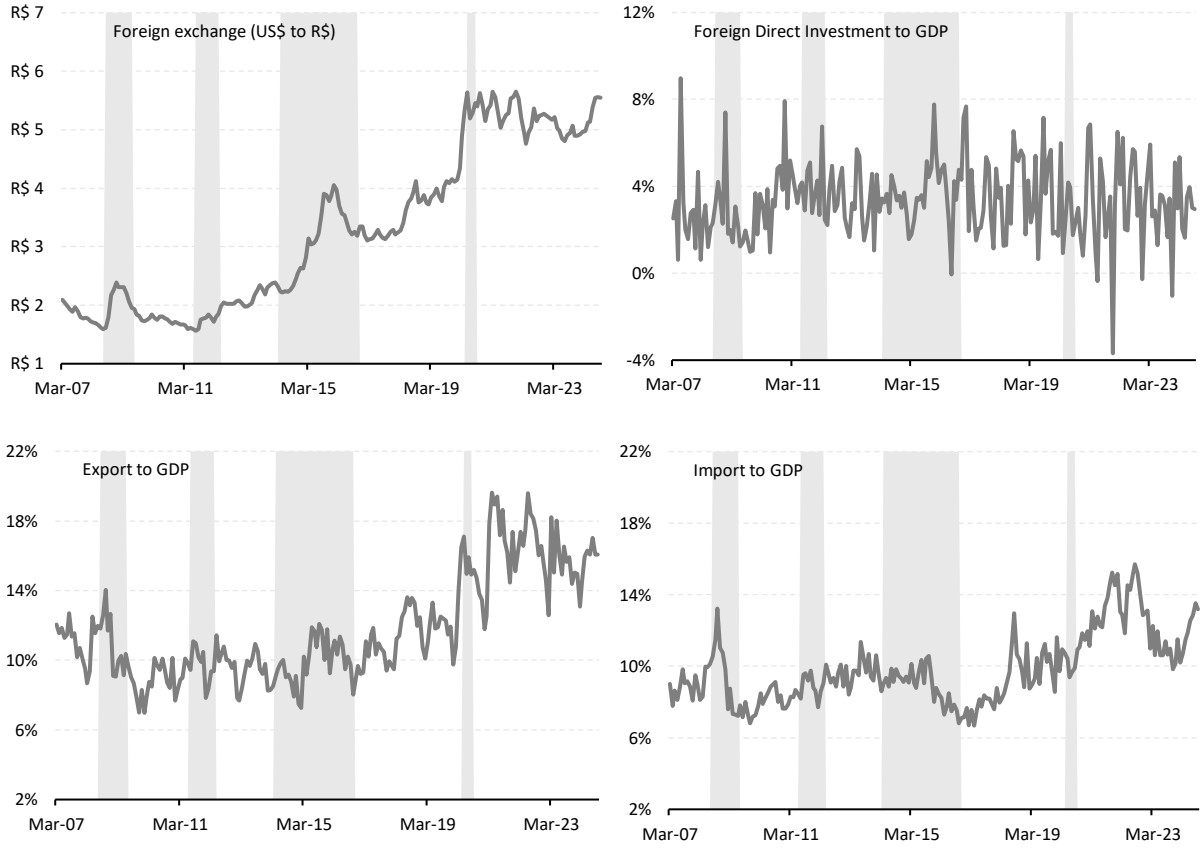
Regarding trade, considering the 12-month accumulated trade balance, the trade surplus begins the period at a level of almost 30% with a downward trend until a trade deficit appears between mid-2013 and mid-2015. After this period, exports started to exceed imports again, with a strong recovery in the trade balance until mid-2017. Despite the declines observed in some specific years, the trade balance (accumulated over 12 months) is above 46%. The monthly average of exports to GDP is 11.8%, higher than the 9.8% of imports to GDP. Exports are also significantly more volatile, with a standard deviation of 3.0%, which is higher than the 2% observed for imports. During recessions, the declines in exports and imports are noteworthy, especially during the subprime crisis. Imports also fell significantly during the fiscal crisis.

Fig. 2. Commodity indices at the level.



Notes: Monthly series from March 2007 to September 2024. Shaded areas correspond to OECD recession periods.

Fig. 3. Open macro variables at the level.



Notes: Monthly series from March 2007 to September 2024. Shaded areas correspond to OECD recession periods.

Table 2 presents the main descriptive statistics of the variables; however, after adjustments, the non-stationary series becomes stationary. The series in R$/capita was manipulated using the difference of the Napierian logarithm, while the series in % was treated using the first difference. FDI to GDP and inflation already presented stationary behavior of the original series at the level.

It is essential to note the high volatility of the primary result compared to other domestic and open macro variables. It is worth noting the even higher volatility of commodity indexes, particularly those related to fertilizers and energy. Finally, all correlations showed relatively low values, except for SELIC (-0.51), exports (0.39), and imports (0.23). The credit variables also presented moderate correlations of approximately 0.17. We also highlight the negative correlations of raw materials, precious metals, and food and beverage indices, respectively, -0.12, -0.10, -0.08, and -0.06.

In Figs. 4, 5, and 6, we report scatter plots between growth versus domestic macro variables, commodities, and open macro variables, respectively. In all figures, we use monthly

series from April 2007 to September 2024, resulting in 56 observations during recessions (red) and 154 observations otherwise (blue). The trend lines follow the same colors.

In Fig. 4, it is noteworthy to observe the change in the unconditional linear relationship between inflation and growth, as well as between capital stock and growth, regardless of whether observations are made during recessions or not. Likewise, we can observe this change in the trend lines in Fig. 5, as shown in the scatter plot involving all commodity indices except beverages.

Finally, in Fig. 6, the trends associated with the scatter plot involving open macro variables also change, with a greater intensity of change in the analysis between growth and imports.

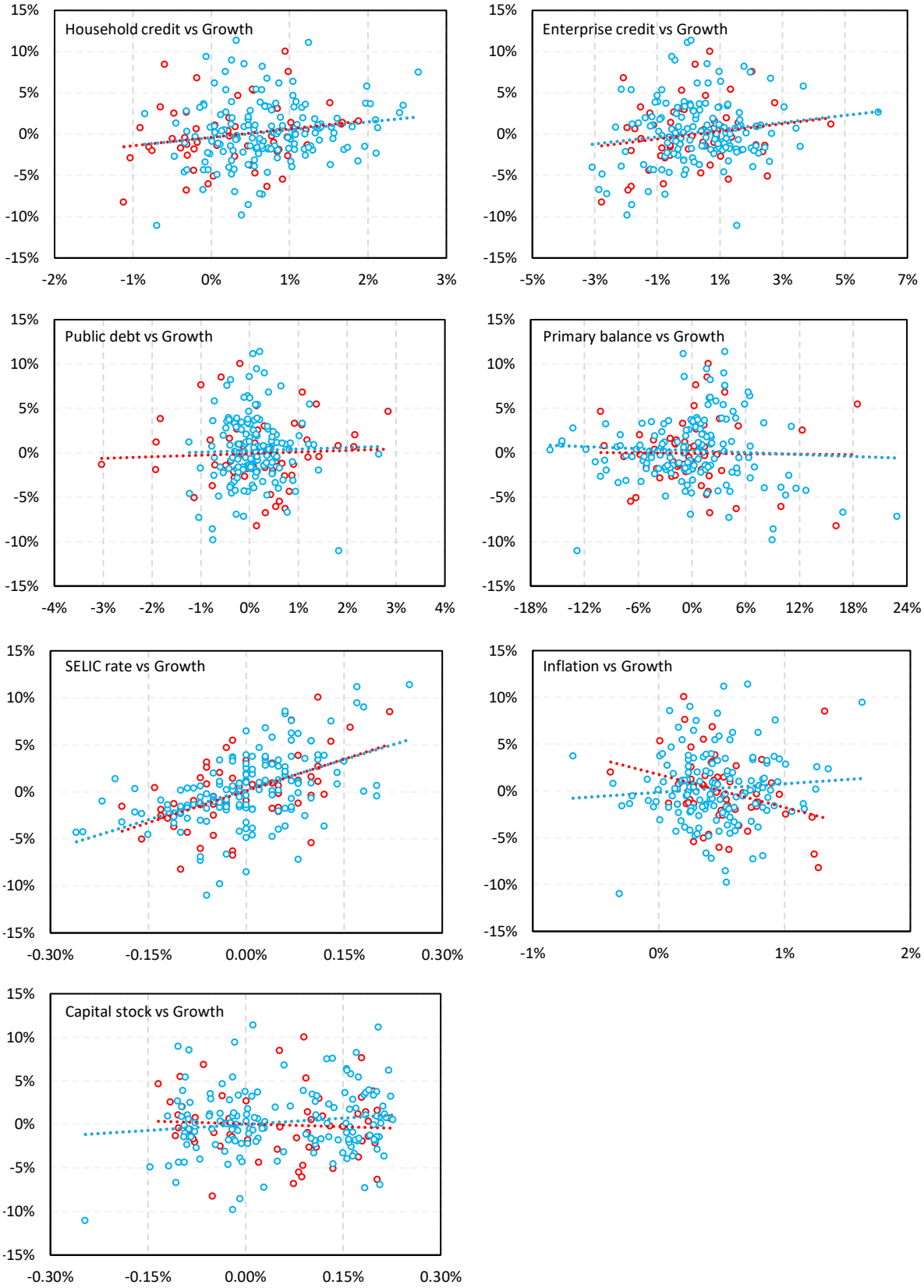
To summarize, according to the scatter plots, the relationship between growth and certain macro variables, as well as most of the commodities' indices, becomes even more complex when considering periods of recession and non-recession. We know that these trend lines or correlations are unconditional; they do not consider the role of other variables simultaneously. Thus, it is necessary to employ the methodology described in Section 3 to obtain more robust and conclusive results on the role of each macroeconomic variable, whether domestic or open, and especially that of commodities. Moreover, such a technique must provide us with insights into relationships that vary over these 14 years, as well as allow us to infer the net positive or negative effects between pairs of variables, that is, that in all relationships, each of the two variables in question can be the transmitting or receiving variable over time. These results will be discussed in the next section.

Table 2. Summary statistics

Variable	Mean	S. D.	Min.	Max.	Correlation (GDP Growth)
GDP [a]	0.18%	3.77%	-11.03%	11.38%	1.00
Domestic macroeconomic variables					
Household credit [a]	0.61%	0.70%	-1.12%	2.65%	0.18
Enterprise credit [a]	0.30%	1.42%	-3.08%	6.08%	0.17
Public debt [b]	0.12%	0.71%	-3.03%	2.85%	0.03
Primary balance [b]	-0.01%	5.66%	-15.81%	22.91%	-0.05
SELIC rate [b]	0.00%	0.09%	-0.26%	0.25%	0.51
Inflation [c]	0.46%	0.34%	-0.68%	1.62%	-0.01
Capital stock [a]	0.05%	0.11%	-0.25%	0.23%	0.09
Commodities					
Energy [a]	0.07%	7.64%	-32.42%	27.75%	0.16
Beverage [a]	0.49%	4.54%	-15.18%	26.12%	-0.06
Food [a]	0.20%	3.56%	-8.95%	10.68%	-0.08
Raw materials [a]	0.01%	3.57%	-10.57%	10.71%	-0.12
Fertilizers [a]	0.20%	8.28%	-28.09%	28.49%	0.07
Metals & minerals [a]	0.01%	4.70%	-16.96%	15.52%	-0.02
Precious metals [a]	0.59%	4.54%	-12.87%	13.95%	-0.10
Open macro variables					
Foreign exchange [a]	0.46%	3.77%	-9.10%	18.86%	-0.03
FDI [c]	3.35%	1.76%	-3.68%	8.98%	0.09
Export [b]	0.02%	1.31%	-3.57%	5.63%	0.39
Import [b]	0.02%	0.95%	-2.52%	3.06%	0.23

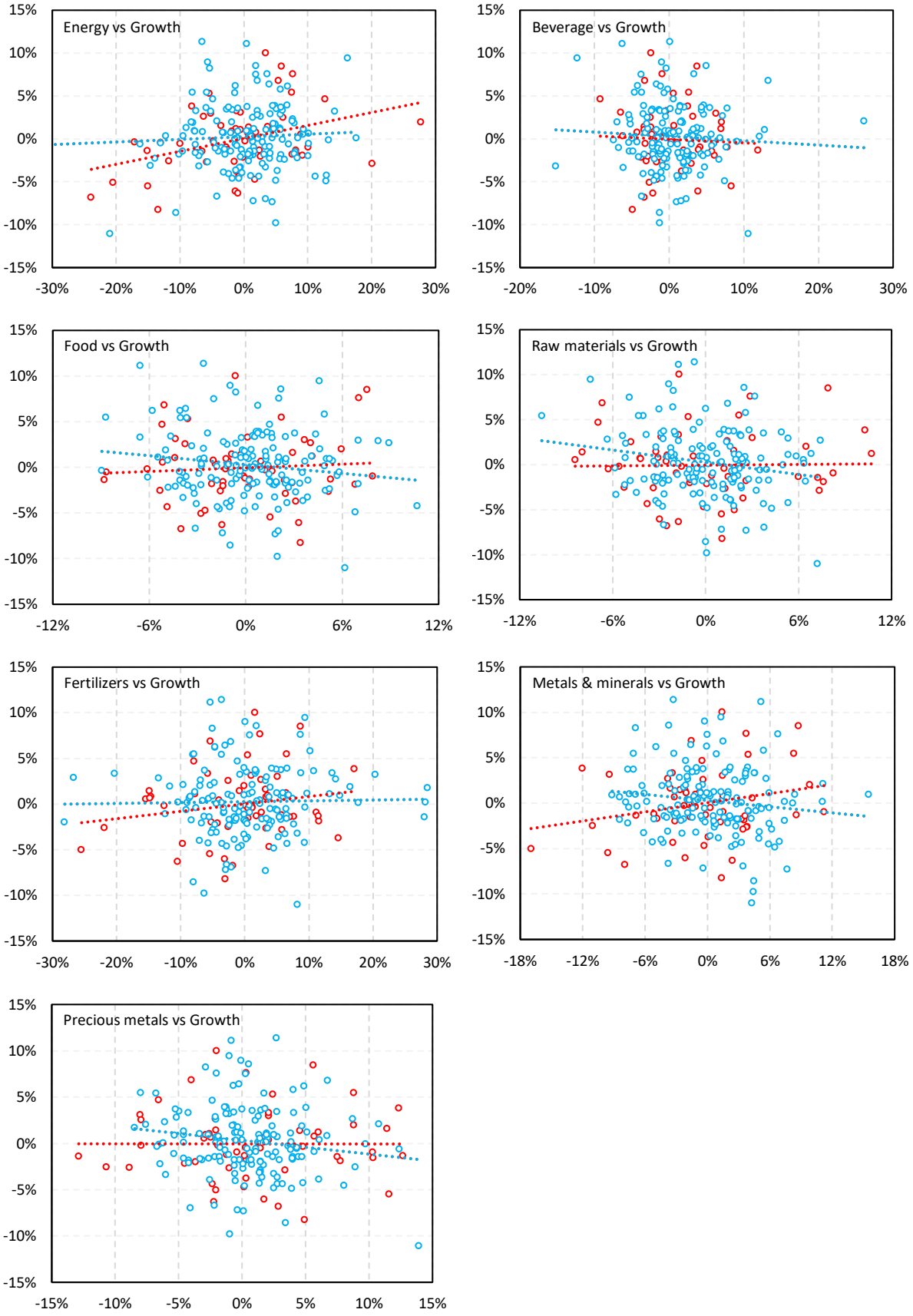
Notes: Monthly series from April 2007 to September 2024. [a] First difference in log. [b] First difference. [c] Variable in level.

