Global Chains, Regional Pains:
Brazil's Socio-Economic Exposure to U.S. Trade Policy

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Abstract

This paper investigates how recent and potential changes in U.S. trade policy affect regional economic performance, labor markets, and income inequality across Brazil, using an integrated global-subnational framework to capture detailed spatial, sectoral, and socioeconomic impacts of international trade shocks. Empirical findings reveal substantial regional heterogeneity in economic outcomes, with pronounced vulnerabilities in parts of the North and Northeast, but also significant losses in selected industrialized areas of the Southeast and South. Labor market responses are similarly uneven, characterized by sharp losses among both high-skill, trade-dependent occupations and more vulnerable informal and low-skill workers. Agriculture, particularly soybean production, emerges as a critical transmission channel, reflecting Brazil's deep integration into China-led global value chains. Income and consumption impacts are regressive, disproportionately affecting lower-income households. These results underscore the importance of accounting for subnational heterogeneity and global value chain linkages when designing compensatory and adjustment policies. Effective policy interventions thus require spatially targeted mechanisms to mitigate adverse regional and distributional effects while leveraging strategic sectoral opportunities arising from trade realignments.

Keywords: External Vulnerability, Trade Policy, Global-Regional Modeling, Labor Market Segmentation, Soybean Trade

[redacted] Introduction

Brazil maintains a multifaceted relationship with the United States, which is both an important trade partner and a competitor in strategic agricultural sectors, while also remaining linked through investment and broader geopolitical interests. At the same time, as a member of the BRICS[1] bloc, Brazil is interested in reducing exposure to dollar dominance and potential U.S. sanctions, building platforms such as BRICS Pay and local currency financing through the New Development Bank (Liu and Papa, 2022). In 2024, then U.S. President-elect Donald Trump proposed imposing 100% tariffs on imports from countries, particularly members of the BRICS bloc, that engage in international trade transactions using currencies other than the U.S. dollar.[2] This proposal, though not implemented, introduces a scenario in which exchange-rate alignment becomes a criterion for trade access, linking monetary strategy directly to tariff enforcement.

On April 5, 2025, the United States implemented a 10% baseline tariff on all trading partners (except Canada and Mexico, which have higher tariff rates) with the objective of reducing trade deficits. Driven by higher tariffs by the U.S. and environmental restrictions on Brazilian exports from European Union and other countries (Carbon Border Adjustment Mechanism), on April 14, 2025 Brazil published the “Economic Reciprocity Law” that gives the Brazilian government authority to impose countermeasures when other countries take unilateral actions that harm Brazilian trade interests. In July 2025, the U.S. announced additional 40% tariffs on many Brazilian imports, citing concerns over the arrest and trial of

[1] BRICS stands for Brazil, Russia, India, China, and South Africa, representing a coalition of major emerging economies. Additional emerging economies are now members of this association (https://www.brics2026.gov.in/).

[2] https://www.bbc.com/news/articles/cgrwj0p2dd9o

former President Jair Bolsonaro, as well as alleged unfair trade practices. In November 2025, both 10% and Brazil-specific 40% tariffs were eliminated for some of the goods, and then terminated for all goods following U.S. Supreme Court ruling in February 2026. For many goods, however, 10-15% global tariffs were reinstated same month under different legal authority.[3]

These recent shifts towards more assertive and protectionist trade policies by the United States and other countries, and potential countermeasures by Brazil, may have significant impacts on Brazil's economy. These impacts are not distributed uniformly within the Brazilian economy; rather, they reverberate unevenly across regions depending on production structures and the extent of their trade dependence. Brazil's substantial reliance on agricultural exports, coupled with their geographical concentration in certain macro-regions, especially the North, Northeast, and Center-West, renders these areas particularly vulnerable to external trade shocks. U.S. trade measures such as tariffs, quotas, and non-tariff barriers can reduce regional economic output, diminish formal employment opportunities, and intensify existing income disparities. Current analytical frameworks rarely capture this degree of subnational detail, limiting policymakers' ability to effectively respond to distributional consequences (Attinasi et al. 2025; Hayakawa et al. 2024; Devarajan et al. 2021; Döbeling et al. 2025).

While numerous studies have examined the macroeconomic implications of trade policy in developing countries, there remains a clear lack of analyses that adequately capture subnational impacts while accounting for the structural transmission mechanisms and international spillovers embedded in global trade dynamics. This absence limits our understanding of how trade shocks translate into spatially and socially differentiated outcomes within large, heterogeneous economies. This research fills this gap by

[3]https://www.atlanticcouncil.org/commentary/trackers-and-data-visualizations/us-brazil-trade-dashboard/

integrating the Global Trade Analysis Project (GTAP) model with the highly detailed subnational structure of the Brazilian version of The Enormous Regional Model (TERM). This combined Computable General Equilibrium (CGE) framework enables a consistent analysis of international trade shocks and their localized socio-economic effects, building upon methodologies proposed by Horridge and Ferreira-Filho (2003). In addition, the analysis is calibrated to the GTAP 12 Data Base with a 2023 reference year, which strengthens the empirical relevance of the simulations for examining recent and prospective trade tensions involving Brazil, the United States, and the BRICS economies (Aguiar et al. 2025).

Despite increasing scholarly attention to regional inequality in global trade discussions, the literature still lacks robust models capable of capturing how trade policy shapes regional development trajectories within large, heterogeneous economies. The theoretical foundation for this concern lies in classical and contemporary models of regional divergence under trade liberalization, such as Myrdal's cumulative causation, Williamson's inverted-U, and Krugman's core-periphery dynamics (Myrdal and Sitohang 1957; Williamson 1965; Krugman 1991). Brazil, as a major exporter characterized by deep regional inequalities, is an ideal context for addressing this gap. To date, no study has applied fully integrated Global and Regional general equilibrium models to assess localized impacts of U.S. trade policy on Brazilian subnational economies.

This paper thus addresses the following research question: How do alternative scenarios of U.S. and trading partner retaliation tariffs affect economic performance and inequality across Brazil's regions? Beyond quantifying the regional distributional effects of international trade shocks, the analysis also seeks to trace the principal transmission channels through which these shocks propagate within Brazil's economy, particularly across labor markets, production structures, and household income groups, and to identify the most critical international trade linkages responsible for generating global spillovers via buyer-supplier relationships embedded in global value chains. By doing so, the study offers empirical insights to inform more spatially attuned and socially inclusive policy interventions amid rising global trade volatility.

[redacted] Literature Review

This research builds upon three key conceptual domains: global value chains (GVCs), regional economic vulnerability, and trade-induced inequality. GVCs refer to the international segmentation of production processes, which exposes specific sectors and regions to policy shocks originating abroad (Baldwin, 2016). Regional vulnerability is conceptualized here as the extent to which a region's economic structure, particularly its export concentration and labor market rigidity, modulates its exposure to external trade disruptions. Finally, trade-induced inequality refers to the distributional consequences of trade shocks, especially when these disproportionately affect low-skilled or informal labor segments. For this study, regional inequality is operationalized through the metrics of income, employment structure, and sectoral dependence at the microregional and county spatial levels.