Fig. 4. Scatter plot: growth vs domestic macroeconomic variables



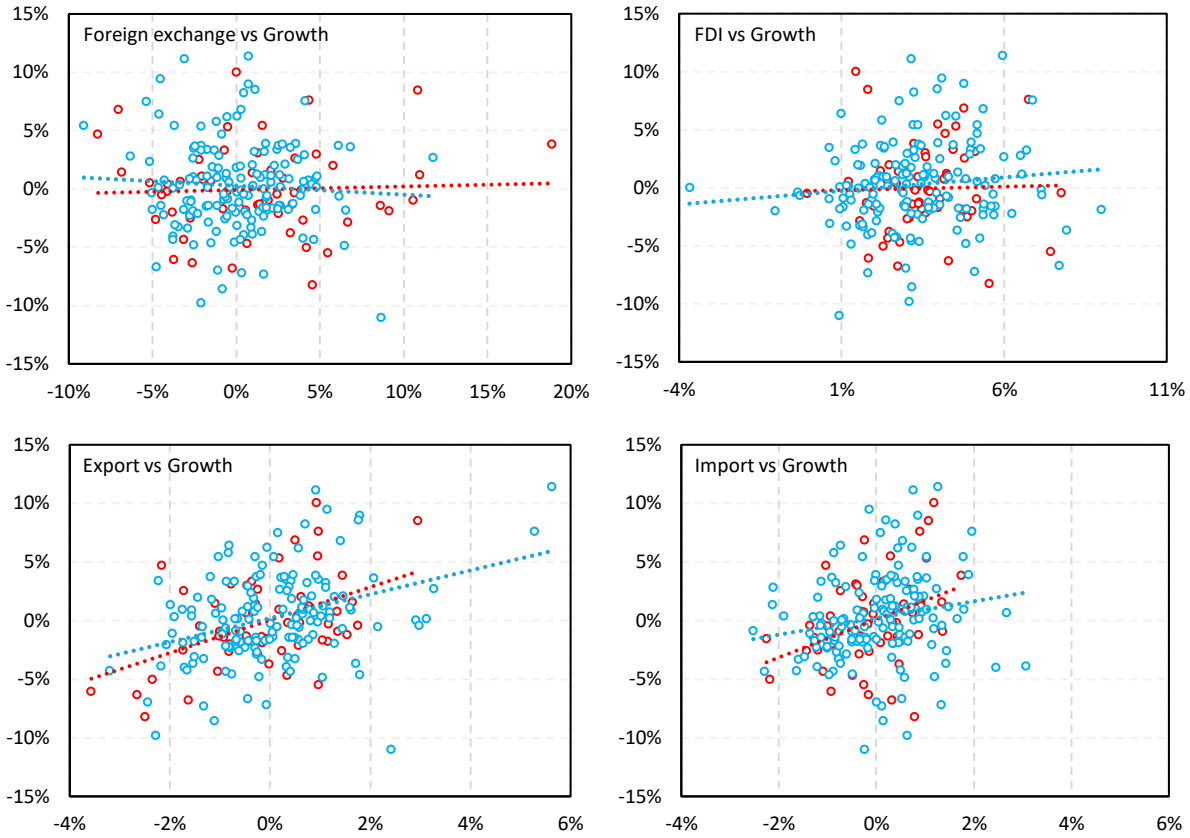
Notes: Growth (vertical) vs domestic macroeconomic variables (horizontal) in difference, except for inflation. Monthly series from April 2007 to September 2024. 56 observations during recessions (red) and 154 observations otherwise (blue).

Fig. 5. Scatter plot: growth vs commodity indices



Notes: Growth (vertical) vs domestic commodity indices (horizontal) in difference. Monthly series from April 2007 to September 2024. 56 observations during recessions (red) and 154 observations otherwise (blue).

Fig. 6. Scatter plot: growth vs open macro variables



Notes: Growth (vertical) vs open macroeconomic variables (horizontal) in difference, except for FDI to GDP. Monthly series from April 2007 to September 2024. 56 observations during recessions (red) and 154 observations otherwise (blue).

6 RESULTS

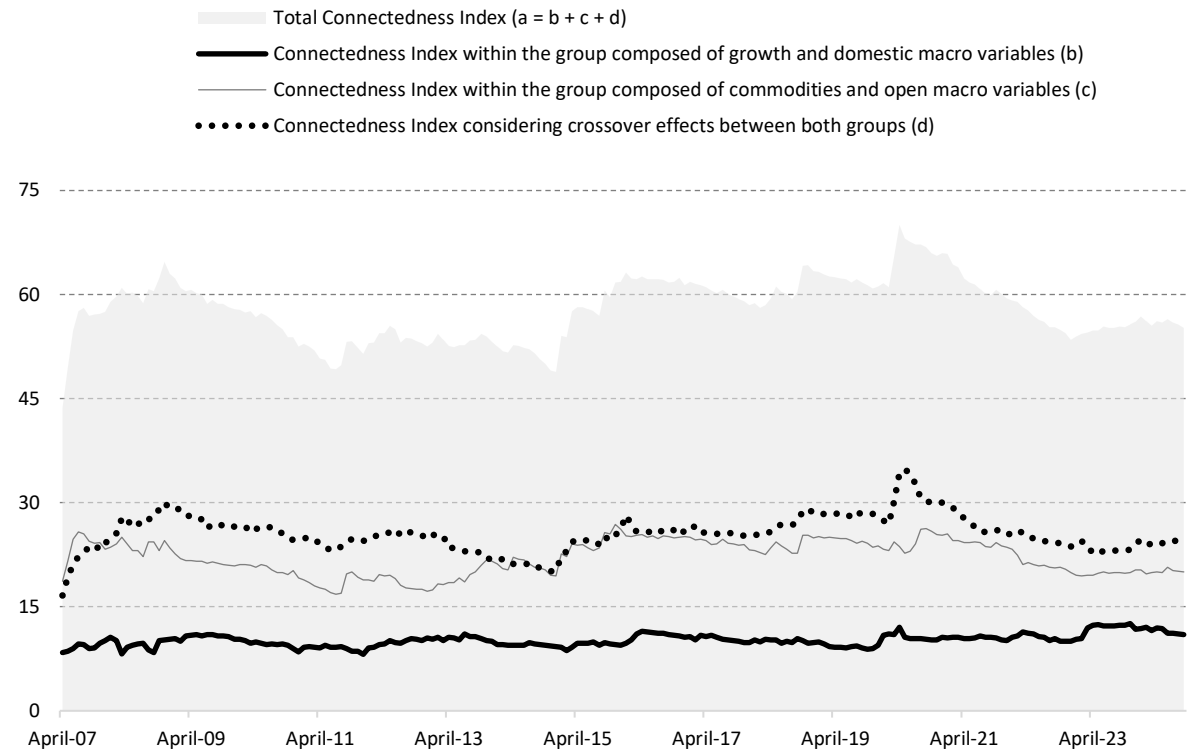
6.1 Total Connectedness Index

We measure the aggregate time-varying spillover using the Total Connectedness Index (TCI). This metric captures the interconnectedness among the entire set of variables by representing the average shock spillover from one series to all others. In other words, TCI aggregates each variable's contribution to all others, similar to the average contribution all other variables have to one variable. If the TCI is low (high), there is low (high) network interconnectedness and then low (high) growth spillover. The aggregated connectedness approach is then employed to investigate the spillovers between growth in Brazil and commodities, as well as domestic and open macro variables, capturing the relationship among all these variables.

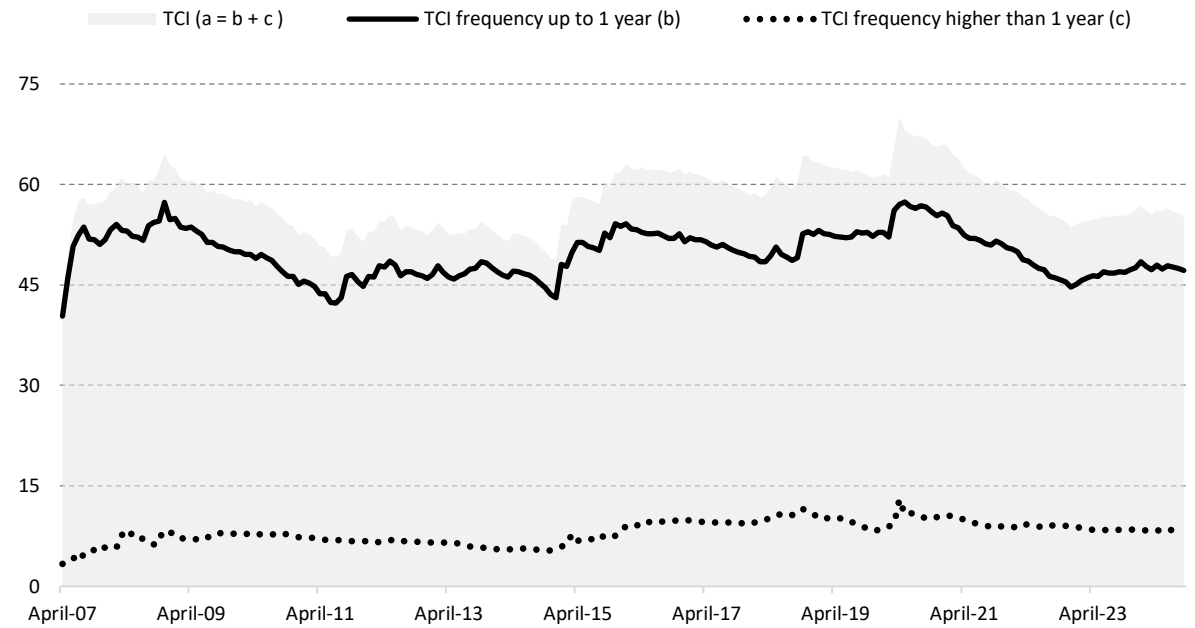
Fig. 7. a. illustrates the evolution of total TCI (series a), considering the main parameters: window size for computing rolling indices (W) and the forecast horizon of the underlying decomposition (H). Regarding this window, since we know that it is not necessary to use the rolling one, we have chosen to use the whole sample (210 months). In comparison, the forecast horizon is given by (12 months) to maximize data utilization.

Between April 2007 and September 2024 (210 months), the average of this aggregate indicator was 57.7. This is a moderate value compared to other studies conducted in different countries, such as the United States (Matos et al., 2025b). The sample standard deviation was 4.4. Considering that four crises were mentioned in the previous section during this period, the analysis of behaviors during periods of recession versus those not in recession suggests differences. During the 56 months of recession, the average was 57.5, close to the value observed in calmer periods, 57.9. However, volatility is higher during recessions, with a standard deviation of 5.6, which is higher than the value of 4.0 observed in months without a recession. The maximum value of 70.0 was observed during the pandemic recession (April 2020), while the lowest value (43.7) was recorded in the first month of the sample. Looking only at the four recession periods, the highest average TCI, 67.8, was recorded precisely during the pandemic. The lowest connectedness values were recorded between 2011 and 2014.

Fig. 7. Total Connectedness Index (W = 210 and H = 12)
7.a. TCI and its composition by groups



7.b. TCI and its composition by frequency



Still, based on Fig. 7a, we can infer the relevance of the groups of variables. More precisely, we measure the same index, keeping the same parameters but restricting the set of variables to growth and other domestic macro variables. The index within this group (series b in Fig. 7.a.) has an average of 10.2 and a volatility of 0.9. Its peak was also 12.6 during the

pandemic. This order of magnitude is much lower when compared to the total TCI. This figure illustrates the connectedness index within the group comprising commodities and open macro variables (series C). This metric has an average value of 22.1, with a deviation of 2.5. Its maximum value (26.9) was recorded in November 2015, at the height of the fiscal crisis in Brazil. Finally, we also report in this figure the index considering crossover effects between both groups (series d), whose average is 25.6. Therefore, we could measure in this initial analysis the role of expanding this study about the exercise proposed by Matos et al. (2025a). In other words, we have an average TCI of 10.2 when using only domestic political decision variables. When we expand the group to include commodities and open macro variables, the average increase in TCI resulting from these new variables (22.1) and their crossover effects (25.6) is 47.7. This connectedness associated with the expansion of variables to capture the external impact of the Brazilian economy corresponds to 82.4% of the average total TCI of 57.8. In Fig. 7 b, we analyze the total TCI by frequency. Following this literature dealing with macroeconomic data at the monthly level, we define the threshold between the short and medium/long term as one year. Thus, we observe that the TCI with a high frequency (series b) is the most significant, representing 86.0% of the total TCI during this period. This TCI, with a frequency of up to one year, has an average of 49.7 and a standard deviation of 3.4. The TCI with a frequency higher than one year (series c) averages 8.1. To summarize this frequency-based analysis, considering that TCI is a statistic that represents the average contribution of all other variables to one variable, we can say that short-run variance decomposition seems more relevant to understanding the role of domestic and external sources in transmitting short-run growth shocks in Brazil.

6.2. Dynamic net effects on growth

In Table 1, subsection 2.5, we present the model analyzed. In summary, we used seven domestic macro variables. The external variables comprise four open macro variables and seven commodity indices. In this subsection, we aim to measure the net effect of the relationship between economic growth and this group of 18 variables. This net effect is the difference between a) the sum of the effects caused by growth in each of the 18 variables ("To effects") and b) the sum of the effects caused by each of the 18 variables in growth ("From effects"). When this difference is positive for a given month, the economic growth variable is considered a net sender, and this total positive net effect is represented in the figure with a blue

area chart. Similarly, when growth receives more effects than it sends in a given month, growth will be a total net receiver, and, in the graph, this total adverse net effect will be represented by a red area chart.

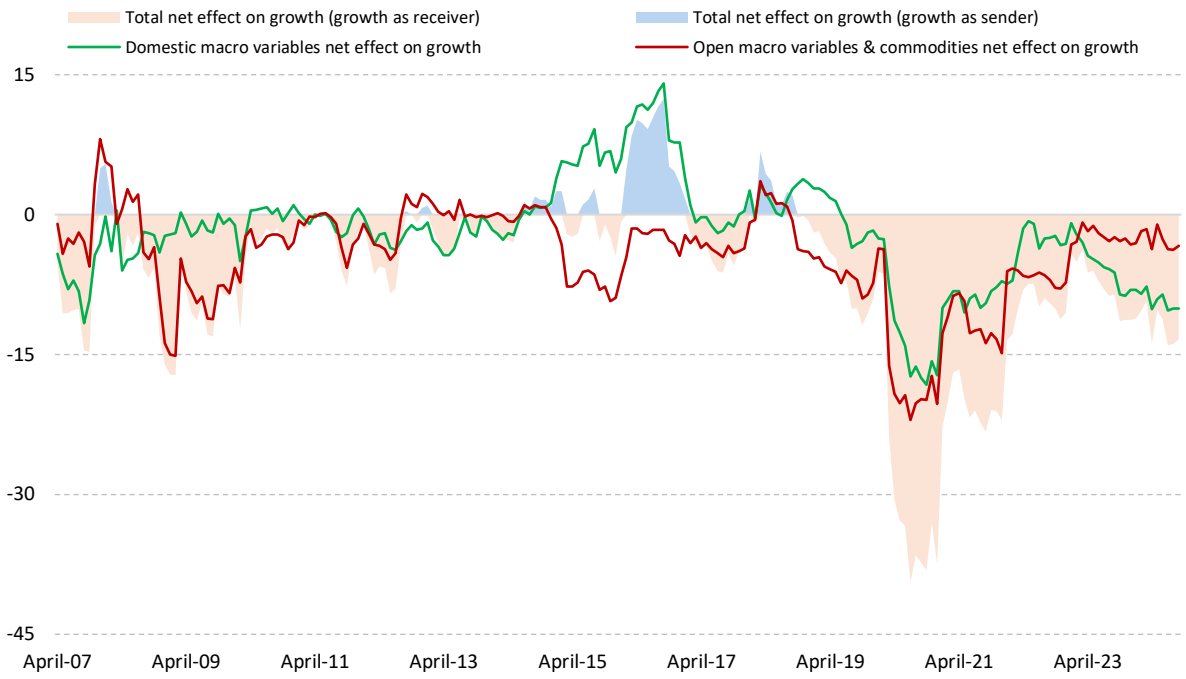
This reasoning applies to Figures 8a and 8 b. In Fig. 8.a., we will try to understand this total net effect (positive or negative) between growth and the other 18 variables, breaking it down by source of impact, that is, by group: a) with the seven domestic macro variables (green line) and b) with the 11 external variables (red line). The sum of the net effects associated with the internal and external sources gives the total net effect. In Fig. 8. b., the decomposition of the total impact is by frequency: a) up to one year (green line) and b) greater than one year (red line). Again, the sum of both gives the total net effect.

Initially, a total net effect was observed, and in 210 months, growth was noted in the net sender, which occurred over 39 months. In the remaining 171 months, growth was a net receiver. The average positive net effect was 3.78. The negative net effect was -8.69. During the four recessions, there was evidence of a positive net impact in only the fiscal crisis (from February 2014 to August 2016), with a positive value in 18 of the 31 months, averaging 4.60. The highest value of the total positive net effect (12.41) was recorded shortly after the end of the fiscal crisis in September 2016. Therefore, in other crises, the Brazilian economy's growth has been more susceptible to shocks in relation to the 18 variables than it is capable of sending shocks. During the pandemic, the most recent crisis, this total adverse net effect reached its peak of 39.40 in July 2020.

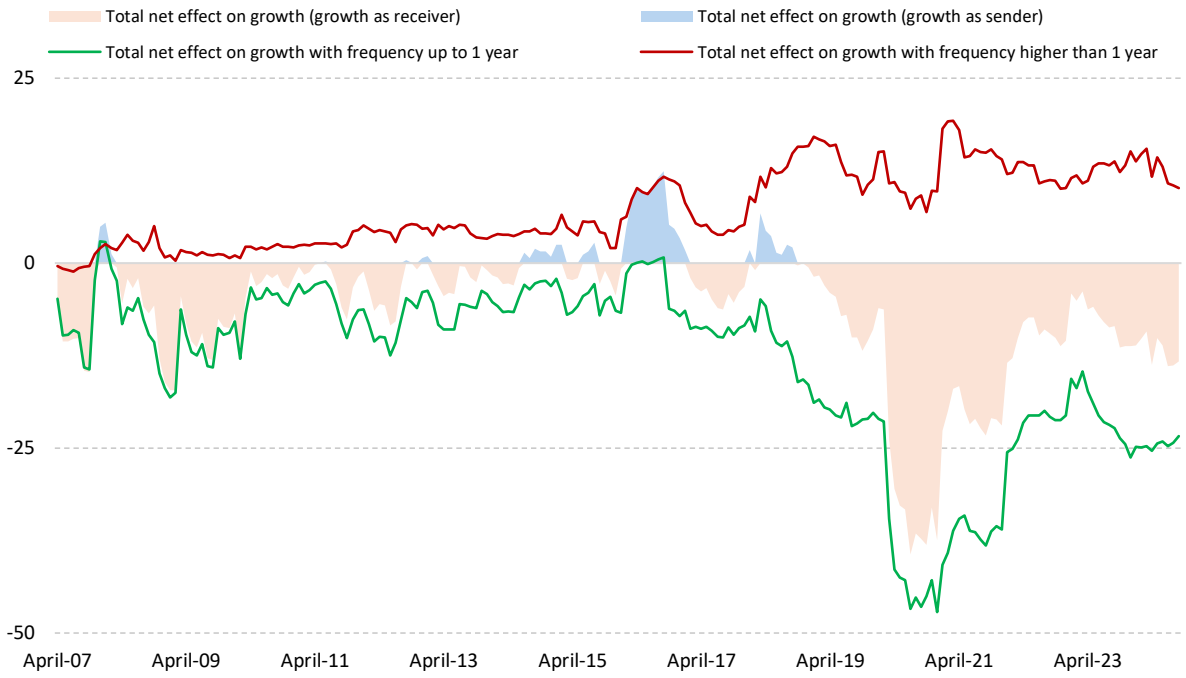
As explained in Fig. 8.a., we decompose this total net effect by source: internal and external. Observing the entire sample (210 months), 69% of the explanation is associated with the group composed of the four open macro variables and seven commodity indexes. Therefore, 31% are associated with the group with seven domestic macro variables. Considering the total adverse net effect observed over 171 months, the most significant relevance (61%) is associated with the net effects concerning external sources. In contrast, in the 39 months with a positive net effect, the explanation is mainly attributed to internal sources.

Fig. 8. Dynamic net effects on growth: conditional directional connectedness (W = 210 and H = 12).

8.a. Dynamic net effects on growth and its composition by source of such effects



8.b. Dynamic net effects on growth and its composition by frequency



In Fig. 8 b, the frequency decomposition clearly shows that, with rare and specific exceptions, the net effect over up to one year is adverse, while the effect at lower frequencies (over one year) is positive. This allows us to state that the transmission of shocks influencing

Brazilian growth (red area) occurs in the short term. In contrast, the power of growth to send shocks or influence other variables occurs in a period longer than one year.

6.3. Dynamic net pairwise connectedness involving growth

The Conditional Connectedness framework is useful for evaluating the pairwise relationships between the short-run Brazilian growth and each of the other (seven) commodity indices, (seven) domestic and (four) open macro variables, while controlling for the influence of the remaining (17) variables. This section aims to show the results when we isolate the instrumentalized relationship between growth and household credit, for instance. An essential advantage of calculating pairwise relationships within the conditional framework is the reduction of omitted variable bias. By recognizing and controlling the spillover effects of the instrument set on the system, the model ensures a more accurate and robust representation of the interactions.

Fig. 9 illustrates the dynamic behavior of the pairwise Conditional Connectedness relationships between growth and domestic macroeconomic variables. Fig. 10 shows the same results but involving commodities, and the following figure shows pairwise considering growth and open macro variables. The graph illustrates the net influence between growth and the respective variable for each pairwise comparison. For example, when we observe the relationship between growth and household credit, the color of the area of the graph, as seen at the beginning of the time series until 2015, indicates that shocks from household credit more influence the variance decomposition of Brazilian economic activity growth than the reverse. Conversely, from 2020 to 2024, the growth influence on this credit is more significant, i.e., the net effect is positive, and the area is blue. This analysis holds for all pairwise relationships.

The relationship between growth and the credit variables shows a net influence exerted by household credit from 2008 to 2015, and again in 2019. From then on, enterprise credit begins to influence growth until the end of 2023. With comparable value, growth can have a net positive influence on enterprise credit between 2007 and 2019, and on other private credit between 2020 and 2024. It is essential to emphasize the role of household credit in the fiscal crisis (from 2014 to 2016) and enterprise credit during the pandemic. On average, the net effects exerted by households and enterprises are -1.36 and -0.93, respectively, while the net effects exerted by growth in these variables are 1.48 and 1.41, respectively.

Regarding the fiscal scenario, we observe a low order of magnitude of the net effects between growth and debt, corroborating the evidence by Matos et al (2025a). We highlight the net influence exerted by debt during the fiscal crisis in 2015 and from May 2020 to April 2021, the peak of the pandemic recession's effects. The primary balance has demonstrated its capacity to transmit shocks to growth only after the end of the fiscal recession, with a greater emphasis between 2019 and 2021. In mid-2020, this influence reached very high values. On average, the influence of debt is -0.58, and the primary result is -1.98. It is also important to comment on the influence that growth exerted on the primary result in the recessions of 2011 and the fiscal crisis.

The influence of monetary variables shows very distinct patterns. While inflation influenced growth only in 2011 and 2019, in some months of 2019 and from 2022 onwards, with an average net effect of -0.58, the SELIC had an average net influence of -1.90, with a greater emphasis on the period of the subprime crisis and from the end of the fiscal crisis until 2024. The peak of this influence was precisely during the subprime crisis. We also highlight that growth exerted a net influence on inflation, with greater intensity during the same recession.

The net influence of growth in the capital stock during almost all 210 months of the sample, with an average net effect of 2.79 associated with higher values since the fiscal crisis, shows the dependence of public investment on the economic scenario. The net influence of growth in the capital stock during almost all 210 months of the sample, with an average net effect of 2.79 associated with higher values since the fiscal crisis, shows the dependence of public investment on the economic scenario. In other words, it does not seem that the capital stock is crucial for boosting the economy, but rather that it fluctuates due to economic growth, private credit, and, mainly, debt. [5]

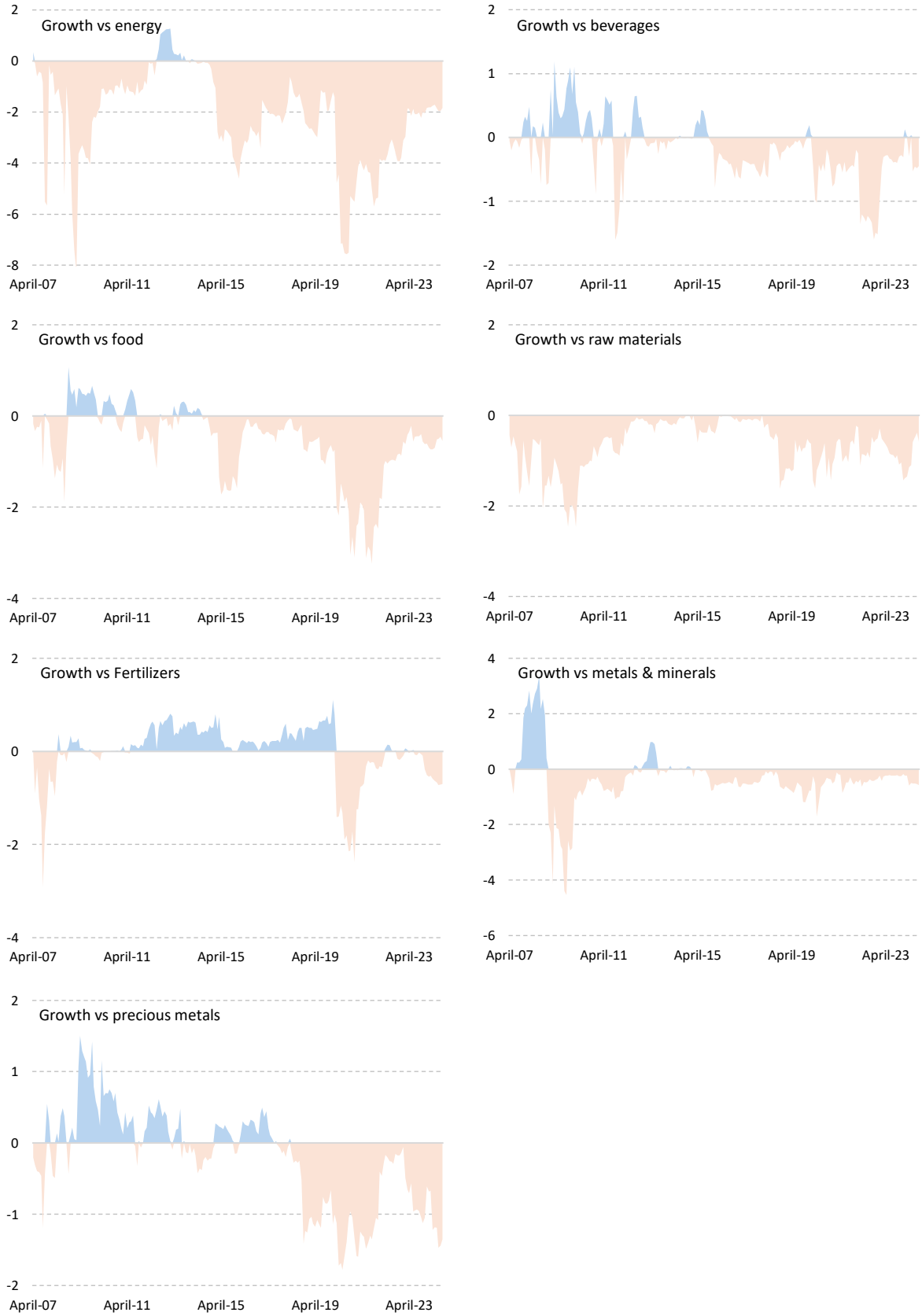
The dynamics of the net effects concerning the seven commodity indexes (Fig. 10) indicate an external dependence on short-term growth in Brazil, primarily driven by energy, food, and raw material commodities. This is justified by the average net effects received by growth, -2.45, -0.82, and -0.69, respectively, as well as by evidence of this influence in most of the 210 months. The average influence of the beverages index of -0.41 is not the highest, but it also occurs in more than 70% of the sample period.

[5] The relationship between capital stock and other variables is being analyzed by Matos and da Silva (2025).

Fig. 9. Dynamic net pairwise connectedness: growth versus domestic macro variables (W = 210 and H = 12).

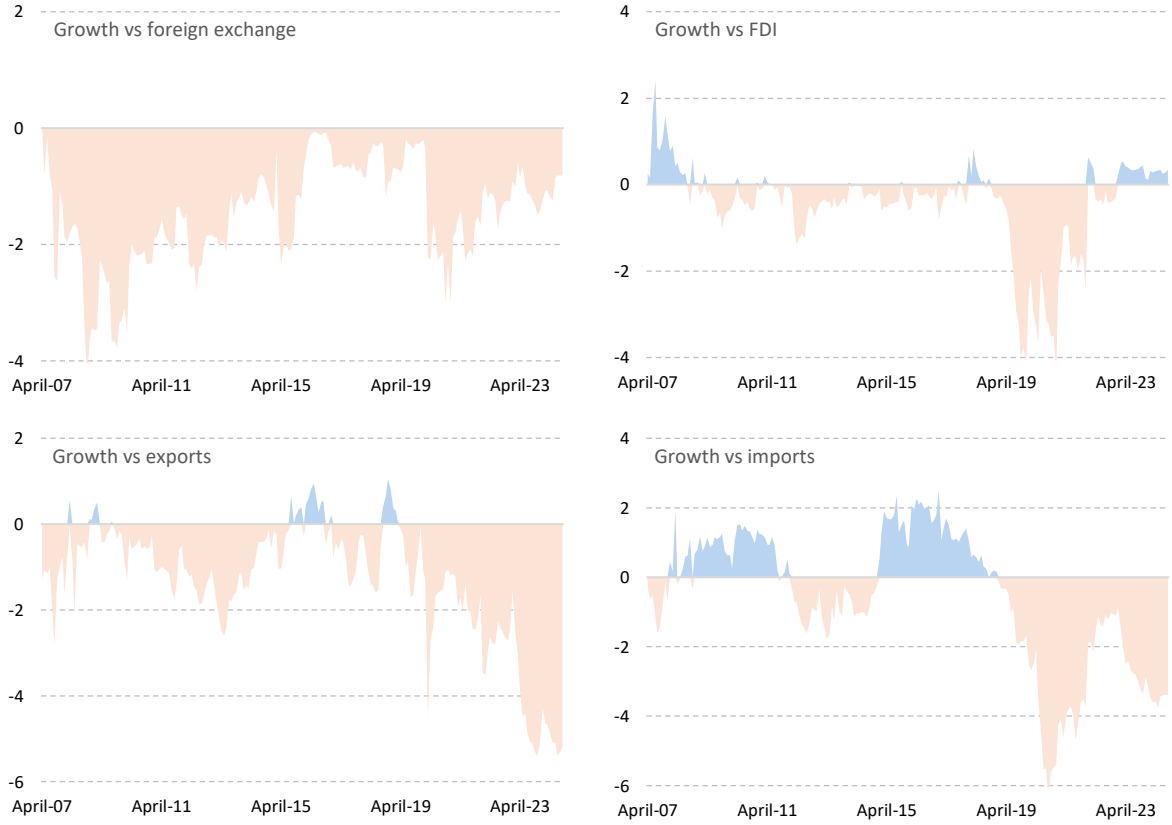
Notes: Blue areas mean growth as a shock sender, while red areas mean growth as a shock receiver - monthly series from April 2007 to September 2024.

Fig. 10. Dynamic net pairwise connectedness: growth versus commodities (W = 210 and H = 12).



Notes: Blue areas mean growth as a shock sender, while red areas mean growth as a shock receiver—monthly series from April 2007 to September 2024.

Fig. 11. Dynamic net pairwise connectedness: growth versus open macro variables (W = 210 and H = 12).



Notes: Blue areas mean growth as a shock sender, while red areas mean growth as a shock receiver—monthly series from April 2007 to September 2024.

There is also an intense net influence exerted by the metals and minerals index in 2009 and 2010, by the fertilizers index during the subprime crisis, the pandemic, and more recently, with the war between Russia and Ukraine, as well as by precious metals since 2019. It is worth highlighting the significant role of the Brazilian economy in generating positive net effects, specifically influencing most commodities, with a particular emphasis on the impact on metals and minerals in 2007 and 2008, precious metals in the first half of the sample period, and, mainly, fertilizers between 2011 and 2018.

The extreme dependence of short-term growth in Brazil on external factors is corroborated by Fig. 11. On the one hand, there are specific periods in which growth had a positive net effect on FDI, exports, and imports. The latter relationship is characterized by an impact with greater average intensity (1.12) and duration (from 2008 to 2011 and 2015 to 2018). On the other hand, we evidence a strong net effect exerted by FDI between 2019 and 2022 (-1.76) and a net impact of imports between 2012 and 2014, and mainly from 2019 onwards, whose average intensity was (-2.76). The net effect exerted by exports has been almost every month, with greater intensity also from 2019 onwards. The average impact on growth from

January 2023 onwards is also very striking, -4.54. Moreover, the exchange rate plays a leading role. The influence of this variable on Brazilian growth is consistent throughout the period, with an average effect of -1.47. Considering the 4 months of pandemic recession, this average effect is -1.97.

In the appendix (Figures A.1 to A.6), we show the decomposition of the net effect in each pairwise analysis already analyzed here in this subsection by frequency: a) up to one year (green line) and b) greater than one year (red line). Again, the sum of both gives the total net effect. We can summarize a significant amount of information about the relationship between growth and 18 economic and financial variables, highlighting that the comparison between the net effects in short (less than one year) and medium/long (more than one year) terms reveals a considerable difference in most pairwise relationships. Considering domestic macro variables, for example, growth becomes a net sender during most months concerning debt, inflation, capital stock, household, and enterprise credit, with a frequency of more than one year. Regarding commodities, there is a reduction in the intensity of the net effects received by growth after one year. The net effects of open macro variables also differ depending on the time horizon. We now demonstrate a net influence exerted by growth on FDI and exchange rates, a phenomenon that is unusual in the short term.