First, the analytical relevance of global value chains (GVCs) in this study stems from their role as conduits for sector-specific transmission of external shocks within globally integrated production architectures. Beyond their spatial configuration, GVCs organize production across borders in ways that amplify the exposure of peripheral economies to sectorally differentiated policy or demand shifts originating in core markets (Grossman and Rossi-Hansberg 2008; Gereffi et al. 2005; Baldwin 2016; Hayakawa et al. 2024). In Brazil, this exposure is especially acute in agriculture, where subnational economies are strongly tied to the global trade of commodities such as soybeans, beef, and sugar. Because GVC participation is uneven across sectors, shifts in U.S. trade policy transmit asymmetrically through Brazil's production structures.

Second, regions with concentrated export portfolios, particularly in primary commodities, and a higher incidence of informal or low-skilled labor tend to be more susceptible to trade shocks (Rodríguez-Pose 2012; Brakman et al. 2001). Recent evidence on supply chain decoupling further suggests that these effects are amplified when shocks disrupt intermediate input linkages and trigger heterogeneous price and employment adjustments across space and skill groups (Attinasi et al. 2025; Mao and Görg 2020). In Brazil, this vulnerability is especially pronounced in the North, Northeast, and Center-West, where economic structures are heavily tied to agricultural exports and where structural buffers, such as industrial diversification, advanced logistics, or social safety nets, are weaker (Haddad and Hewings 2001; Bittencourt et al. 2010; Ferraz et al. 2013).

Third, the distributional consequences of international trade tend to produce spatially and socially asymmetric outcomes that reinforce pre-existing disparities in income and regional development. Concerns about the spatial effects of international trade date back to the origins of development theory. From the foundational work of Ohlin (1967) on interregional trade, through Myrdal and Sitohang (1957) analysis of cumulative regional disparities and Hirschman's (1958) emphasis on development linkages, the literature has long highlighted trade’s potential to amplify territorial inequalities. Williamson (1965) inverted-U hypothesis on regional inequality dynamics and Krugman's (1991) formulation of the New Economic Geography later formalized the mechanisms by which trade liberalization can concentrate economic activity in more competitive regions, exacerbating spatial inequality. The contributions of Helpman and Krugman (1987) further reinforced these effects by incorporating imperfect market structures and increasing returns to scale.

In the Brazilian context, where labor markets are segmented, informality is widespread, and regional disparities are pronounced, trade-induced inequality have been shown to disproportionately impact rural households, informal workers, and low-skilled labor concentrated in agriculture-dependent macro-regions such as the North, Northeast, and Center-West (Filho and Horridge 2009). Recent empirical findings for developing economies indicate that although trade liberalization can contribute to poverty reduction, particularly through gains in real consumption, it often exacerbates inequality by generating disproportionate benefits for skilled workers and formal labor in globally integrated sectors (Ramachandran et al. 2026). These regressive dynamics are particularly evident in South–South trade contexts, where comparative advantages in more skill-intensive exports elevate the relative demand for educated labor, thereby widening wage gaps and reinforcing vertical inequality (Gourdon 2007).

The academic literature identifies several transmission mechanisms through which trade policy reforms, such as tariff adjustments, non-tariff barriers, and regulatory shifts, affect national and regional economies. These mechanisms operate through both macro-structural adjustments and microeconomic behavioral responses, with particular salience in labor markets, production structure, and household welfare. Understanding these channels is essential for identifying the drivers of spatial and distributional impacts within general equilibrium models.

Sectoral Reallocation and Output Effects: Trade policy changes alter relative prices across sectors, leading to a reallocation of resources, particularly labor and capital, toward sectors that experience relatively smaller losses or larger gains in competitiveness and profitability after the policy shock. This process affects regional output differently depending on sectoral composition and comparative advantage. For countries embedded in GVCs, trade policy can affect not only exports but also imported intermediate inputs and competitiveness (Gereffi et al. 2005; Melitz 2003; Grossman et al. 2024; Mao and Görg 2020).

Skill-Based Effects: The labor market is a central transmission channel through which trade policy affects inequality, particularly in developing countries. Trade policy changes generally affect educational labor categories unevenly, with high-skilled (more educated) workers tending to experience stronger responses in labor demand and wages compared to low-skilled workers. This differentiated effect is particularly salient in economies integrated into skill-intensive global value chains, where production structures and technological complementarities are more closely aligned with the qualifications and productivity attributes of skilled labor (Anderson 2020; Gourdon 2007; Ramachandran et al. 2026).

Sectoral and Informal Employment Shifts: job creation in competitive, export-oriented industries may be accompanied by job destruction in import-competing or structurally weaker sectors, with the overall impact contingent on factors such as labor mobility, geographic frictions, and segmentation between formal and informal employment (Maloney 1999; Fields 2011). In labor markets characterized by rigidities and limited social protection, as is often the case in Brazil, these shocks can further induce an expansion of informal employment, especially among low-educated workers, exacerbating income volatility and deepening socio-economic exclusion (Porto 2006).

Household Consumption and Price Pass-Through: Changes in trade policy influence consumer prices, particularly for food, energy, and imported goods. Lower-income households, which spend a higher share of income on essentials, are more vulnerable to price spikes caused by import restrictions or retaliatory tariffs (Nicita 2009; Hertel et al. 2004). Conversely, trade openness may reduce consumer prices and improve real income, especially among the poor, depending on the CPI composition (Hertel et al. 2014). However, households that derive a substantial share of their income from agricultural production may be adversely affected by food price declines, as lower output prices compress farm revenues. Consequently, lower consumer prices can benefit net consumers, but the overall distributional impact depends on households' net market position as buyers or sellers of agricultural goods.

These channels interact in complex ways, particularly in structurally heterogeneous economies. In the case of Brazil, a spatially vast country marked by extreme regional disparities in income, infrastructure, and productive specialization, trade policy shocks do not diffuse uniformly. The combination of a continental geographic scale and a deeply segmented socio-economic structure amplifies the risk that aggregate models may obscure localized vulnerabilities and misestimate distributional effects. Therefore, a framework capable of capturing global value chain linkages, regional differentiation, and labor market segmentation is particularly well-suited to analyzing such complexities. In this study, these transmission mechanisms are explicitly mapped using a hard-linked GTAP-TERM model, which integrates global trade flows with detailed subnational representations of the Brazilian economy. This allows for a granular assessment of how trade shocks affect different regions, labor segments, and income groups within Brazil's uniquely unequal spatial landscape.

[redacted]Method

Multi-Scale Framework

This study employs an integrated multi-scale computable general equilibrium (CGE) framework that combines the GTAP model with the TERM model for Brazil. This technical integration, implemented through a hard-linking strategy, allows for a consistent transmission of trade shocks between global and regional economic systems. Figure 1 provides a schematic representation of the integrated GTAP–TERM framework, highlighting the main trade and labor market transmission channels linking the global model to the Brazilian regional model. The framework is particularly well-suited for assessing how international policy changes, such as shifts in U.S. tariff schedules, affect spatially heterogeneous economies like Brazil.