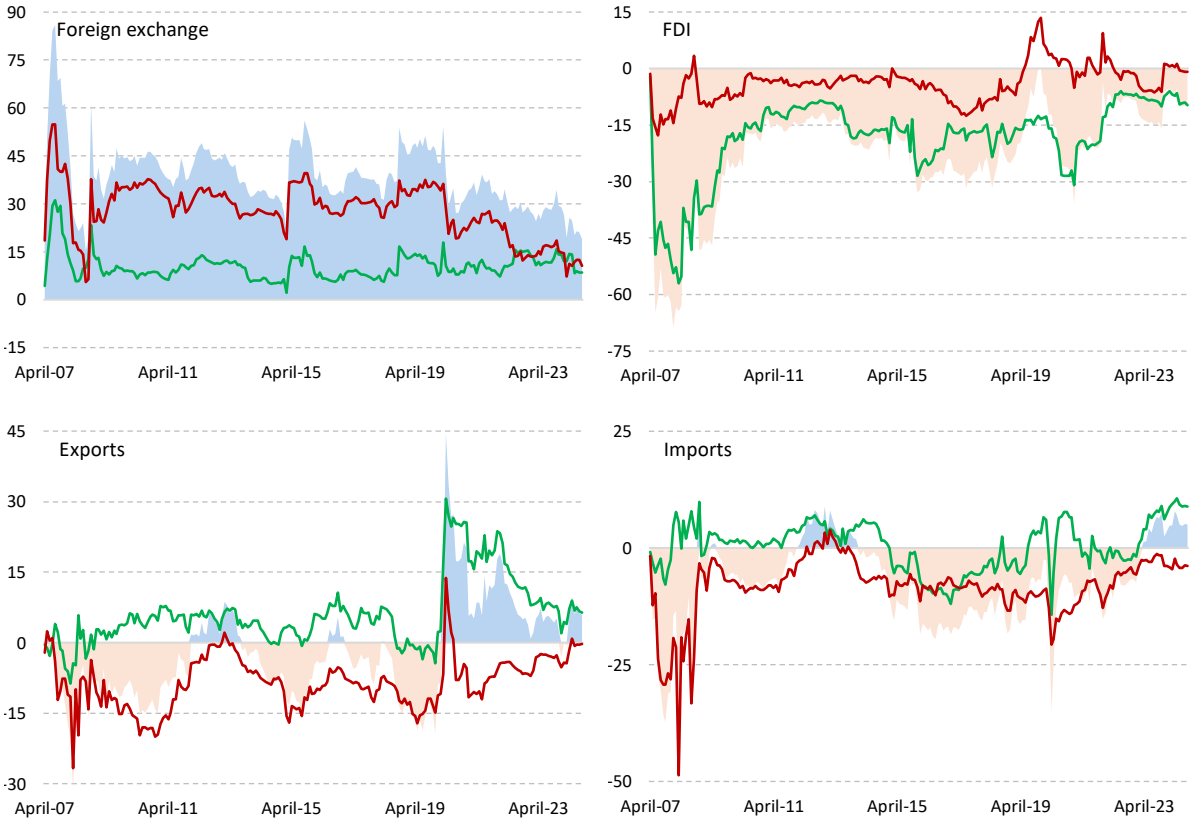
6.4. Dynamic net effects on commodities, domestic, and open macro variables: conditional directional connectedness

In this subsection, our objective is to perform the same analysis as in subsection 6.2 but without placing growth at the center of the discussion. Now, we will consider the relationships between the seven domestic macro variables, the four open macro variables, the seven commodities, and growth, as well as the other 17 variables. For example, we aim to measure the net effect of the relationship between economic debt and the remaining variables. When debt is the key variable, this net effect is the difference between a) the sum of the effects caused by debt in each of the 18 variables ("To effects") and b) the sum of the effects caused by each of the 18 variables in debt ("From effects"). When this difference is positive for a given month, the debt will be considered a net sender, and this total positive net effect will be represented in the figure with a blue area chart. Similarly, when debt receives more effects than it sends in a given month, debt will be a total net receiver, and, in the graph, this total adverse net effect will be represented by a red area chart.

Once more, we try to understand this total net effect (positive or negative) between each variable and the other 18 variables, breaking it down by source of impact, that is, by group: a) with the domestic macro variables (green line) and b) with the external variables (red line). The sum of the net effects associated with the internal and external sources gives the total net

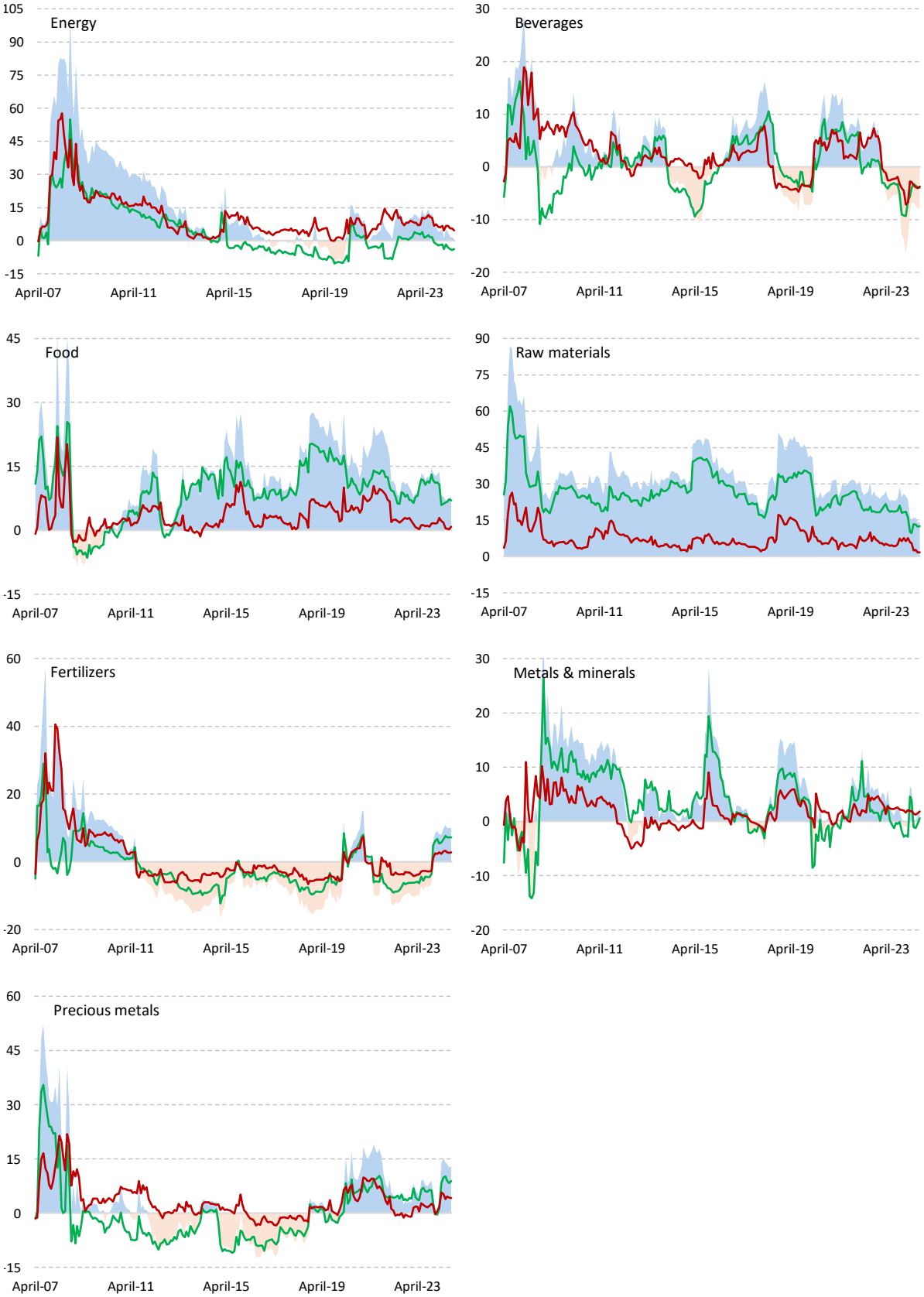
effect. In Fig. 12, the key variables are the open macro variables, while commodities are analyzed in Fig. 13. Fig. 14 shows the domestic macro variables.

Fig. 12. Dynamic net effects on open macro variables and their composition by source of such effects



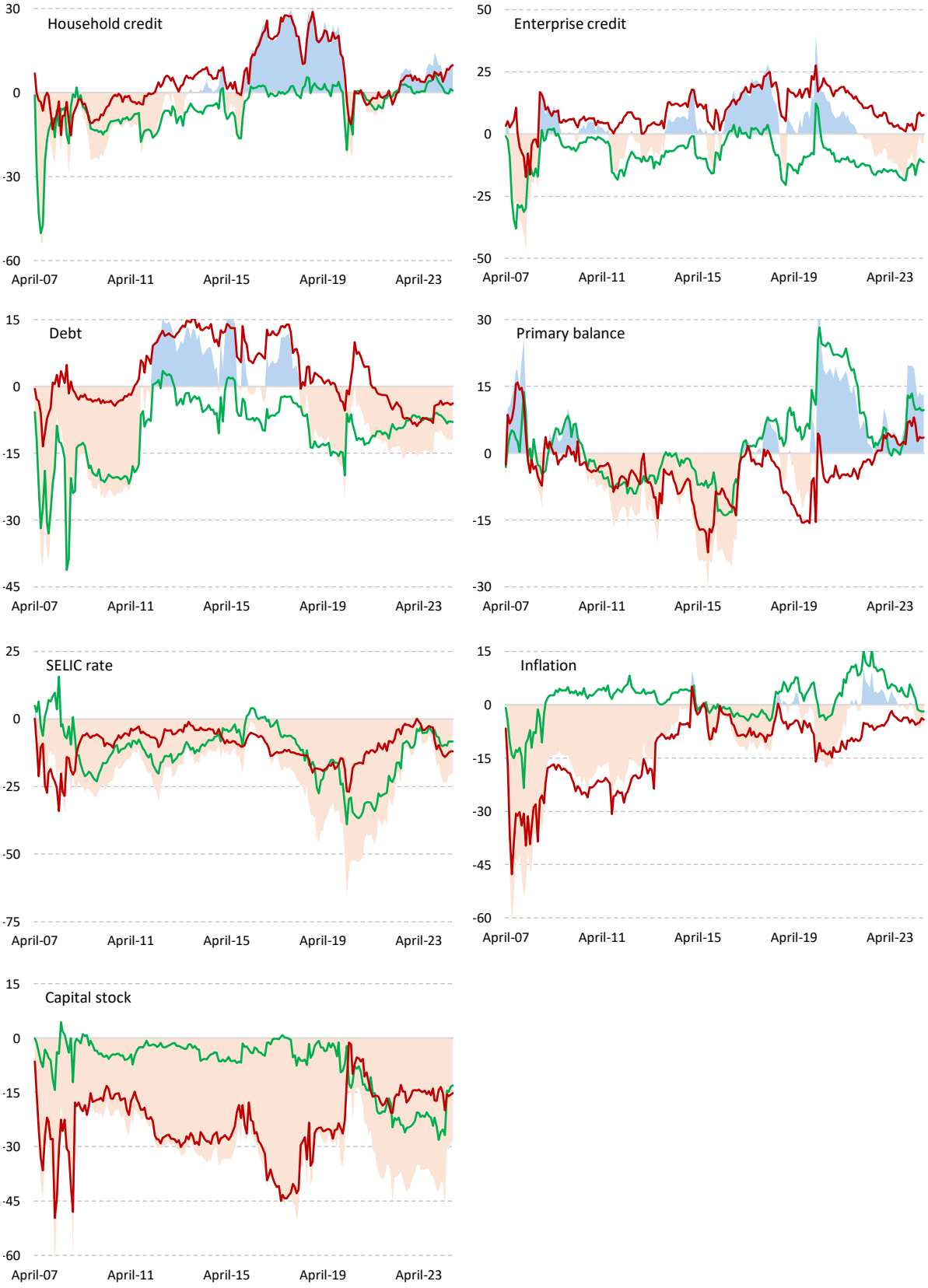
Notes: TVP-VAR (W = 210 and H = 12). Blue areas indicate growth as a shock sender, while red areas indicate growth as a shock receiver. Red (green) lines indicate the net effects of open macro variables and commodities (domestic macro variables) on the respective variable's monthly series from April 2007 to September 2024.

Fig. 13. Dynamic net effects on commodities and their composition by source of such effects



Notes: TVP-VAR (W = 210 and H = 12). Blue areas indicate growth as a shock sender, while red areas indicate growth as a shock receiver. Red (green) lines indicate open macro variables and commodities (domestic macro variables), with net effects on the respective variable - monthly series from April 2007 to September 2024.

Fig. 14. Dynamic net effects on domestic macro variables and their composition by source of such effects



Notes: TVP-VAR (W = 210 and H = 12). Blue areas indicate growth as a shock sender, while red areas indicate growth as a shock receiver. Red (green) lines indicate the net effects of open macro variables and commodities (domestic macro variables) on the respective variable's monthly series from April 2007 to September 2024.

In each graph, it is possible to see whether the key variable of interest is a net sender or net receiver relative to the entire group or relative to internal or external variables over each of the 210 months between April 2007 and September 2024, during both stable and recessionary periods. Our summary analysis here will focus on the average net effects to identify which variable is an average net receiver or net sender.

In Fig. 12, we can see that foreign exchange is a net sender throughout the period, while FDI is a net receiver in all months. Except for the period between 2012 and mid-2013, and in the last decade, imports and exports have been net receivers. The average effect exerted by the foreign exchange rate is 38.55, while the average net effects received by FDI, imports, and exports are -22.15, -7.75, and -2.24, respectively. Except for FDI, the other three open macro variables are more influenced by external variables.

The results for commodities (Fig. 13) are more homogeneous and comparable. Except for the fertilizer index, all others are net senders. We highlight the average net effects exerted by raw materials (34.08), energy (15.45), and food (12.50). It is also interesting to note the greater representation exerted by external sources, particularly in the commodities of energy, beverages, and precious metals.

According to Fig. 14, of the seven domestic variables, only enterprise credit is a net sender, with an average effect of 0.61. We highlight the average net effects received by capital stock, SELIC, inflation, and debt of -30.70, -21.80, -11.34, and -7.25, respectively. Examining the decomposition of sources, internal variables are found to be more significant in influencing household credit, debt, and SELIC. The leading role of external sources in this net influence is related to enterprise credit, primary balance, inflation, and capital stock.

6.5. Dynamic net effects considering all pairwise connectedness

Following this literature, which is based on the use of TVP-VAR conditional connectedness, it is helpful to summarize the information on pairwise relationships varying over time analyzed in subsection 6.3 in an average number. It is equally important to measure the average of the effects transmitted and received by each of the 19 variables of the model concerning all the other N-1 variables.

In Table 3, we report all net effects resulting from growth, commodities, and domestic and open macroeconomic variables. To do so, choose one of these 19 variables and look at the row where this variable is located. The sum of the 19 values in the same row, including the own effect (gray shading), gives 100%. In the last column (gray shading), we

show the sum of the impact received by the variable (row), excluding the own effect. This is the sum of the "Effects FROM (other N-1 variables)".

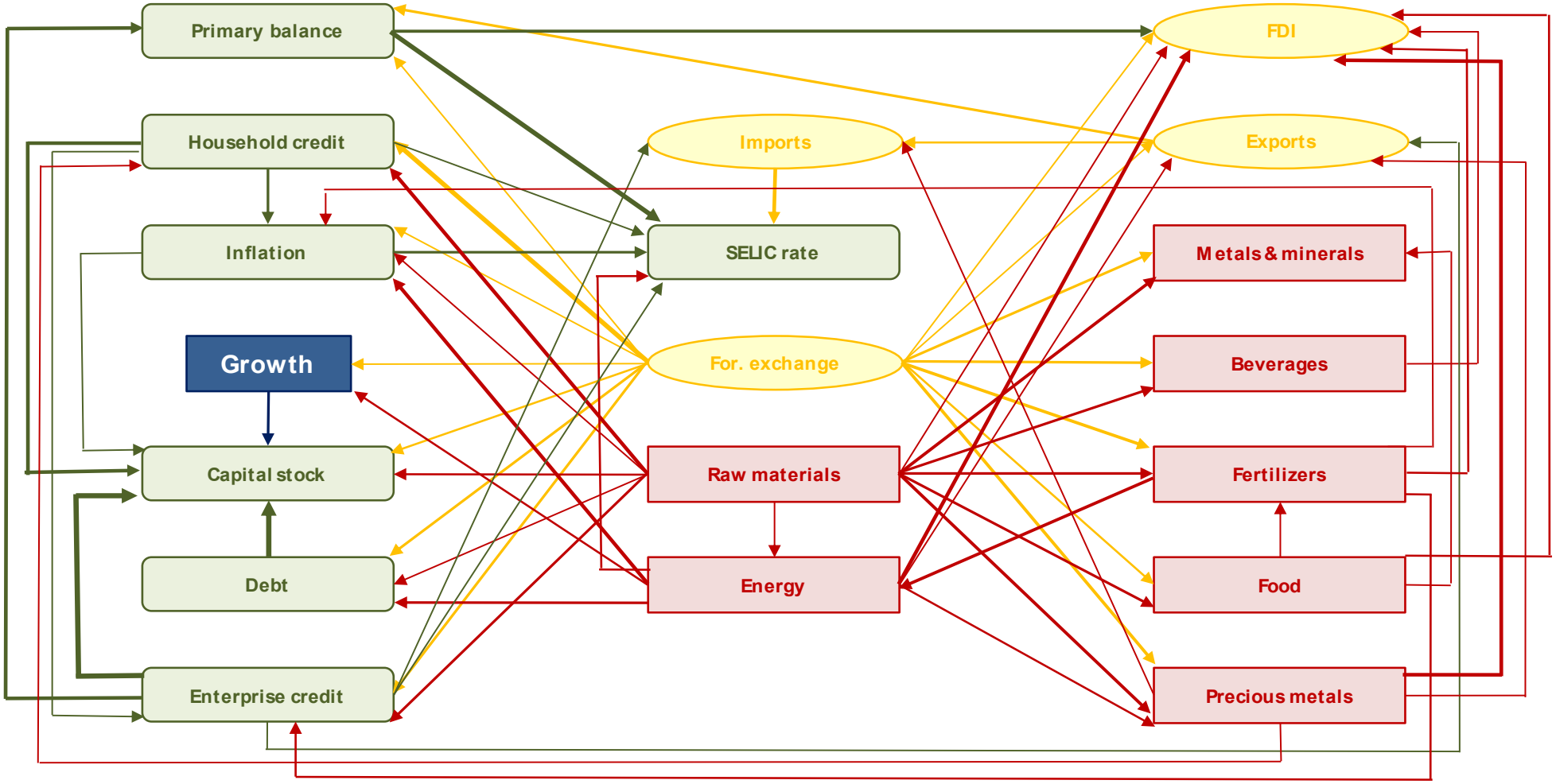
Analyzing any column allows observing the values of the effects sent by a given variable to all the others. The sum of all 19 sent impacts, including the variable itself (gray shading), offers a value that can be compared to the sum of 100 effects received, including the effect itself. In the penultimate row (gray shading), we have the sum of the "Effects TO (other N-1 variables)". In the penultimate row, we have the NET Effect, which is the subtraction between "Effect TO (other N-1 variables)" and "Effect FROM (other N-1 variables)". Remember that all the values in this table are average effects extracted from the whole sample between April 2007 and September 2024. In this penultimate line, when the value is reported in red (blue), the variable is a net receiver (sender) concerning the N-1 variables. In the last line, we have the number of variables that receive net influence from the variable in question (reported at the top of the respective column).

After normalization, and assuming the threshold of 0.25 commonly adopted in this literature, we summarize in the network graph in Fig. 15 the relationships whose net effects are most important through arrows connecting the variable that sends the influence and the one that receives it. The thicker this arrow, the greater the intensity of this influence. This network graph allows us to visualize all 63 most significant pairwise relationships in a single figure, showing the transmission of shocks between the 19 variables used in the model. From the relationships between economic growth and the other 18 variables in the model, we highlight the relationships of net influence exerted by economic growth on capital stock and the net influence received by foreign exchange and the energy commodity index. Among these 63 relationships, 12 involve only growth and other domestic macro variables. This analysis of the transmission of internal shocks in the Brazilian economy will be carried out in the following subsection.

Table 3. Pairwise Connectedness Measures (average monthly value from April 2007 to September 2024). TVP-VAR (W = 210 and H = 12).

	Endogenous	Domestic macro variables							Open macro variables				Commodities								
Sender → / Receiver ↓	Growth	Household credit	Enterprise credit	Debt	Primary balance	SELIC rate	Inflation	Capital stock	Foreign exchange	Exports	Imports	FDI	Energy	Beverages	Food	Raw materials	Fertilizers	Metals & minerals	Precious metals	Sum of effects FROM (including own variable)	Sum of effects FROM (other N-1 variables)
Growth	46.55	5.23	3.81	1.72	3.13	9.41	2.38	1.92	1.94	6.65	4.81	1.65	3.14	2.12	1.5	1.18	0.59	1.26	1,00	100,00	**53.45**
Household credit	4.94	39.57	6.06	2.64	1.04	2.78	12.69	2.69	5.39	2.31	2.68	0.84	2.04	1.97	1.45	4.22	2.22	1.9	2.57	100,00	**60.43**
Enterprise credit	4.41	9.36	36.03	2.29	5.87	0.82	2.05	1.52	7.05	4.01	1.34	1.21	1.99	2.55	4.19	6.13	2.19	4.72	2.27	100,00	**63.97**
Debt	1.72	3.55	3.46	42.81	3.84	1.01	1.55	2.57	7.73	1.08	1.65	1.42	4.17	3.53	4.2	6.3	3.97	2.29	3.15	100,00	**57.19**
Primary balance	2.74	0.82	9.49	3.09	52.86	2.78	0.61	1.91	2.76	6.74	2.39	0.83	1.14	2.61	2.2	1.96	1.33	2.49	1.26	100,00	**47.14**
SELIC rate	8.43	4.59	2.57	1.68	7.78	36,00	4.09	0.95	1.57	7.83	11.81	2.11	3.04	1.45	1.6	1.16	1.32	0.92	1.1	100,00	**64.00**
Inflation	2.49	15.63	1.06	1.32	0.89	1.16	48.33	1.71	2.57	2.29	2.39	2.06	4.76	1.87	1.83	2.77	2.27	2.17	2.41	100,00	**51.67**
Capital stock	4.62	6.38	7.02	7.96	2.04	0.8	3.47	44.73	2.72	2.27	1.08	1.44	3.43	1.95	1.7	2.73	2.09	2.07	1.51	100,00	**55.27**
Foreign exchange	0.47	0.7	4.19	5.17	1.21	0.57	0.94	0.78	27.02	2.86	2.09	1.08	1.85	6.81	8.98	17.12	7.57	3.76	6.82	100,00	**72.98**
Exports	5.31	2.8	5.52	0.98	4.28	7.86	1.68	1.09	4.5	40.31	6.15	1.22	2.85	3.03	1.71	2.42	2.7	2.25	3.33	100,00	**59.69**
Imports	4.2	3.02	2.79	2.08	3.05	8.07	1.96	1.19	3.39	8.39	46.73	1.04	2.02	1.29	1.3	1.92	3.24	1.58	2.73	100,00	**53.27**
FDI	1.19	1.9	1.67	2.15	4.31	1.69	1.73	0.7	2.73	1.4	1.46	57.03	4.74	1.96	3.36	2.34	1.83	3.13	4.68	100,00	**42.97**
Energy	0.94	0.8	1.61	1.19	1.21	1.05	1.1	2.14	2.55	1.14	1.21	0.95	60.07	1.56	3.97	4.14	2.57	10.96	0.82	100,00	**39.93**
Beverages	1.92	0.99	1.97	2.28	1.27	0.97	1.29	0.93	9.7	1.9	0.72	0.48	2.07	38.56	9.85	10.8	3.86	3.65	6.78	100,00	**61.44**
Food	0.91	0.41	2.91	3.03	1.11	0.66	0.72	0.83	11.26	1.21	0.76	1.16	2.76	8.86	33.2	13.64	4.62	5.54	6.38	100,00	**66.8**
Raw materials	0.5	0.42	3.43	4.41	0.87	0.56	0.96	0.62	17.87	1.55	0.79	0.59	2.32	8.19	11.02	26.74	5.5	5.6	8.07	100,00	**73.26**
Fertilizers	0.58	1.16	2.15	3.5	0.91	0.75	0.96	0.97	10.93	2.64	2.55	0.9	2.59	4.2	6.03	7.97	44.19	2.6	4.43	100,00	**55.81**
Metals & minerals	0.91	1.38	2.6	1.76	2.28	0.56	0.75	1.45	6.68	1.57	0.59	1.2	7.52	3.58	7.18	9.04	2.5	42.67	5.79	100,00	**57.33**
Precious metals	0.78	0.7	2.26	2.66	0.68	0.69	1.39	0.59	10.2	1.61	1.01	0.63	2.96	6.97	7.26	11.5	4.31	5.82	37.97	100,00	**62.03**
Sum of effects TO (including own variable)	93.62	99.39	100.61	92.73	98.65	78.2	88.66	69.3	138.55	97.76	92.25	77.85	115.45	103.06	112.5	134.08	98.88	105.39	103.07		
Sum of effects TO (other N-1 variables)	**47.07**	**59.83**	**64.58**	**49.91**	**45.79**	**42.2**	**40.33**	**24.57**	**111.53**	**57.45**	**45.52**	**20.82**	**55.38**	**64.51**	**79.3**	**107.34**	**54.69**	**62.72**	**65.1**		
NET = Sum of effects To - Sum of effects FROM	**-6.38**	**-0.61**	**0.61**	**-7.27**	**-1.35**	**-21.8**	**-11.34**	**-30.7**	**38.55**	**-2.24**	**-7.75**	**-22.15**	**15.45**	**3.06**	**12.5**	**34.08**	**-1.12**	**5.39**	**3.07**		
NPT	4	**9**	7	4	**9**	2	4	2	**18**	7	4	4	**13**	**13**	**16**	**17**	**11**	**15**	**12**		

Fig. 15. Network graph based on Pairwise Connectedness Measures (average monthly value from April 2007 to September 2024). TVP-VAR (W = 210 and H = 12).



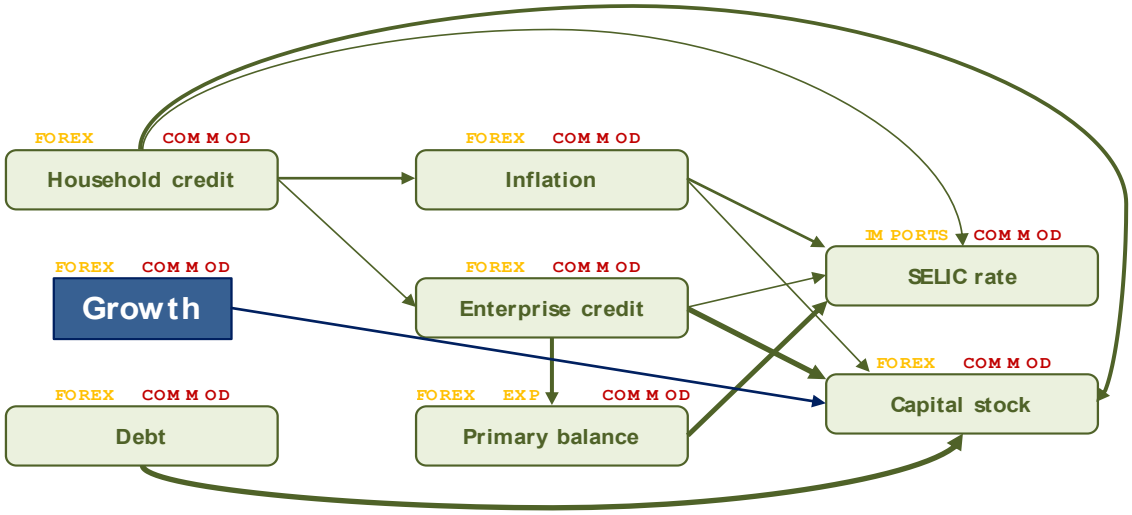
Notes: The thickness of the line is proportional to the intensity of the (normalized) weight assigned to the pairwise connectedness measure, threshold 0.25.

According to Table 3, growth is a net receiver, with an average net effect of -6.38, as mentioned in subsection 6.3. All other domestic macro variables, except for household credit, are net receivers, particularly capital stock, with a high average effect of -30.70. Of the open macro variables, only foreign exchange is a net sender, and all commodities are net senders, except fertilizers. The energy index is the most important net sender of commodities. Regarding the number of variables influenced, growth has a positive net effect on four variables: enterprise credit, inflation, capital stock, and debt. Even the capital stock variable, highly influenced by the other variables, is a net sender concerning imports and the SELIC rate. Still considering the domestic macro variables, the ones that manage to exert the most significant net influence are household credit and primary balance, with nine variables being influenced by each. We have already seen that exchange rates have a net influence on all others, and commodities can also influence many other variables.

6.6. Dynamic net pairwise connectedness involving domestic macro variables

In this last subsection, our objective is to identify, measure, and analyze the transmission of shocks of external origin (originating from exports, imports, foreign exchange, or commodities) within the Brazilian economy based on variance decomposition and the concept used in this paper of time-varying conditional connectedness. In Fig. 16, we summarize the 63 relationships reported in Fig. 15, limiting the analysis to the 12 relationships involving only growth and other domestic variables. In Fig. 17, we explore the 12 relationships through graphs with the pairwise relationships' net effect time series.

Fig. 16. Network graph based on Pairwise Connectedness Measures (average monthly value from April 2007 to September 2024), considering only domestic macro variables. TVP-VAR (W = 210 and H = 12).



Notes: The thickness of the line is proportional to the intensity of the (normalized) weight assigned to the pairwise connectedness measure. Threshold 0.25.

A first observation, still according to Table 3, is that considering only the seven domestic macro variables, growth is a net receiver concerning household credit, SELIC rate, and primary balance. However, after normalization, none of these three channels is sufficiently relevant. Thus, according to Fig. 16, growth only receives shocks directly from external sources, such as foreign exchange and the energy commodity index. Once this shock is transmitted to economic growth, it passes on only to the capital stock. The most important variable is household credit, which transmits this shock to SELIC, capital stock, inflation, and enterprise credit when receiving shocks from foreign exchange and commodities. Debt, like household credit and growth, also does not receive an internal shock; when receiving an external shock, it transmits it to the capital stock. Inflation and enterprise credit, when receiving shocks from household credit, transmit shocks to capital stock and the SELIC rate. There is also the primary balance, which receives an internal shock only from enterprise credit and passes it on to interest and capital stock.

Our findings exhibit meaningful intersections with the results of Hu et al. (2020), particularly regarding the role of macroeconomic and geopolitical factors in amplifying volatility and transmitting external shocks to domestic variables. While Hu et al. (2020), focus on the realized volatility of specific commodity futures -namely soybeans, gold, and crude oil - driven by factors such as economic policy uncertainty (EPU), market sentiment (VIX and SI), and geopolitical risk (GPR), our results extend this perspective to the macroeconomic domain by identifying economic growth in Brazil as a predominant net receiver of external shocks,

especially from exchange rate fluctuations and the energy commodity index. Both studies underscore the time-varying nature of macro-financial transmission and the differentiated sensitivity of variables to distinct categories of shocks. Furthermore, similar to how Hu et al. find that oil and gold are more reactive to sentiment and geopolitical uncertainty, we observe that inflation and credit channels in the Brazilian economy are activated primarily following external disturbances, reinforcing the idea that macroeconomic dynamics are shaped by a layered process of transmission where external volatility first impacts aggregate indicators before permeating domestic structures.

Fig. 17 visually supports this interpretation by illustrating the evolution of dynamic net pairwise effects over time. Blue areas indicate periods during which growth acts as a net transmitter of shocks, while red areas signal its position as a net receiver. Notably, throughout most of the sample period, Brazilian growth consistently functions as a recipient of external disturbances, with limited endogenous propagation to other domestic variables. The empirical evidence from our model further indicates that economic growth functions predominantly as a net recipient of external shocks, with particular sensitivity to disturbances stemming from exchange rate fluctuations and variations in the energy commodity index. Once internalized, these shocks are primarily transmitted to the capital stock, while feedback effects on other domestic macroeconomic channels remain limited. Within the domestic transmission structure, household credit emerges as the most influential conduit, disseminating external shocks to key variables, including the SELIC interest rate, capital stock, inflation, and enterprise credit.

These findings are broadly consistent with international evidence reported by Kyriazis et al. (2024), who identify inflation, economic policy uncertainty indices (EPU and MPU), and oil prices as principal net recipients of global shocks. In alignment with their results, the present analysis also underscores the role of domestic variables - most notably inflation and credit aggregates - as secondary transmitters of external volatility, activated primarily in the aftermath of exogenous disturbances. Such parallels suggest the existence of a systemic asymmetry in both advanced and emerging economies, whereby external shocks are absorbed and propagated internally through select macro-financial channels.