The global component is calibrated using the GTAP 12 Data Base, with 2023 as the reference year (Aguiar et al. 2025). This is particularly relevant for the present analysis, as it allows the simulations to reflect a recent configuration of world trade patterns and policies, bilateral linkages, and sectoral specialization, thereby improving the consistency of the counterfactual experiments with the contemporary trade policy environment examined in this paper. The GTAP model provides a global macroeconomic perspective, simulating bilateral trade flows, production, and consumption across 21 aggregated global regions and 25 tradable sectors (Tables A.1 and A.2). It adopts Armington-style imperfect substitution between domestic and imported goods, with elasticities varying by commodity. Consumption follows a non-homothetic Constant Difference Elasticity (CDE) specification, which captures differential marginal propensities to consume across household income levels. In the GTAP-TERM linked system, capital income in Brazil is pooled nationally and redistributed across subregions, while labor income is retained locally. For other global regions, households retain both capital and labor income generated domestically (Corong et al. 2017; Aguiar et al. 2025).

TERM disaggregates the Brazilian economy into 5,570 microregions and 30 sectors. The model features nested CES production technologies and inter-regional trade flows, capturing detailed sectoral and spatial interdependencies. At the regional level, aggregate employment is defined as the wage-weighted aggregation of sectoral labor demand, so that changes in regional employment reflect changes in sectoral activity and labor demand across industries.

On the labor market side, a CET-based occupational transformation mechanism allows workers of a given skill group to reallocate across occupations in response to changes in relative nominal wages. The composition of labor supply by skill is exogenous within each subregion, that is, the share of each skill in total regional labor supply is fixed, although total regional labor supply is not fixed in absolute terms. Reallocation within skill groups across occupations is endogenous and governed by nominal wage differentials. Thus, aggregate regional employment is determined by labor demand, while the composition of labor supply within each region is fixed by skill. With regional real wages held fixed, labor market adjustment operates through endogenous nominal wage changes, occupational reallocation within skill groups, and endogenous changes in the occupational skill mix of labor demand across regions and sectors.

In the database underlying the present simulations, skill categories correspond to educational attainment levels (incomplete high school, complete high school, bachelor's degree, and graduate degree), while occupational categories comprise Office, Services, Technical and Professional, and Unskilled activities. Each occupational category is split into formal and informal labor segments, capturing institutional differences in employment arrangements. Employment and demographic data are disaggregated by income decile, educational attainment, and employment formality, enabling the assessment of heterogeneous welfare impacts (M. Horridge 2012).

The integration between GTAP and TERM follows the general strategy proposed by Horridge and Ferreira-Filho (2003), adapted here to link a global model to a spatially explicit regional CGE model. In this iterative configuration, external shocks to Brazilian export quantities and import prices projected by GTAP, such as those induced by changes in U.S. tariffs, are passed to TERM as exogenous changes in trade conditions. TERM then simulates the resulting domestic adjustments in prices, output, labor demand, and household income. Revised estimates of Brazil's import demand quantities and export supply prices are then fed back into GTAP. The iterative loop continues until convergence, ensuring that global and regional adjustments are fully reconciled.

Transmission Channels

Building on the integrated structure illustrated in Figure 1, this section describes the primary mechanisms through which tariff-induced trade shocks propagate across the Brazilian economy within the integrated Global-Regional framework. These channels operationalize the conceptual links between international trade disruptions and regional socio-economic outcomes, as outlined in the previous section.

In this study, policy interventions enter the model as exogenous increases in the import tariffs, calculated as ad-valorem equivalent, on affected commodities. In the global model (GTAP), such changes alter relative prices across global sectors and trade partners, triggering adjustments in bilateral trade flows, sectoral competitiveness, and production patterns at the global level.

In the integrated framework, GTAP solves for the effects of these tariff shocks on Brazil's external environment, particularly changes in external demand for Brazilian products and in the prices of imported goods faced by Brazil. These changes are then transmitted to the Brazilian regional model, TERM, as exogenous shifts in export demand and import prices. In the regional model, these shocks affect production costs, sectoral competitiveness, output, labor demand, household income, and domestic absorption across Brazilian regions. TERM then returns updated changes in Brazil's aggregate import demand and export supply prices to GTAP, allowing the next global iteration to reconcile domestic regional adjustment with the external equilibrium. This hard linked architecture ensures consistency between global and subnational outcomes and captures feedback effects that propagate through trade linkages and global value chains.

This transmission operates through the following channels. The regional component receives updated import prices and sectoral export demand shifts, which reflect changes in Brazil's terms of trade and bilateral trade flows. These changes in import prices affect the cost structure of domestic production, especially in sectors reliant on foreign intermediate inputs, thereby influencing regional price levels and sectoral competitiveness across Brazil. The resulting changes in external demand and input costs induce internal reallocation processes. Sectoral output adjusts in response to changes in export demand, with more trade-exposed sectors (e.g., soybeans, beef, sugar) experiencing contraction or stagnation in the face of diminished international competitiveness. These sectoral adjustments cascade into the labor market, where demand for labor changes according to sectoral contraction or expansion, mediated by wage differentials and occupational mobility constraints.

The labor module captures the endogenous reallocation of workers within skill categories, based on relative wage changes across occupations and regions. Importantly, this reallocation mechanism also distinguishes between formal and informal labor market segments. Trade-exposed sectors with limited absorptive capacity or structural rigidity often shed formal jobs, contributing to an expansion of informal employment, particularly in lower-income or structurally vulnerable regions.

The households in the TERM model are affected by these labor market dynamics through changes in wage income, employment structure, and price-indexed consumption. Household demand is modeled using a

Linear Expenditure System (LES), which incorporates a subsistence consumption component. Under this specification, a portion of expenditure is committed to minimum consumption levels before discretionary spending adjusts to relative price changes. This structure is particularly important for the present analysis, as it allows the model to capture heterogeneous consumption patterns across income deciles. Lower-income households allocate a larger share of their budgets to essential goods and therefore have more limited substitution possibilities when relative prices change. As a result, trade-induced shifts in food and import prices translate into differentiated real income effects, amplifying the distributional consequences of external trade shocks across Brazilian regions.

In a subsequent stage of the iterative process, the regional model returns updated estimates of Brazil's import demand quantities and export supply prices to the global model. This feedback ensures that the new domestic conditions, including shifts in demand for foreign goods and the altered competitiveness of Brazilian exports, are reflected in the global equilibrium. The hard-linking architecture of the framework guarantees convergence across scales and captures feedback effects along global value chains and is particularly relevant for understanding the spatially uneven and interdependent nature of trade shocks in complex, regionally diverse economies such as Brazil.

Simulation Design and Scenario Structure

This study simulates two illustrative trade-policy scenarios aimed at uncovering how protectionist measures targeting trade flows between Brazil and the United States, and between the United States and BRICS countries, generate uneven economic consequences across Brazil's regions and social groups. These scenarios do not attempt to predict future policy outcomes but instead serve as empirical lenses through which to examine the structural transmission of trade shocks within a complex and spatially heterogeneous economy. The decomposition of the shocks is also analytically important because the welfare and competitiveness implications of "joining" a trade war may differ sharply from those of non retaliation or third market reorientation, particularly for developing economies exposed to trade diversion effects (Devarajan et al. 2021; Bouët and Laborde 2018).

Scenario 1 (Bilateral Retaliation: Brazil–U.S.) simulates a symmetric escalation of import tariffs between Brazil and the United States, in which both countries impose a uniform 50% tariff on all bilateral imports. The decomposition of this scenario into unilateral shocks allows for the identification of policy effects in each direction of the bilateral trade relationship, highlighting how inward and outward trade barriers trigger different regional adjustment mechanisms.