Moreover, pairwise connectedness decomposition confirms the centrality of household credit in the diffusion process within the domestic economy. Notably, its role as a transmission mechanism becomes significant only subsequent to the occurrence of external shocks, thereby reinforcing the hypothesis that the behavior of domestic macroeconomic dynamics is predominantly conditioned by global variables, particularly commodity price cycles and exchange rate volatility.

These findings are further substantiated by Zou and Hu (2025), whose analysis focuses on the Chinese economy and its systemic role in transmitting shocks to commodity markets. Their results demonstrate that Chinese macroeconomic uncertainty serves as a dominant net transmitter, particularly affecting commodities with strong ties to industrial production, such as chemical engineering materials and non-ferrous metals. The authors emphasize that this influence intensified during periods of heightened global disruption, most notably during the COVID-19 pandemic, when production shutdowns magnified volatility across international commodity markets.

Collectively, these studies point to a shared pattern: macroeconomic uncertainty tied to real activity and supply-side disruptions exerts a greater and more persistent effect on connectedness across markets than policy uncertainty alone. Furthermore, they highlight the relevance of structural characteristics - such as China's role in global manufacturing or Brazil's exposure to commodity cycles - in determining a country's position as a net transmitter or receiver of volatility. These insights reinforce the importance of accounting for external vulnerabilities and endogenous transmission asymmetries when designing macroeconomic policy in emerging economies.

Fig. 17. Dynamic net pairwise connectedness involving only domestic macro variables

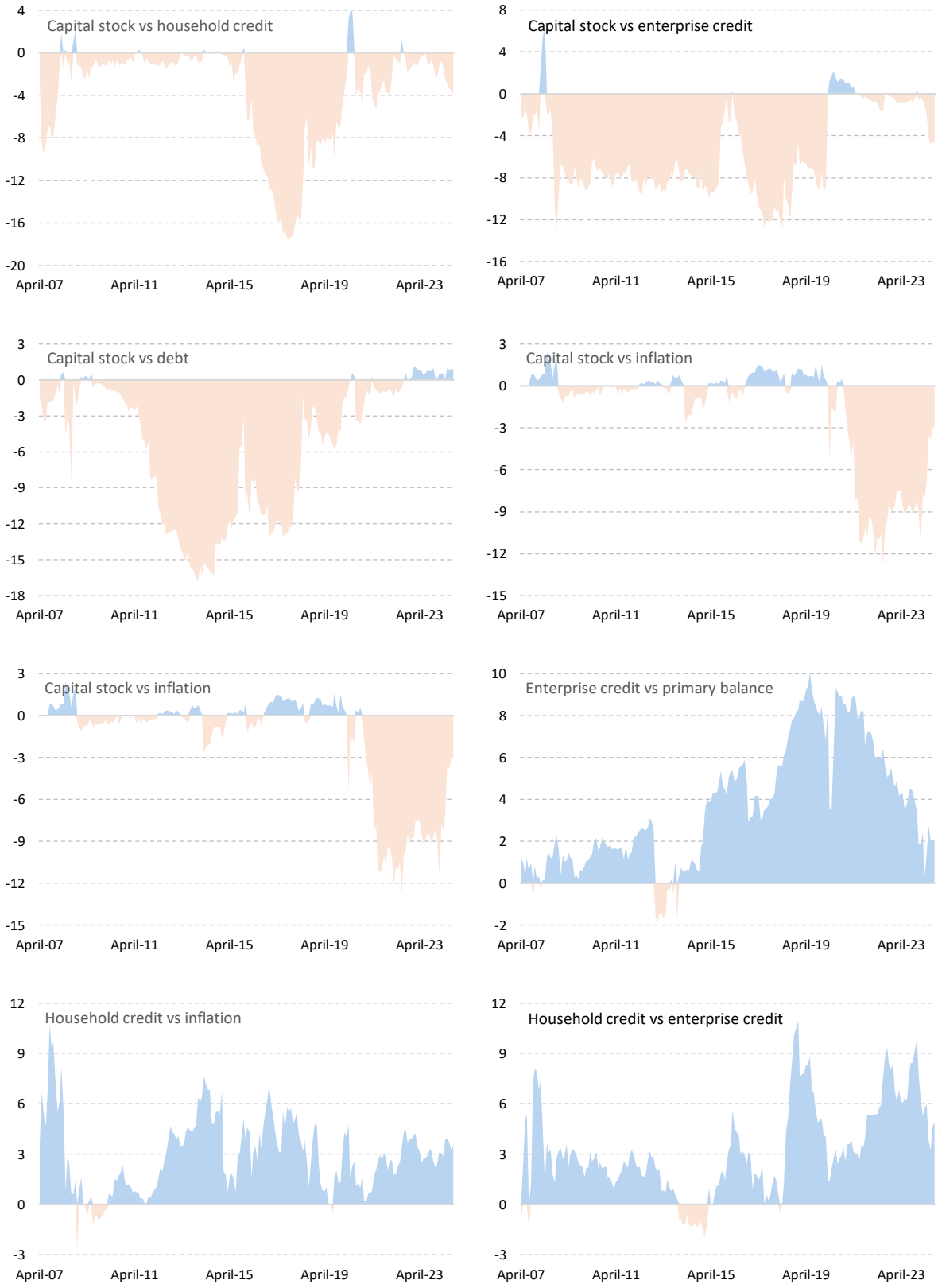


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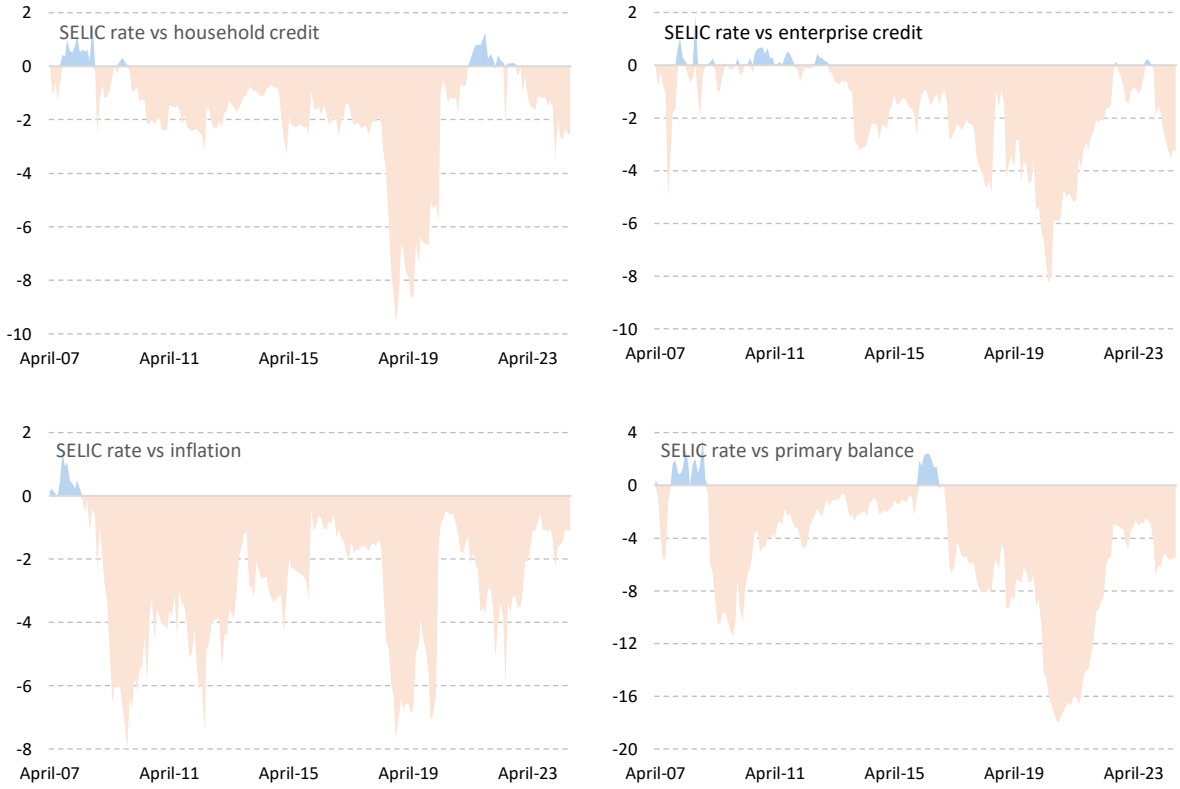
Fig. 17. Dynamic net pairwise connectedness involving only domestic macro variables



Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as a shock sender, while red areas mean growth as a shock receiver. Monthly series from April 2007 to September 2024.

7. CONCLUSION

We investigated the time-varying transmission of short-run growth shocks in Brazil by distinguishing the roles of domestic macroeconomic variables, external factors, and commodity price dynamics. Leveraging a Time-Varying Parameter Vector Autoregressive (TVP-VAR) model within a connectedness framework, we quantify both the magnitude and direction of shock spillovers from April 2007 to September 2024. Our empirical exercise offers a novel contribution to the literature by integrating internal and external sources of volatility in a unified setting, allowing for granular identification of net transmitters and receivers of shocks.

Our findings reveal that Brazil's economic growth acts predominantly as a net receiver of shocks, particularly from external channels such as exchange rates and energy commodity prices. While domestic variables, especially household credit and the primary balance, do exhibit episodic transmission capacity, their influence is typically secondary and often activated in the aftermath of exogenous disturbances. The decomposition of the Total Connectedness Index (TCI) further confirms that more than 80% of growth volatility is attributable to external sources and their crossover effects, underscoring Brazil's structural vulnerability to global dynamics.

Frequency-based decomposition supports the notion that these spillovers primarily occur in the short term, while Brazil's capacity to influence other variables, especially in terms of capital accumulation, emerges more clearly in the long run. The net directional analysis also reveals heterogeneous patterns across different episodes, such as the fiscal crisis and the COVID-19 recession, with commodities and open macroeconomic variables playing distinct roles in each period.

Finally, our analysis identifies household credit as a central node in the domestic transmission mechanism, albeit one whose influence is often contingent upon prior external shocks. These results have relevant implications for macroeconomic policy design, particularly for emerging economies exposed to volatile terms of trade and exchange rate fluctuations. Strengthening internal buffers and reducing procyclical exposure to commodity cycles and capital flows may enhance Brazil's resilience against external growth volatility.

REFERENCES

ADEKOYA, O. B. et al. Crude oil and Islamic sectoral stocks: asymmetric TVP-VAR connectedness and investment strategies. **Resources Policy**, v. 78, 102877, 2022. DOI: https://doi.org/10.1016/j.resourpol.2022.102877.

ADRIAN, T.; MOENCH, E.; SHIN, H. Macro risk premium and intermediary balance sheet quantities. **IMF Economic Review**, v. 58, p. 179–207, 2010. DOI: https://doi.org/10.1057/imfer.2010.5.

AGHION, P.; HOWITT, P. A model of growth through creative destruction. **Econometrica**, v. 60, p. 323–335, 1992. DOI: https://doi.org/10.3386/w3223.

AGYEI, S. K.; BOSSMAN, A. Exploring the dynamic connectedness between commodities and African equities. **Cogent Economics & Finance**, v. 11, n. 1, p. 2186035, 2023. DOI: https://doi.org/10.1080/23322039.2023.2186035.

ALAM, M. K. et al. The impacts of the Russia–Ukraine invasion on global markets and commodities: a dynamic connectedness among G7 and BRIC markets. **Journal of Risk and Financial Management**, v. 15, n. 8, p. 352, 2022. DOI: https://doi.org/10.3390/jrfm15080352.

ALIU, F. et al. Assessing the impact of the Russia-Ukraine war and COVID-19 on selected European currencies and key commodities. **Journal of Business Economics and Management**, v. 25, n. 5, p. 1097–1119, 2024. DOI: https://doi.org/10.3846/jbem.2024.22518.

ANTONAKAKIS, N.; GABAUER, D. Refined measures of dynamic connectedness based on TVP-VAR. **MPRA Paper**, n. 78282, p. 1–15, 2017. Disponível em: https://mpra.ub.uni-muenchen.de/id/eprint/78282. Acesso em: 12 out. 2025.

ANTONAKAKIS, N.; CHATZIANTONIOU, I.; GABAUER, D. Cryptocurrency market contagion: market uncertainty, market complexity, and dynamic portfolios. **Journal of International Financial Markets, Institutions & Money**, v. 61, p. 37–51, 2019. DOI: https://doi.org/10.1016/j.intfin.2019.02.003.

ANTONAKAKIS, N.; CHATZIANTONIOU, I.; GABAUER, D. Refined measures of dynamic connectedness based on time-varying parameter vector autoregressions. **Journal of Risk and Financial Management**, v. 13, n. 4, p. 84, 2020. DOI: https://doi.org/10.3390/jrfm13040084.

ARBACHE, J.; SARQUIS, S. J. B. Growth volatility and economic growth in Brazil. In: BLANCHARD, O.; FISCHER, S.; RAJAN, R. G. (Org.). **The Oxford Handbook of the Brazilian Economy**. Oxford: Oxford University Press, 2018. DOI: https://doi.org/10.1093/oxfordhb/9780190499983.013.17.

AZARIADIS, C. Riddles and models: a review essay on Michel De Vroey's *A History of Macroeconomics from Keynes to Lucas and Beyond*. **Journal of Economic Literature**, v. 56, n. 4, p. 1538–1576, 2018. DOI: https://doi.org/10.1257/jel.20181439.

BALCILAR, M.; GABAUER, D.; UMAR, Z. Crude Oil futures contracts and commodity markets: new evidence from a TVP-VAR extended joint connectedness approach. **Resources Policy**, v. 73, 102219, 2021. https://doi.org/10.1016/j.resourpol.2021.102219.

BAFFES, J.; NAGLE, P. Commodity Markets: Evolution, Challenges and Policies. Washington, DC: **World Bank**, 2022.

BAN, C.; BLYTH, M. The BRICs and the Washington Consensus: An introduction. **Review of International Political Economy**, v. 20, n. 2, p. 241–255, 2013. https://doi.org/10.1080/09692290.2013.779374.

BARRO, R. J. Economic growth in a cross section of countries. **The Quarterly Journal of Economics**, v. 106, n. 2, p. 407–443, 1991. https://doi.org/10.2307/2937943.

BARRO, R. Government spending in a simple model of endogenous growth. **Journal of Political Economy**, v. 98, p. S103–S125, 1990. https://www.jstor.org/stable/2937633.

BARUNÍK, J.; KŘEHLÍK, T. Measuring the frequency dynamics of financial connectedness and systemic risk. **Journal of Financial Economics**, v. 16, n. 2, p. 271–296, 2018. https://doi.org/10.1093/jjfinec/nby001.

BECK, T.; BUYUKKARABACAK, B.; RIOJA, F.; VALEV, N. Who gets the credit? And does it matter? Household vs. firm lending across countries. **The B.E. Journal of Macroeconomics**, v. 12, p. 1–44, 2012. https://doi.org/10.1515/195-1690.2262.

BERG, A.; BUFFIE, E.; PATTILLO, C.; PRESBITERO, A.; ZANNA, L. Some misconceptions about public investment efficiency and growth. **IMF Working Paper**, WP 15/72, 2015. https://www.imf.org/external/pubs/ft/wp/2015/wp15272.pdf.

BULMER-THOMAS, V. The Brazilian devaluation: national responses and international consequences. **International Affairs**, v. 75, n. 4, p. 729–741, 1999. https://doi.org/10.1111/1468-2346.00105.

CAGLI, E. F.; MANDACI, P. E.; TASKIN, D. The volatility connectedness between agricultural commodity and agri businesses: evidence from time-varying extended joint approach. **Finance Research Letters**, v. 52, 103555, 2023. https://doi.org/10.1016/j.frl.2022.103555.

CANUTO, O.; CAVALLARI, M.; REIS, J. G. Brazilian exports: climbing down a competitiveness cliff. **World Bank Policy Research Working Paper**, n. 6302, 2013.

CAVALCANTI, T.; DA MATA, D.; TOSCANI, F. Winning the oil lottery: the impact of natural resource extraction on growth. **Journal of Economic Growth**, v. 24, p. 79–115, 2019. https://doi.org/10.1007/s10887-018-09161-z.

CAVALCANTI, T.; JALLES, J. T. Macroeconomic effects of oil price shocks in Brazil and in the United States. **Applied Energy**, v. 104, p. 475–486, 2013. https://doi.org/10.1016/j.apenergy.2012.10.039.

CÉSPEDES, L. F.; VELASCO, A. Was this time different?: Fiscal policy in commodity republics. **Journal of Development Economics**, v. 106, p. 92–106, 2014. https://doi.org/10.1016/j.jdeveco.2013.07.012.

CHATZIANTONIOU, I.; GABAUER, D. EMU risk-synchronisation and financial fragility through the prism of dynamic connectedness. **The Quarterly Review of Economics and Finance**, v. 79, p. 1–14, 2021. https://doi.org/10.1016/j.qref.2020.12.003.