Scenario 2 (Multilateral Confrontation: U.S.–BRICS) broadens the scope to a conflict between global powers, in which the United States imposes a 100% tariff (brics_100) on all imports from the BRICS countries (Brazil, Russia, India, China, and South Africa), reflecting a hypothetical decoupling motivated by geopolitical tensions and the rise of alternative currency blocs, and BRICS countries retaliate with proportional increase in tariffs on all U.S. goods and services. The scenario is decomposed into effects of U.S. tariffs (brics_100), retaliation by Brazil (reta_brazil2) and retaliation by the other BRICS members (reta_brics), allowing for an isolated assessment of Brazil's strategic responses relative to its geopolitical peers.

These scenarios are summarized in Table 1, embedded within the GTAP–TERM framework to capture their full macro-to-micro implications, ranging from international trade disruptions to localized labor market and welfare effects. The simulation design enables a rigorous analysis of escalation of trade tensions, and their differentiated effects across Brazil's sectors, subregions, and demographic groups.

Scenario	Component	Description	Tariff Target	Sectors	Tariff (%)
1	usa_50	U.S. all-sector tariffs	U.S. → Brazil	All	50
	reta_brazil1	Brazil retaliates	Brazil → U.S.	All	50
2	brics_100	U.S. targets BRICS	U.S. → BRICS	All	100
	reta_brazil2	Brazil retaliates U.S.	Brazil → U.S.	All	100
	reta_brics	Other BRICS retaliate U.S.	BRICS → U.S.	All	100

Source: Authors' elaboration.

Table 1: Structure of Simulated U.S. and Retaliation Tariffs Scenarios

The simulations adopt a comparative static closure designed to identify structural transmission mechanisms rather than dynamic adjustment paths. Under this specification, the regional composition of labor supply by skill is fixed within each Brazilian subregion. Thus, the share of each skill group in total regional labor supply does not change in response to the simulated shock, even though total regional employment may vary. Adjustment therefore does not occur through changes in relative skill composition within each subregion.

However, given this region-specific skill composition, workers are reallocated across sector/occupation destinations according to a CET transformation frontier. Occupational and sectoral labor allocation therefore responds endogenously to relative nominal wage deviations across sectoral and occupational uses of labor, allowing workers within a given skill group to move toward sector/occupation combinations offering relatively higher nominal returns. In this setup, labor mobility is permitted across sectors and occupations within each subregion/skill group, but not across skill categories or across Brazilian subregions.

For Brazil, gross investment is endogenous in both scenarios, allowing investment to adjust in response to the macroeconomic effects of the simulated trade shocks and the associated external balance conditions.

In the model, investment is treated as a component of final demand associated with the creation of new capital goods, which are assembled from domestic and imported intermediates through a CES structure, so that the composition of investment responds to the relative prices of domestic and imported inputs. Because government expenditure, technology and demographics are frozen at benchmark values, the results capture short- to medium-run deviations rather than long-run equilibria. The closure therefore isolates the structural incidence of the tariff measures, working through employment, output and relative prices, without conflating them with longer-term accumulation dynamics.

[redacted] Results

Impacts on Employment and Labor Market Composition

The simulated trade scenarios reveal pronounced heterogeneity in labor market responses in Brazil, distinctly shaped by educational attainment, occupation category, and employment formality. Two components of Scenario 1, the additional 50% U.S. tariff on imports from Brazil and retaliation by Brazil, result in labor market contraction, with retaliation by Brazil leading to larger negative impacts on employment (Figure 2). The combined reductions in demand for workers amount to about 1.67 million workers (1.8% of total Brazilian employment) and are widespread across nearly all occupation categories, highlighting significant vulnerability to trade shocks. Workers with a lower level of education, particularly those with incomplete high school education, experience substantial reductions in both formal and informal employment, notably in the technical and professional (TechPro) occupations, where informal employment sharply declines by approximately 128,000 jobs. Unskilled occupation workers similarly face severe job losses (around 101,000 informal and 67,000 formal positions), underscoring their susceptibility to economic disruptions stemming from global value chain (GVC) integration.

Highly educated groups, specifically college graduates and holders of graduate degrees, encounter notable absolute reductions in formal office employment (approximately 84,000 and 156,000 jobs, respectively), suggesting the pronounced impact of trade disturbances on occupations closely linked to internationally competitive sectors. Employment losses in services are uneven across education groups. They are comparatively smaller among graduate workers, but substantial among workers without university education and also among Bachelor-level workers, particularly in informal service occupations, thereby reinforcing employment precarity and socioeconomic vulnerability. This outcome reflects the critical role of informal labor markets as secondary adjustment channels, yet with limited capacity to absorb significant external shocks fully, underscoring labor market segmentation and rigidity as structural constraints on adjustment processes (Maloney 1999; Fields 2011).

In Scenario 2 (the U.S. imposes a 100% tariff on BRICS countries, followed by retaliatory measures by Brazil and other BRICS members, figure 3), the labor market exhibits similar structural vulnerabilities but with notable adjustments resulting from broader geopolitical dynamics. The initial U.S. tariffs again trigger extensive contractions across education and occupation categories. However, retaliatory measures by the other BRICS members against the United States expand trade within the bloc and generate modest cushioning effects in the Brazilian labor market, partially mitigating losses in selected low-skilled and informal occupations. Overall, the combined effects of the tariff escalation and retaliatory measures result in a contraction of approximately 1.77 million workers (1.9% of total Brazilian employment).

Despite these mitigative effects, significant contractions persist, particularly among formally employed workers with higher educational levels. Graduate-level office employment contracts by approximately 168,000 positions, underscoring the heightened exposure of skilled labor integrated into global value chains. Additionally, informal TechPro employment benefits from the retaliatory response of the other BRICS members, recovering approximately 40,000 positions in aggregate, but still recording a severe total loss of about 259,000 jobs.

Unskilled workers are notably affected, with combined informal and formal employment losses reaching approximately 600,000 jobs. However, these workers benefit slightly from employment recovery resulting from BRICS' retaliatory actions (approximately 37,000 recovered positions across various informal occupations). Nonetheless, these informal employment recoveries occur primarily in low-productivity activities, raising concerns over long-term implications for employment quality and socioeconomic equity.

The comparative analysis of both scenarios highlights critical structural mechanisms operationalized in the GTAP-TERM framework, where tariff-induced changes in relative prices prompt labor reallocation toward lower productivity, domestically oriented activities. Such reallocations affect both highly educated formal workers in trade-exposed occupations and lower-skilled workers concentrated in more vulnerable segments of the labor market, intensifying employment precarity and reinforcing spatial and skill-based inequalities. The employment shifts observed across these scenarios underscore the limited effectiveness of retaliatory trade measures in safeguarding labor markets against significant external shocks, emphasizing the need for targeted policy interventions addressing labor market rigidity, regional economic specialization, and structural vulnerability within global value chains.

Effects on Household Income Distribution

Scenario 1 results in a predominantly regressive distributional impact (Figure 4). U.S. tariffs significantly reduce nominal wages across all household income deciles, with greater declines observed in higher-income groups (-3.31% for the lowest decile versus -3.46% for the highest decile). Although consumer prices fall across all income deciles (-2.50% for the lowest decile and -2.70% for the highest decile), the larger nominal wage losses among higher-income households drive slightly larger real consumption reductions at the top end of the distribution (-0.92% at the highest decile versus -0.80% at the lowest).