CHATZIANTONIOU, I.; GABAUER, D.; GUPTA, R. Integration and risk transmission in the market for crude oil: new evidence from a time-varying parameter frequency connectedness approach. **Resources Policy**, v. 84, 103729, 2023. https://doi.org/10.1016/j.resourpol.2023.103729.

CHEN, P.; HE, L.; YANG, X. On interdependence structure of China's commodity market. **Resources Policy**, v. 74, 102256, 2021. https://doi.org/10.1016/j.resourpol.2021.102256.

DEMIRER, M.; DIEBOLD, F. X.; LIU, L.; YILMAZ, K. Estimating global bank network connectedness. **Journal of Applied Econometrics**, v. 33, n. 1, p. 1–15, 2018. https://doi.org/10.1002/jae.2585.

DIEBOLD, F. X.; YILMAZ, K. Measuring financial asset return and volatility spillovers, with application to global equity markets. **The Economic Journal**, v. 119, n. 534, p. 158–171, 2009. https://doi.org/10.1111/j.1468-0297.2008.02208.x.

DIEBOLD, F. X.; YILMAZ, K. Better to give than to receive: predictive directional measurement of volatility spillovers. **International Journal of Forecasting**, v. 28, p. 57–66, 2012. https://doi.org/10.1016/j.ijforecast.2011.02.006.

DIEBOLD, F. X.; YILMAZ, K. On the network topology of variance decompositions: measuring the connectedness of financial firms. **Journal of Econometrics**, v. 182, n. 1, p. 119–134, 2014. https://doi.org/10.1016/j.jeconom.2014.04.012.

DIEBOLD, F. X.; YILMAZ, K. Financial and macroeconomic connectedness: A network approach to measurement and monitoring. Oxford: **Oxford University Press**, 2015.
FEDER, G. On exports and economic growth. **Journal of Development Economics**, v. 12, n. 1–2, p. 59–73, 1983. https://doi.org/10.1016/0304-3878(83)90031-7.

FERNÁNDEZ, A.; GONZÁLEZ, A.; RODRIGUEZ, D. Sharing a ride on the commodities roller coaster: common factors in business cycles of emerging economies. **Journal of International Economics**, v. 111, p. 99–121, 2018. https://doi.org/10.1016/j.jinteco.2017.11.008.

FLECHTNER, S.; MIDDELANIS, M. The role of the commodity price boom in shaping public social spending: evidence from Latin America. **World Development**, v. 182, 106717, 2024. https://doi.org/10.1016/j.worlddev.2024.106717.

FURUOKA, F.; YAYA, O. S.; LING, P. K.; AL-FARYAN, M. A. S.; ISLAM, M. N. Transmission of risks between energy and agricultural commodities: frequency time-varying VAR, asymmetry and portfolio management. **Resources Policy**, v. 81, 103339, 2023. https://doi.org/10.1016/j.resourpol.2023.103339.

GABAUER, D.; GUPTA, R. On the transmission mechanism of country-specific and international economic uncertainty spillovers: evidence from a TVP-VAR connectedness decomposition approach. **Economics Letters**, v. 171, p. 63–71, 2018. https://doi.org/10.1016/j.econlet.2018.07.007.

GABAUER, D.; CHATZIANTONIOU, I.; STENFORS, A. Model-free connectedness measures. **Finance Research Letters**, v. 54, 103804, 2023. https://doi.org/10.1016/j.frl.2023.103804.

GABAUER, D.; GUPTA, R.; MARFATIA, H. A.; MILLER, S. M. Estimating US housing price network connectedness: evidence from dynamic elastic net, lasso, and ridge vector autoregressive models. **International Review of Economics & Finance**, v. 89, p. 349–362, 2024. https://doi.org/10.1016/j.iref.2023.10.013.

GONG, X.; XU, J. Geopolitical risk and dynamic connectedness between commodity markets. **Energy Economics**, v. 110, 106028, 2022. https://doi.org/10.1016/j.eneco.2022.106028.

GUO, J.; TANAKA, T. Do biofuel production and financial speculation in agricultural commodities influence African food prices? New evidence from a TVP-VAR extended joint connectedness approach. **Energy Economics**, v. 116, 106422, 2022. https://doi.org/10.1016/j.eneco.2022.106422.

HO, C.; WANG, W.; YU, J. Growth spillover through trade: a spatial dynamic panel data approach. **Economics Letters**, v. 120, p. 450–453, 2013. http://dx.doi.org/10.1016/j.econlet.2013.05.027.

HODRICK, R.; PRESCOTT, E. Postwar U.S. business cycles: an empirical investigation. **Journal of Money, Credit and Banking**, v. 29, p. 1–16, 1997. http://www.jstor.org/stable/2953682.

HOWITT, P. Endogenous growth and cross-country income differences. **American Economic Review**, v. 90, p. 829–846, 2000. https://doi.org/10.1257/aer.90.4.829.

HU, M.; ZHANG, D.; JI, Q.; WEI, L. Macro factors and the realized volatility of commodities: a dynamic network analysis. **Resources Policy**, v. 68, 101813, 2020. https://doi.org/10.1016/j.resourpol.2020.101813.

IASCO-PEREIRA, H. C.; LIBÂNIO, G.; MISSIO, F. The real exchange rate and industrial investment: new evidence for Brazil. **Cambridge Journal of Economics**, v. 48, n. 4, p. 741–766, 2024. https://doi.org/10.1093/cje/beae020.

IMBS, J. The real effects of financial integration. **Journal of International Economics**, v. 68, p. 296–324, 2006. https://doi.org/10.1016/j.jinteco.2005.05.003.

INTERNATIONAL MONETARY FUND. World Economic Outlook – Legacies, Clouds, Uncertainties. Washington, D.C.: **International Monetary Fund**, 2014. https://www.imf.org/-/media/Websites/IMF/imported-flagship-issues/external/pubs/ft/weo/2014/02/pdf/_textpdf.ashx.

INTERNATIONAL MONETARY FUND. Global financial stability report: Safeguarding financial stability amid high inflation. Washington, D.C.: **International Monetary Fund**, 2023. https://www.elibrary.imf.org/display/book/9798400233241/9798400233241.xml.

KANG, S. H.; MCIVER, R.; YOON, S. M. Dynamic spillover effects among crude oil, precious metal, and agricultural commodity futures markets. **Energy Economics**, v. 62, p. 19–32, 2017. https://doi.org/10.1016/j.eneco.2016.12.011.

KARKOWSKA, R.; URJASZ, S. Connectedness structures of sovereign bond markets in Central and Eastern Europe. **International Review of Financial Analysis**, v. 74, 101644, 2021. https://doi.org/10.1016/j.irfa.2020.101644.

KARKOWSKA, R.; URJASZ, S. Importance of geopolitical risk in volatility structure: new evidence from biofuels, crude oil, and grains commodity markets. **Journal of Commodity Markets**, v. 36, 100440, 2024. https://doi.org/10.1016/j.jcomm.2024.100440.

KEHOE, T.; NICOLINI, J. A Monetary and Fiscal History of Latin America, 1960–2017. Minneapolis: **University of Minnesota Press**, 2021.

KLENOW, P.; RODRIGUEZ-CLARE, A. Externalities and growth. In: AGHION, P.; DURLAUF, S. (Eds.). **Handbook of Economic Growth**. Amsterdam: Elsevier, 2005. p. 817–861.

KOSE, M.; PRASAD, E.; TERRONES, M. How does globalization affect the synchronization of business cycles. **American Economic Review**, v. 93, p. 57–62, 2003. https://doi.org/10.1257/000282803321946804.

KYRIAZIS, N.; PAPADAMOU, S.; TZEREMES, P.; CORBET, S. Examining spillovers and connectedness among commodities, inflation, and uncertainty: a quantile-VAR framework. **Energy Economics**, v. 133, 107508, 2024. https://doi.org/10.1016/j.eneco.2024.107508.

LEVINE, R.; RENELT, D. A sensitivity analysis of cross-country growth regressions. **American Economic Review**, p. 942–963, 1992. https://www.jstor.org/stable/2117352.

LUCAS JR., R. E. Inflation and welfare. **Econometrica**, v. 68, n. 2, p. 247–274, 2000. https://doi.org/10.1111/1468-0262.00109.

MATOS, P.; ALVES, D.; MONTEIRO, V. On the time-frequency effects of macroeconomic policy on growth cycles in Brazil. **Research in International Business and Finance**, v. 73, 102660, 2025a. https://doi.org/10.1016/j.ribaf.2024.102660.

MATOS, P. R. F.; ALBUQUERQUE VIEIRA, D.; DA SILVA, C.; LUCENA, I. G10 cross-country connectedness over US growth. **Journal of Economic Studies (Bradford)**, v. 52, p. 1–26, 2025b. https://doi.org/10.1108/JES-08-2024-0575.

MATOS, P.; COSTA, A.; DA SILVA, C. Analyzing U.S. GDP-debt-inflation linkages in the time-frequency domain. **International Journal of Economics and Finance**, v. 26, p. 27–40, 2024. https://doi.org/10.5539/ijef.v16n11p27.

MATOS, P.; ALBUQUERQUE, D.; DA SILVA, C. A note on the effect of decomposing credit for explaining Brazilian cross-state GDP growth. **Revista Brasileira de Economia**, v. 74, n. 2, p. 155–166, 2020. https://doi.org/10.5935/0034-7140.20200009.

MATOS, P.; DA SILVA, C. What drives the dynamics of public capital stock in Brazil? Mimeo. Fortaleza: **CAEN/UFC**, 2025.

MISHRA, A.; KUMAR, P. A. Agricultural commodities: an integrated approach to assess the volatility spillover and dynamic connectedness. **Economics and Business Review**, v. 7, n. 21, p. 28–53, 2021. https://doi.org/10.18559/ebr.2021.4.3.

MISHRA, A. K.; ARUNACHALAM, V.; OLSON, D.; PATNAIK, D. Dynamic connectedness in commodity futures markets during Covid-19 in India: new evidence from a TVP-VAR extended joint connectedness approach. **Resources Policy**, v. 82, 103490, 2023. https://doi.org/10.1016/j.resourpol.2023.103490.

MISHRA, A. K.; GHATE, K. Dynamic connectedness in non-ferrous commodity markets: evidence from India using TVP-VAR and DCC-GARCH approaches. **Resources Policy**, v. 76, 2022. https://doi.org/10.1016/j.resourpol.2022.102572.

MOHADDES, K.; RAISSI, M. Do sovereign wealth funds dampen the negative effects of commodity price volatility? **Journal of Commodity Markets**, v. 8, p. 18–27, 2017. https://doi.org/10.1016/j.jcomm.2017.08.004.

OZCELEBI, O.; KANG, S. H. Extreme connectedness and network across financial assets and commodity futures markets. **North American Journal of Economics and Finance**, 102099, 2024. https://doi.org/10.1016/j.najef.2024.102099.

PAIVA, M. C. Trade elasticities and market expectations in Brazil. Washington, D.C.: **International Monetary Fund**, 2003.

PHAM, B.; SALA, H. Cross-country connectedness in inflation and unemployment: measurement and macroeconomic consequences. **Empirical Economics**, v. 62, p. 1123–1146, 2021. https://doi.org/10.1007/s00181-021-02052-0.

POLAT, O.; BAŞAR, B. D.; TORUN, E.; EKŞI, İ. H. Dynamic interlinkages between geopolitical stress and agricultural commodity market: novel findings in the wake of the Russian–Ukrainian conflict. **Borsa Istanbul Review**, v. 23, p. S74–S83, 2023. https://doi.org/10.1016/j.bir.2023.05.007.

REINHART, C.; ROGOFF, K. Growth in time of debt. **American Economic Review: Papers & Proceedings**, v. 100, p. 573–578, 2010. https://doi.org/10.1257/aer.100.2.573.

REINHART, C.; ROGOFF, K.; SAVASTANO, M. Debt intolerance. **Brookings Papers on Economic Activity**, n. 1, p. 1–62, 2003. https://mpra.ub.uni-muenchen.de/13932/.

ROCHA, F. J.; MAGALHÃES, M. R.; BRILHANTE, Á. A. Monetary policy, commodity prices and credit in Brazil: a SVAR approach. **Theoretical Economics Letters**, v. 12, n. 2, p. 434–450, 2022. https://doi.org/10.4236/tel.2022.122024.

ROSSI JÚNIOR, J. L.; DE CARVALHO ROSSI, M. D.; CUNHA, D. C. Transmission of monetary policy through the wealth channel in Brazil: does the type of asset matter? **Research in International Business and Finance**, v. 50, p. 279–293, 2019. https://doi.org/10.1016/j.ribaf.2019.06.009.

SAUER, S.; BALESTRO, M. V.; SCHNEIDER, S. The ambiguous stance of Brazil as a regional power: piloting a course between commodity-based surpluses and national development. **Globalizations**, v. 15, n. 1, p. 32–55, 2017. https://doi.org/10.1080/14747731.2017.1400232.

SOLOW, R. A contribution to the theory of economic growth. **The Quarterly Journal of Economics**, v. 70, p. 65–94, 1956. https://doi.org/10.2307/1884513.

TREVIÑO, L. J.; MIXON JR., F. G. Strategic factors affecting foreign direct investment decisions by multinational enterprises in Latin America. **Journal of World Business**, v. 39, n. 3, p. 233–243, 2004. https://doi.org/10.1016/j.jwb.2004.04.003.

VO, D. H.; TRAN, M. P. B. Volatility spillovers between energy and agriculture markets during the ongoing food & energy crisis: does uncertainty from the Russo-Ukrainian conflict matter? **Technological Forecasting and Social Change**, v. 208, 123723, 2024. https://doi.org/10.1016/j.techfore.2024.123723.

VUBA, N.; QABHOBHO, T. The risk transfer among exchange rates, energy commodities, and agricultural commodity prices in SADC countries. **International Journal of Energy Economics and Policy**, v. 14, n. 2, p. 287–298, 2024. https://doi.org/10.32479/ijeep.15372.

WAN, J.; YIN, L.; WU, Y. Return and volatility connectedness across global ESG stock indexes: evidence from the time-frequency domain analysis. **International Review of Economics & Finance**, v. 89, p. 397–428, 2024. https://doi.org/10.1016/j.iref.2023.10.038.

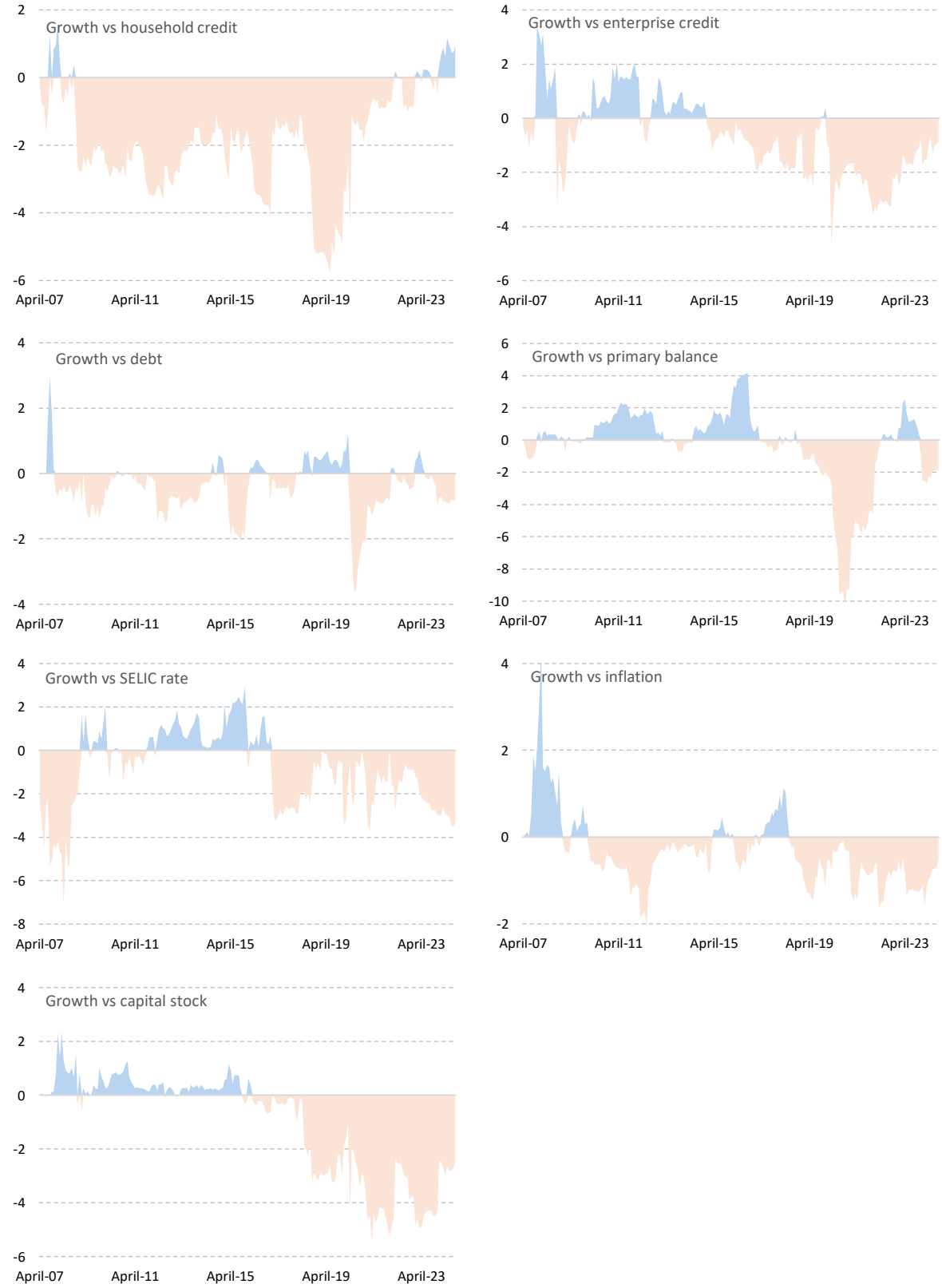
WANG, M.; CHANG, T.; MIKHAYLOV, A.; LINYU, J. A measure of quantile-on-quantile connectedness for the US treasury yield curve spread, the US Dollar, and gold price. **North American Journal of Economics and Finance**, v. 74, p. 1–16, 2024. https://doi.org/10.1016/j.najef.2024.102232.