This reflects a progressive impact due to the disproportionate nominal wage erosion affecting households more reliant on sectors integrated into international trade.

Brazil's retaliatory tariffs, in contrast, have a distinctly regressive distributional effect. Nominal wages increase progressively more for higher-income households (from 0.97% in the lowest decile up to 1.59% in the highest decile). However, retaliatory tariffs lead to a relatively uniform increase in consumer prices, from 1.76% to 1.87%. These price increases disproportionately harm lower-income households, whose consumption patterns are more sensitive to price changes in essential goods. Consequently, real consumption falls more for lower-income groups (-0.78% at the lowest decile) compared to relatively smaller losses at the top (-0.28% at the highest decile).

The combined effects ("Total") for Scenario 1 further reinforce a regressive pattern overall. Although nominal wages decline more significantly for lower-income households (-2.34% for the lowest decile versus -1.87% for the highest), the simultaneous consumer price reductions are smaller for lower deciles (-0.75% lowest decile compared to -0.83% highest). This results in greater real consumption losses among lower-income households (-1.58% at the lowest decile versus -1.09% at the highest).

In Scenario 2, the initial U.S. tariff again results in a progressive distributional effect (Figure 5). Higher-income households experience more substantial nominal wage reductions (-3.46% for the lowest decile compared to -3.58% for the highest decile). Despite significant consumer price decreases across deciles (from -2.62% lowest decile to -2.81% highest decile), the larger wage losses at the higher end result in relatively greater real consumption declines among upper-income groups (-0.83% highest decile versus -0.81% lowest).

Brazilian retaliatory tariffs within Scenario 2 demonstrate a regressive distributional impact. Although nominal wage increases are significant (ranging from 1.23% lowest decile to 1.96% highest decile), these gains disproportionately favor higher-income households. Additionally, inflationary pressures (consumer price increases ranging from 2.14% to 2.29%) disproportionately harm lower-income households, translating into larger real consumption reductions at lower-income levels (-0.90% lowest decile compared to -0.33% highest decile).

Retaliatory tariffs by other BRICS nations generate a small positive spillover effect on Brazilian households. Nominal wages rise modestly (from 1.30% to 1.09% across deciles), with relatively uniform consumer price increases approximately 0.9%. This indirectly improves real consumption across all deciles, ranging from 0.38% to 0.22%, demonstrating modest uniform welfare improvements from this external intervention.

Considering all three components of the Scenario 2 together, nominal wages decline across all household income deciles, from -0.93% in the lowest decile to -0.53% in the highest, while consumer prices increase from 0.45% to 0.34%. Real consumption therefore falls throughout the distribution, with larger losses among lower- and middle-income households, ranging from -1.35% in the lowest decile to around -1.51% in the second decile, before moderating to -0.92% in the highest decile. This pattern indicates that higher-income households are better positioned to absorb the inflationary and wage effects associated with the combined shock.

The distributional outcomes observed in the simulations are closely linked to structural features of household demand under trade shocks. Lower-income households devote a larger share of their budget to essential goods and therefore have more limited scope for substitution when relative prices change. As a result, consumer price increases under retaliatory tariff scenarios translate more directly into welfare losses, especially when combined with declining or weak wage growth. By contrast, higher-income households benefit from more diversified income sources and greater flexibility in consumption adjustment. These structural asymmetries help explain why trade disruptions tend to reinforce existing inequalities in real consumption.

Regional Impacts on GDP and HH consumption

The simulated results illustrate considerable regional heterogeneity in response to trade policy shocks in both scenarios. In Scenario 1 (Figure 6), comprising the unilateral U.S. tariff and Brazil's retaliatory tariff, real GDP contractions are widespread across Brazilian regions, with pronounced adverse effects concentrated particularly in states within the North and Northeast regions. Under the unilateral U.S. tariff shock, states such as Amazonas (AM), Ceará (CE), Maranhão (MA), and Roraima (RR) experience substantial GDP losses, regularly surpassing -0.75%, indicating heightened vulnerability to disruptions in trade with the United States. Conversely, southern states, characterized by greater industrial diversification, exhibit relatively smaller GDP impacts, with certain subregions registering negligible effects or slight positive adjustments.

The introduction of Brazilian retaliatory tariffs reinforces these spatial disparities. However, the pattern of regional impacts shifts notably, as regions previously less affected, particularly in the South, Southeast, and Center-West, experience intensified economic contraction. Notably, Minas Gerais (MG), Espírito Santo (ES), Goiás (GO), and São Paulo (SP) record pronounced GDP declines often exceeding 1%, reflecting higher exposure to intermediate import disruptions from the United States. States in the North and Northeast remain significantly impacted, with some GDP gains in Amazonas contrasted with losses in Pará (PA) reflecting persistent vulnerability linked to primary commodity dependence and limited sectoral flexibility.

Scenario 2 (Figure 7), representing a broader trade conflict with retaliatory measures from Brazil and other BRICS countries, also highlights distinct regional adjustment patterns. The initial U.S. tariff inflicts a pronounced negative impact on northern and northeastern states, especially Amazonas (AM), Ceará (CE), and Maranhão (MA) where GDP reductions reach up to 2%. The Southeast and South exhibit relatively moderate contractions.

Brazil's retaliatory tariffs in Scenario 2 intensify adverse regional effects, particularly affecting states such as Mato Grosso do Sul (MS), Mato Grosso (MT), and Pará (PA), with GDP declines frequently surpassing 1%. However, the retaliatory measures enacted by other BRICS members generate positive outcomes for many regions. Significant gains emerge in states such as Mato Grosso (MT), Maranhão (MA), Piauí (PI), and selected areas within Goiás (GO), where real GDP and household consumption notably improve. The Center-West region, benefitting from trade diversion and enhanced competitiveness in alternative markets, display notable economic resilience.

Despite partial offsetting effects from BRICS-related trade diversion, the total impact of Scenario 2 is negative for most Brazilian states and is characterized by strong spatial asymmetries. These asymmetries disproportionately affect not only poorer states in the North and Northeast, but also several industrial and import-dependent areas in the Southeast and South. The regional patterns therefore reflect multiple transmission channels, including commodity dependence, exposure to imported intermediates, labor market rigidities, and heterogeneous household consumption structures. Taken together, these results reinforce the need for targeted regional and social policies capable of addressing both peripheral vulnerability and the adjustment costs borne by more industrialized regions.

Macroeconomic drivers

Detailed decomposition of GDP[4] elucidates key transmission channels underpinning regional responses to economic shocks. Under Scenario 1 (Figure 8), the imposition of a 50% tariff by the U.S. significantly

[4] For each Brazilian state, GDP is defined as the sum of Private Consumption, Investment, Government Consumption, and net exports, where net exports comprise both international trade and interregional trade. Formally, GDP = C + I + G + (International Exports − International Imports) + (Interregional Exports − Interregional Imports). All components are measured at the state

reduces household consumption, particularly in the North and Northeast regions, with larger negative contributions concentrated in Amazonas (AM), Bahia (BA), Ceará (CE), Maranhão (MA). These results indicate that the contraction is transmitted not only through export exposure, but also through its effects on domestic demand. Investment also declines in all states, although with smaller contributions than household consumption, with relatively stronger negative effects in Amazonas (AM), Espírito Santo (ES), Minas Gerais (MG), São Paulo (SP), and several northeastern states. Amazonas (AM), Ceará (CE), and Roraima (RR) experience pronounced GDP declines, with contractions surpassing 0.75%. This highlights regional vulnerability stemming from heavy reliance on export-oriented agricultural commodities, shipped to other Brazilian states (e,g, from AM and RR) and internationally (from CE), and associated income dependencies.

Brazil's retaliatory tariffs shifts the contractionary burden more clearly toward the South, Southeast, and Center-West. In the decomposition, the strongest negative contributions come from household consumption and from the decline in both international and regional exports, while international and regional imports contribute positively to GDP in most states because they enter the decomposition with a negative sign and contract under the shock. The deterioration in international exports is particularly relevant in the Southeast and South, especially in São Paulo (SP), Rio de Janeiro (RJ), Espírito Santo (ES), Paraná (PR), Rio Grande do Sul (RS), and Santa Catarina (SC). At the same time, northern states remain

level. International exports and imports represent trade between the state and foreign countries, whereas interregional exports and imports capture trade flows between Brazilian states. It is important to note that Figures 7 and 8 report signed contributions of each GDP component to percentage changes in state GDP, rather than simple percentage changes in the underlying monetary flows.

adversely affected, showing that the propagation of the retaliatory shock is not confined to industrialized regions, but also interacts with preexisting structural vulnerabilities in peripheral economies.

In Scenario 2 (Figure 9), regional adjustments again display marked spatial heterogeneity, shaped by the interaction between the U.S. tariff shock on BRICS, Brazil’s retaliation, and the response of the other BRICS members. The initial U.S. imposition of 100% tariffs on BRICS substantially reduces household consumption in the North and Northeast, with stronger negative contributions in Maranhão (MA, 1.04), Ceará (CE, 0.93), Bahia (BA, 0.91). Brazil’s retaliatory tariffs reinforce these losses, adding further downward pressure in parts of the South, Southeast, and Center-West.

However, retaliation measures by other BRICS nations create mitigating effects for several regions, notably in the Center-West. Mato Grosso (MT), Goiás (GO), and Mato Grosso do Sul (MS) benefits from positive contributions to household consumption, driven by international exports reorientation. In a few cases, such as Mato Grosso (MT) and Piauí (PI), the contribution of international exports also turns positive, partially offsetting the contractionary effects of the U.S. and Brazilian tariff shocks. Even so, these favorable effects remain localized and are insufficient to reverse the broader negative pattern across most states.

Overall, the differentiated impacts across regions in both scenarios highlight the structural channels through which global trade shocks propagate domestically, particularly emphasizing the role of household consumption dynamics, regional export specialization, labor market segmentation, and GVC integration. Household consumption is the most pervasive contractionary channel, investment amplifies the downturn in most states, and trade components transmit shocks through both international and interregional linkages. These mechanisms, deeply embedded in Brazil’s spatially uneven economic structure, underline the necessity of nuanced policy interventions designed to address underlying regional vulnerabilities (Rodríguez-Pose 2012; Haddad and Hewings 2001; Williamson 1965).

At the national aggregate level, the imposition of 50% reciprocal tariffs between Brazil and the U.S. in Scenario 1 produces broad-based contractionary effects across key macroeconomic aggregates, transmitted primarily through external trade and domestic demand channels. As shown in Table 1, household consumption and exports decline by 1.36% and 7.50%, respectively, while investment falls by 1.63%. In contribution terms, household consumption and exports reduce GDP by 0.87 and 0.96 percentage points, respectively, yielding a total GDP contraction of 1.15%. Scenario 2 is slightly more severe at the aggregate level, with GDP declining by 1.19% (Table 2), driven by a 9.01% contraction in exports and a 1.23% fall in household consumption, while investment declines by 1.44%. Their respective contributions to GDP are -1.15 percentage points for exports and -0.79 percentage points for household consumption. In both scenarios, imports also contract sharply, contributing positively to GDP in the expenditure decomposition as import compression offsets part of the external shock. These results reflect the dual role of the United States as both a key destination for Brazilian exports and a supplier of intermediate inputs relevant for domestic production.

Sectoral drivers

The sectoral results for Scenario 1 in Table 3 highlight the uneven structure of this contraction. Manufacturing sectors integrated into global value chains (GVCs), including ferrous metals (-9.69%), motor vehicles (-4.14%), and rest of manufacturing (-1.88%), record severe output declines, reflecting direct exposure to U.S. trade barriers. Export-oriented agriculture such as coffee (-1.23%) and bioethanol (-1.43%) also experience marked reductions, reinforcing the conceptual literature linking GVC exposure to trade-induced vulnerability (Baldwin 2016; Grossman and Rossi-Hansberg 2008; Grossman et al. 2024). At the same time, the contraction is not uniform across agriculture, since some activities, such as rest of agriculture[5], orange, and livestock, display positive output responses despite weaker demand components. Industrial imports fall across nearly all subsectors, consistent with reduced absorption capacity and substitution effects triggered by tariff distortions.

Services, particularly rest of services[6] and construction, account for the largest negative contributions to domestic absorption in Scenario 1 (Table 4). Rest of services contributes 0.58 percentage points to the fall in household consumption, while construction contributes 0.86 percentage points to the decline in investment. Financial and business services also reinforce the contraction, especially through consumption and import channels. These patterns resonate with the findings of Hertel et al. (2004, 2014) regarding the role of domestic non-tradables in mediating trade shocks via consumption effects. Despite price declines in some sectors (e.g., coffee, orange and services), these adjustments are generally insufficient to stabilize household welfare.

The sectoral results for Scenario 2 (Table 5) underscore the importance of retaliation dynamics. Soybeans emerge as the clear beneficiary of BRICS retaliation, recording a 3.62% increase in output and an 8.41% surge in exports. This reflects trade diversion and improved market access in non-U.S. markets, particularly China, validating empirical expectations regarding GVC restructuring under trade fragmentation (Grossman et al. 2024). However, these gains are insufficient to compensate for widespread

[5] Rest of agriculture comprises sugar cane and sugar beet, crops nec and related services, permanent crops nec, forestry, and fishing; the full sectoral concordance is reported in Tables A.2 and A.3 of the Appendix.

[6] Rest of services comprises trade, transport, accommodation and food services, information and communication, real estate, public administration and defense, education, health and other service activities; the full sectoral concordance is reported in Tables A.2 and A.3 of the Appendix.

losses across industrial sectors, where petroleum (-25.46%), chemicals (-19.11%), and machinery (-24.96%) experience severe export contractions.

Consistent with the literature on sectoral vulnerability and GVC dependence, services continue to transmit macroeconomic shocks through reductions in household consumption and investment channels in Scenario 2 (Table 6) (Rodríguez-Pose 2012; Melitz 2003). Rest of services contributes -0.53 percentage points to the contraction in household consumption, while construction contributes 0.75 percentage points to the decline in investment. While some regional gains emerge, particularly in the Center-West due to soybean expansion, the contractionary effect on formal industrial employment and demand outweighs these localized improvements.