XIANG, Y.; BORJIGIN, S. High–low volatility spillover network between economic policy uncertainty and commodity futures markets. **Journal of Futures Markets**, v. 44, n. 8, p. 1295–1319, 2024. https://doi.org/10.1002/fut.22511.

ZOU, X.; HU, J. The dynamic connectedness between macroeconomic uncertainty and commodity volatility: evidence from China. **Applied Economics**, v. 57, n. 2, p. 169–190, 2025. https://doi.org/10.1080/00036846.2024.2303406.

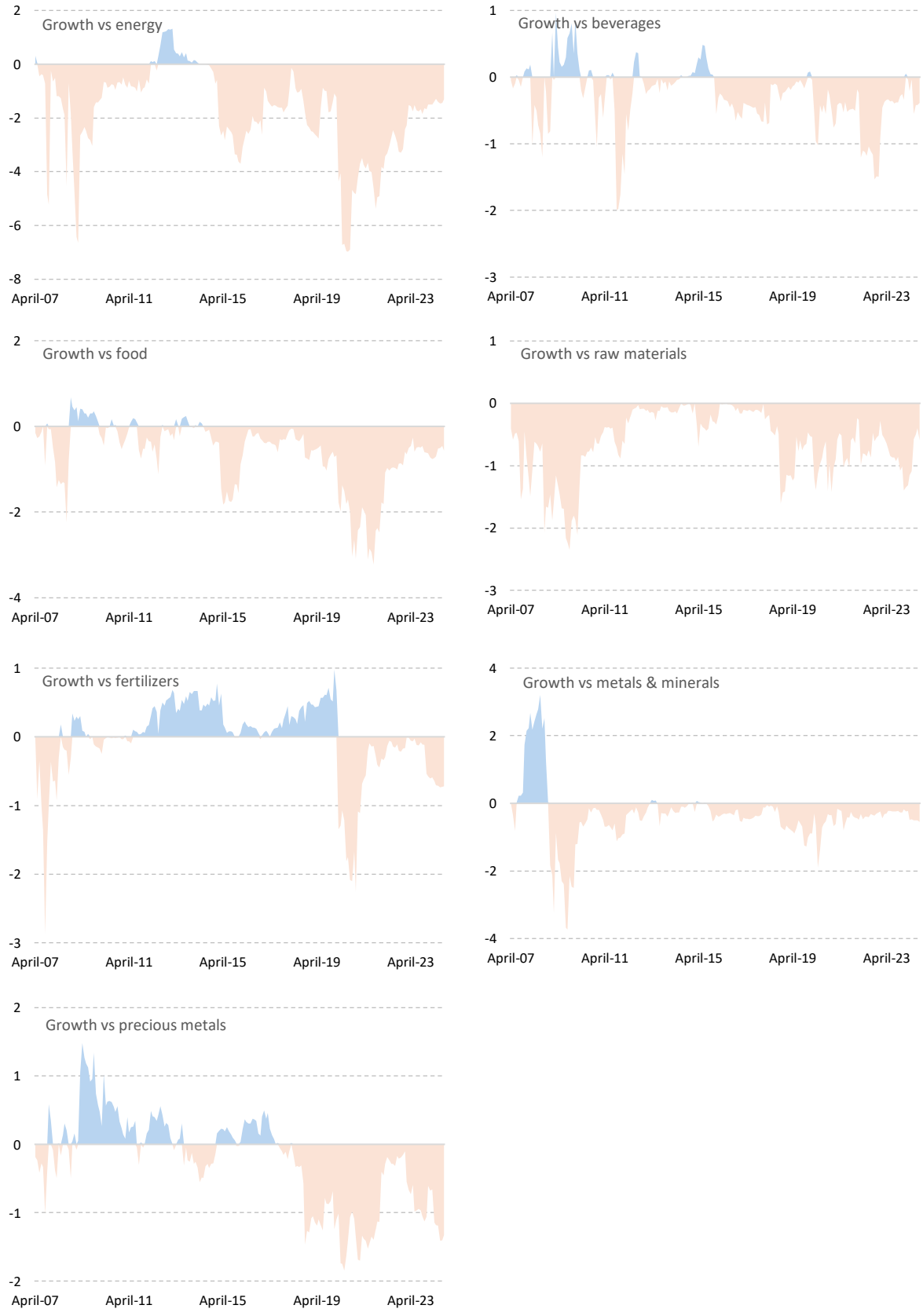
APPENDIX

Fig. A.1. Dynamic net pairwise connectedness (frequency < 1 year): growth versus domestic macro variables



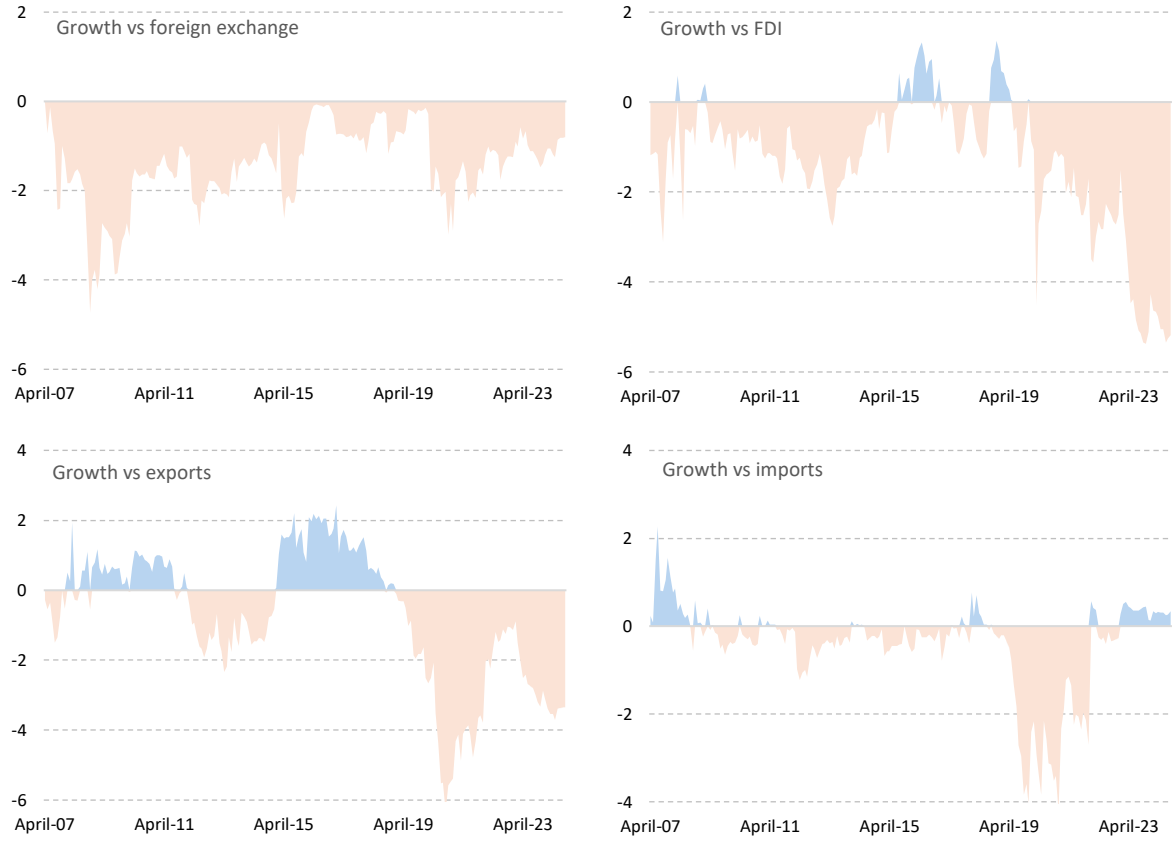
Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.

Fig. A.2. Dynamic net pairwise connectedness (frequency < 1 year): growth versus commodities



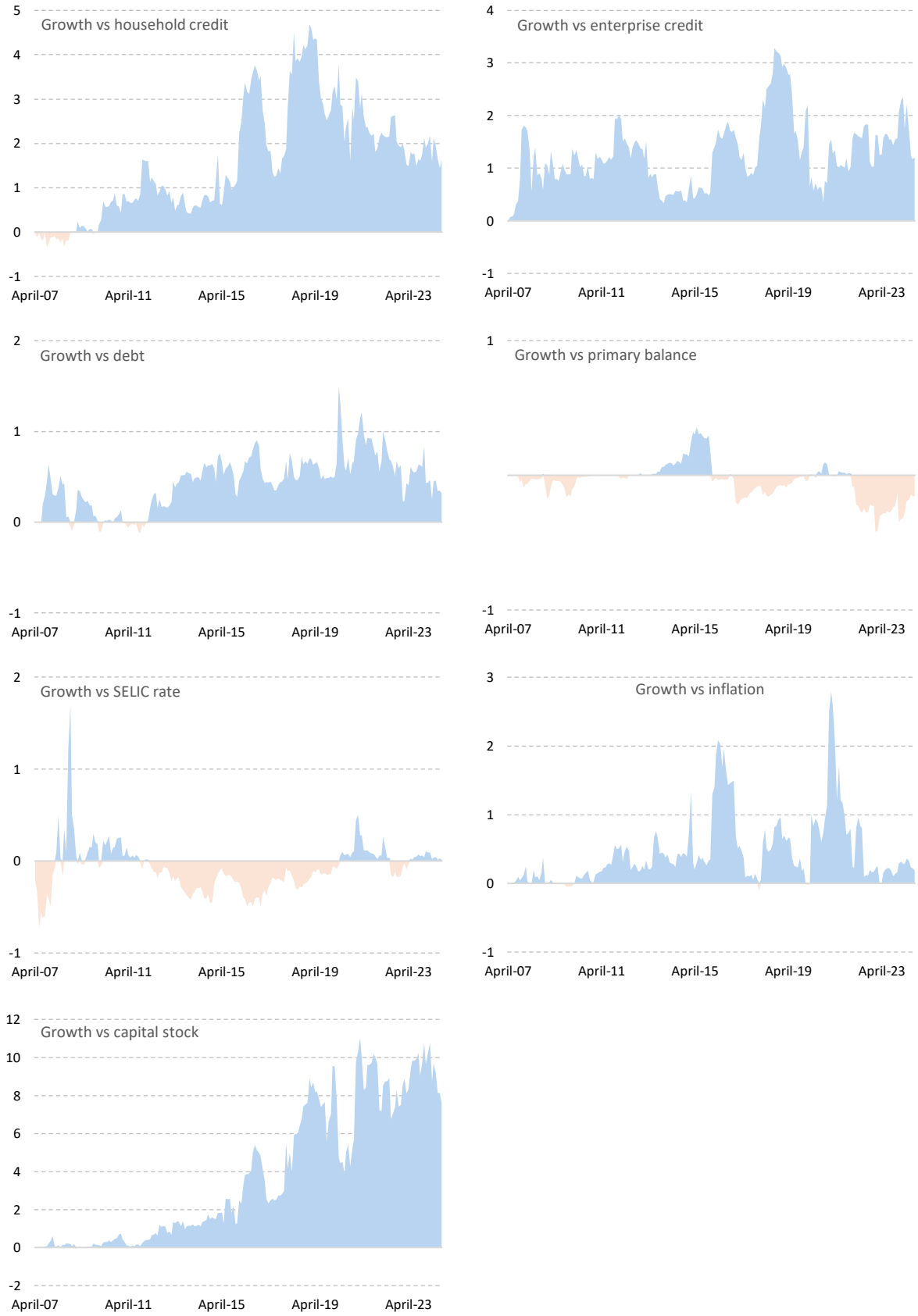
Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.

Fig. A.3. Dynamic net pairwise connectedness (frequency < 1 year): growth versus open macro variables



Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.

Fig. A.4. Dynamic net pairwise connectedness (frequency > 1 year): growth versus domestic macro variables

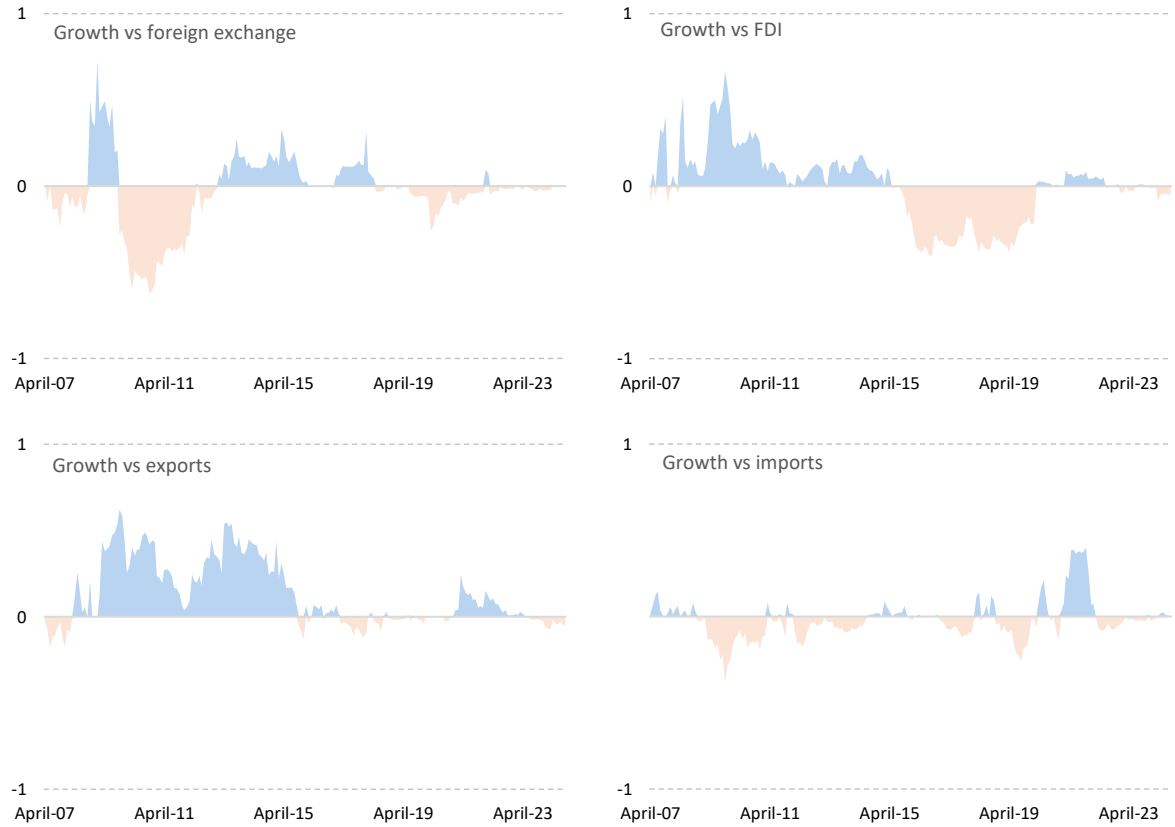


Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.

Fig. A.5. Dynamic net pairwise connectedness (frequency > 1 year): growth versus commodities

Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.

Fig. A.6. Dynamic net pairwise connectedness (frequency > 1 year): growth versus open macro variables



Notes: TVP-VAR (W = 210 and H = 12). Blue areas mean growth as shock sender, while red areas mean growth as shock receiver. Monthly series from April 2007 to September 2024.