The sectoral decomposition of macro components confirms this dynamic (Tables 5–6). Services (Rest of services and Financial/Business services) contribute most to the fall in consumption and exports. Industrial sectors drive the decline in investment and trade, particularly machinery and electronics, which face sharp reductions in both exports and imports. These results reaffirm Brazil’s structural vulnerability, combining weak domestic demand transmission through non tradables with the strong exposure of industrial competitiveness to external shocks. Under intensified tariff conflicts, international trade channels become even more relevant, and their effects spread domestically through interregional trade linkages, while remaining closely intertwined with domestic absorption effects.

Global Chain Drivers

Figures 10 to 13 provide a nuanced portrayal of how recent U.S.–Brazil trade policy shocks propagate through sectoral and bilateral channels, significantly reshaping Brazil's external sector dynamics. The simulations underscore substantial sector-specific and spatially differentiated impacts, consistent with Brazil's established integration into global value chains (GVCs), especially through commodity exports to China and manufactured imports from the United States.

Scenario 1 underscores the vulnerability of Brazilian industry and agriculture to bilateral tariff escalations with the United States. As shown in Figure 10, the 50% U.S. tariff increase strongly affects Brazilian metallurgy and transport equipment, with particularly large output reductions in metallurgy and sizable losses in transport equipment, reflecting their integration into U.S.-centered trade linkages. Brazil's retaliatory tariffs deepen these contractions in several industrial branches, further reducing output in metallurgy (3.07%), transport equipment (2.67%), machinery (1.63%), electrical equipment (1.93%), and chemicals (1.44%). Retaliation also intensifies losses in coffee grain (1.45%) and Orange (1.01%), This illustrates that domestic retaliatory measures can inflict greater damage on Brazil's economy than external barriers alone, reinforcing concerns from earlier research on the limited efficacy and high domestic costs of symmetric trade retaliation (Amiti et al. 2019; Grossman et al. 2024).

Interestingly, the bilateral decomposition of Scenario 1 (Figure 11) reveals intricate shifts within trade flows, notably through the redirection of trade from the United States towards China and, to a lesser extent, Europe and the Rest of Asia. A pronounced reduction in petroleum (0.53%) and manufactured goods (1.51%) exports to the U.S. contrasts with modest export gains of minerals and petroleum to China (+0.77%). These shifts reflect general equilibrium adjustments away from constrained markets, but they only partially offset the broader domestic losses, especially once Brazil's retaliation further weakens manufacturing and selected agri-food activities.

Scenario 2 (Figure 12 and 13) accentuates the magnitude of disruption under the more drastic U.S. tariffs targeting BRICS economies. Soybean exports emerge prominently as a compensatory channel, with Brazilian soybean exports surging substantially under the BRICS retaliatory scenario (+3.77%), reflecting China's increasing reliance on Brazilian commodities amid trade conflicts. Conversely, metallurgical sectors again endure severe contractions, reflecting their high exposure to U.S. markets and vulnerability to disruptions in trade linkages within GVCs. These findings confirm an observation from Baldwin (2016) that policy shocks propagate more intensely within production networks where GVC participation is concentrated, notably affecting sectors with less-diversified trade partners.

The retaliatory responses modeled in Scenario 2, particularly Brazil's unilateral retaliation, deepen sectoral losses in manufacturing, chemicals (1.81%), and transport equipment (3.19%), while failing to mitigate broader economic disruptions. These responses align with findings from Amiti et al. (2019) regarding the unintended domestic costs of protectionist trade policies, underscoring the limited protective efficacy of symmetrical retaliation. However, BRICS-wide retaliation demonstrates a differentiated outcome, particularly in agriculture, further supported by Arnold (2025).

Collectively, the scenarios reveal three salient patterns: (i) China's critical role as a stabilizing market for Brazil's commodity exports amidst U.S. trade barriers; (ii) the heightened vulnerability of manufacturing sectors reliant on U.S. markets; and (iii) the positive effects of trade diversion are spatially and sectorally specific, providing only partial compensation for the losses generated by tariff escalation. These insights align with regional economic vulnerability frameworks and illustrate how global policy shifts selectively amplify local inequalities through labor market segmentation and uneven regional development trajectories (Haddad and Hewings 2001; Ferraz et al. 2013).

The sectoral reallocations and bilateral trade realignments detailed in these scenarios emphasize the necessity of geographically targeted economic policies to address the resulting structural imbalances and mitigate the adverse distributional consequences highlighted throughout the literature (Porto 2006; Nicita 2009). Furthermore, they underscore the importance of considering global value chain linkages and regional heterogeneity in crafting robust, equitable trade policy interventions capable of balancing strategic sectoral adjustments with broader socio-economic stability.

[redacted]Discussion

This study quantifies the effects of recent and potential U.S. trade policy shocks on Brazil's regional economies, employment dynamics, and income distribution using a linked GTAP-TERM CGE framework. The findings underscore significant regional heterogeneity and highlight Brazil's agricultural sector, particularly soybeans, as pivotal in shaping economic vulnerability and resilience to international trade disruptions. These outcomes have substantial implications for regional stability and inequality, highlighting the need for policies attuned to Brazil's spatial economic disparities.

The results underscore the vulnerability of Brazilian industry and agriculture to bilateral tariff escalations with the United States. A tariff imposed by the U.S. notably affects Brazil's metallurgical and transportation equipment sectors, reflecting their deep integration into U.S.-centric value chains. However, Brazil's retaliatory tariffs considerably aggravate these contractions across various sectors, including metallurgy, transportation equipment, machinery, electrical equipment, and notably chemicals, sectors in which the retaliatory impacts clearly exceed initial U.S. tariff effects. Brazil's retaliation broadly undermines agricultural sectors by raising the cost of imported inputs, thereby reducing competitiveness and output, often more severely than the initial U.S. tariffs, as exemplified by coffee grain and other food manufacturing. Such findings underscore that domestic retaliatory policies can produce even more severe economic consequences than external protectionist measures, which is consistent with the broader argument that developing countries often face a strategic dilemma in trade wars, since retaliation may weaken domestic welfare even when it alters external bargaining conditions (Devarajan et al. 2021; Bouët and Laborde 2018).

Labor market outcomes observed in simulations align with theoretical predictions and empirical evidence emphasizing the disproportionate vulnerability of informal and lower-skilled workers to external shocks (Porto 2006; Maloney 1999; Ramachandran et al. 2026). Employment losses are unevenly spread across occupation, education, and formality categories, with particularly severe effects among unskilled and informal workers, although highly educated formal workers in office occupations are also strongly affected. Rather than functioning as an effective adjustment buffer, informal employment also contracts sharply in many segments, highlighting the segmented nature of Brazil's labor market and the structural rigidities that constrain adjustment processes. These results echo Ferreira-Filho and Horridge's (2012) findings, underlining structural risks trade shocks pose to vulnerable labor segments, especially in economies characterized by high informality and labor market rigidities.

The distributional analysis reaffirms literature documenting regressive impacts of trade-induced price shocks (Hertel et al. 2004; Nicita 2009). Lower-income households disproportionately bear the brunt of real income reductions, especially under broad-based tariff escalations. Detailed decile-level results underscore poorer households' heightened vulnerability due to consumption patterns more sensitive to essential goods price shocks, thus empirically validating theoretical assertions regarding regressive effects of trade policy disruptions.

Results emphasize soybeans' strategic role as a major channel of Brazil's aggregate trade adjustments, consistent with global value chain literature identifying risks associated with commodity specialization (Baldwin 2016; Grossman et al. 2024). Soybean exports critically bolster aggregate outcomes under retaliatory trade scenarios involving BRICS partners but simultaneously represent a key vulnerability under U.S.-initiated protectionism, since Brazil's external adjustment relies heavily on a concentrated commodity export whose performance depends on a limited set of foreign markets.. Given Brazil's commodity-dependent export structure, soybean trade thus significantly shapes the economy's resilience or susceptibility to external shocks.

The simulations further highlight China's centrality in Brazil's trade vulnerability and opportunities. Pronounced dependency on Chinese demand, particularly in soybean exports, underscores Brazil's deep integration into global value chains heavily influenced by China. This result aligns with literature noting that GVC integration facilitates growth but simultaneously increases exposure to external shocks (Grossman and Rossi-Hansberg 2008; Gereffi et al. 2005). Brazil's reliance on China echoes classical development theories of cumulative regional effects articulated by Myrdal and Sitohang (1957) and Hirschman (1958), where trade linkages can exacerbate regional disparities or stimulate regional growth poles. The significant Chinese influence observed in the simulations also resonates with Williamson (1965) insights into how concentrated trade interactions can heighten spatial inequality.

Our scenario analyses reflect historical experiences from past U.S.–Brazil trade disputes, particularly the impacts observed from prior U.S. steel tariffs (Grossman et al. 2024). Similar to past episodes, Brazil's strategic responses, including coordinated retaliation within BRICS, demonstrate potential for trade diversion and market realignment. This analysis extends previous studies by explicitly capturing differentiated subnational and sectoral responses, enriching historical and comparative perspectives.

By integrating the global GTAP framework with TERM's subnational granularity, this study advances regional trade impact assessments by revealing patterns of spatial, income, and labor market inequality that aggregate analyses often miss. This granularity enables more precise targeting of compensatory and adjustment policies, especially for lower-skilled and informally employed workers. The regionalized impacts further resonate with theoretical frameworks describing how concentrated trade linkages and commodity specialization exacerbate regional inequalities through cumulative causation mechanisms (Myrdal and Sitohang 1957; Williamson 1965; Haddad and Hewings 2001).

Subnational modeling, when decomposed by type of international trade shock, reveals not only the external vulnerability of Brazilian regions, but also the distinct ways in which they are exposed. The Center West stands out as highly dependent on Chinese demand for soybeans and is therefore relatively insulated from U.S. export tariffs. However, a possible Brazilian retaliation affects this region more directly by increasing the cost of imported inputs, thereby weakening its competitiveness in global markets and compromising its agricultural commodity exports. At the same time, the Center West is better positioned to benefit from a tariff conflict between the BRICS and the United States, as it can more easily redirect agricultural commodity exports toward BRICS markets, especially China. These results also speak to the recent literature on supply chain decoupling and retaliatory trade responses in developing countries, which shows that trade conflict can reallocate production and labor unevenly across sectors and social groups (Attinasi et al. 2025; Devarajan et al. 2021). Our findings extend this argument by showing that, in developing economies such as Brazil, these adjustment mechanisms acquire a strong subnational dimension because commodity specialization and reliance on imported inputs are unevenly distributed across subregions.

By contrast, several Brazilian regions are more severely affected by U.S. tariffs and the associated reduction in U.S. demand for manufacturing exports tied more closely to the U.S. market, while facing much greater difficulty in redirecting this lost demand toward BRICS partners. These asymmetries are reinforced by Brazil's pronounced socioeconomic inequality, which imposes an additional layer of vulnerability on less developed regions such as the North and Northeast, on lower-income households with limited scope to protect real consumption through substitution, and on lower-skilled and informally employed workers who have weaker access to social protection mechanisms.

The recent trade war literature has increasingly emphasized the importance of indirect propagation through production and trade linkages, and the soybean results provide a clear illustration of why such spillovers must be explicitly captured (Hayakawa et al. 2024; Mao and Görg 2020). Without incorporating both global trade shocks and subnational details, the model would fail to reveal how China's reallocation of soybean demand toward Brazil generates differentiated impacts across Brazilian regions. The significant growth in soybean exports to China, identified as a direct consequence of retaliatory trade shocks, has substantial and distinct implications for regions specialized in soybean production, such as Brazil's Center-

West, generating both economic opportunities and altering regional inequality dynamics. Absent this methodological integration, the nuanced regional adjustments and indirect distributional effects resulting from altered global trade flows would remain invisible, undermining the effectiveness of policy responses.

[redacted] Conclusion

This study examines the subnational economic impacts of recent and potential U.S. trade policy shocks on Brazil, emphasizing regional, sectoral, and distributional dimensions through a novel integration of the GTAP global and TERM subnational CGE modeling frameworks. The use of the GTAP 12 Data Base with a 2023 reference year strengthens the analysis by reflecting the recent structure of global trade linkages and Brazil's external integration through which U.S. trade policy shocks propagate. The main objective is to quantify how different Brazilian regions, employment groups, and household income levels respond heterogeneously to international trade disruptions and retaliatory measures, considering Brazil's prominent role in global value chains.

The results reveal substantial intra-national disparities in regional economic vulnerability, with especially severe GDP and household consumption losses in several states of the North and Northeast, but also in select industrialized areas of the Southeast and South. Labor market responses further highlight structural vulnerabilities: trade shocks affect both formal employment in high-skill export-dependent occupations and lower-skill workers concentrated in more vulnerable labor market segments. In many cases, informal employment also contracts sharply, indicating that it does not consistently operate as an effective adjustment buffer. Income distribution effects are notably regressive, underscoring heightened real consumption losses among lower-income households due to price pass-through and sectoral reallocation.

The findings reveal that Brazil's retaliatory tariffs often intensify domestic contractions triggered by the initial U.S. tariffs, particularly in manufacturing and input-dependent agricultural sectors. Sectoral analysis emphasizes agriculture, particularly soybean exports, as both a source of resilience and vulnerability. Soybeans act as a critical stabilizing factor under retaliatory trade scenarios, particularly through trade diversion toward China, yet they also expose regions heavily dependent on commodity exports to external demand fluctuations. This dual role underscores Brazil's structural commodity dependence within global value chains, particularly regarding China's market influence.

Methodologically, the integration of global and subnational modeling frameworks constitutes a significant advancement, capturing critical GVC spillovers and regional nuances typically obscured in aggregate national analyses. This granularity offers policy insights essential for designing targeted compensatory mechanisms and effective regional development strategies.

The policy implications are clear: trade adjustment and compensation policies must explicitly recognize regional and sectoral disparities to effectively mitigate inequalities. Additionally, strategies fostering diversification and enhanced resilience in vulnerable regions should prioritize reducing dependence on volatile external markets. Such strategies must be tailored to structural constraints in commodity-dependent and in regions with large number of informally employed workers, especially where labor markets and logistics networks limit adaptive capacity.

Future research should further refine this integrated modeling approach by evaluating longer-term sectoral adjustments, providing policymakers with deeper insights into the persistent impacts of trade disruptions and the effectiveness of policy responses.

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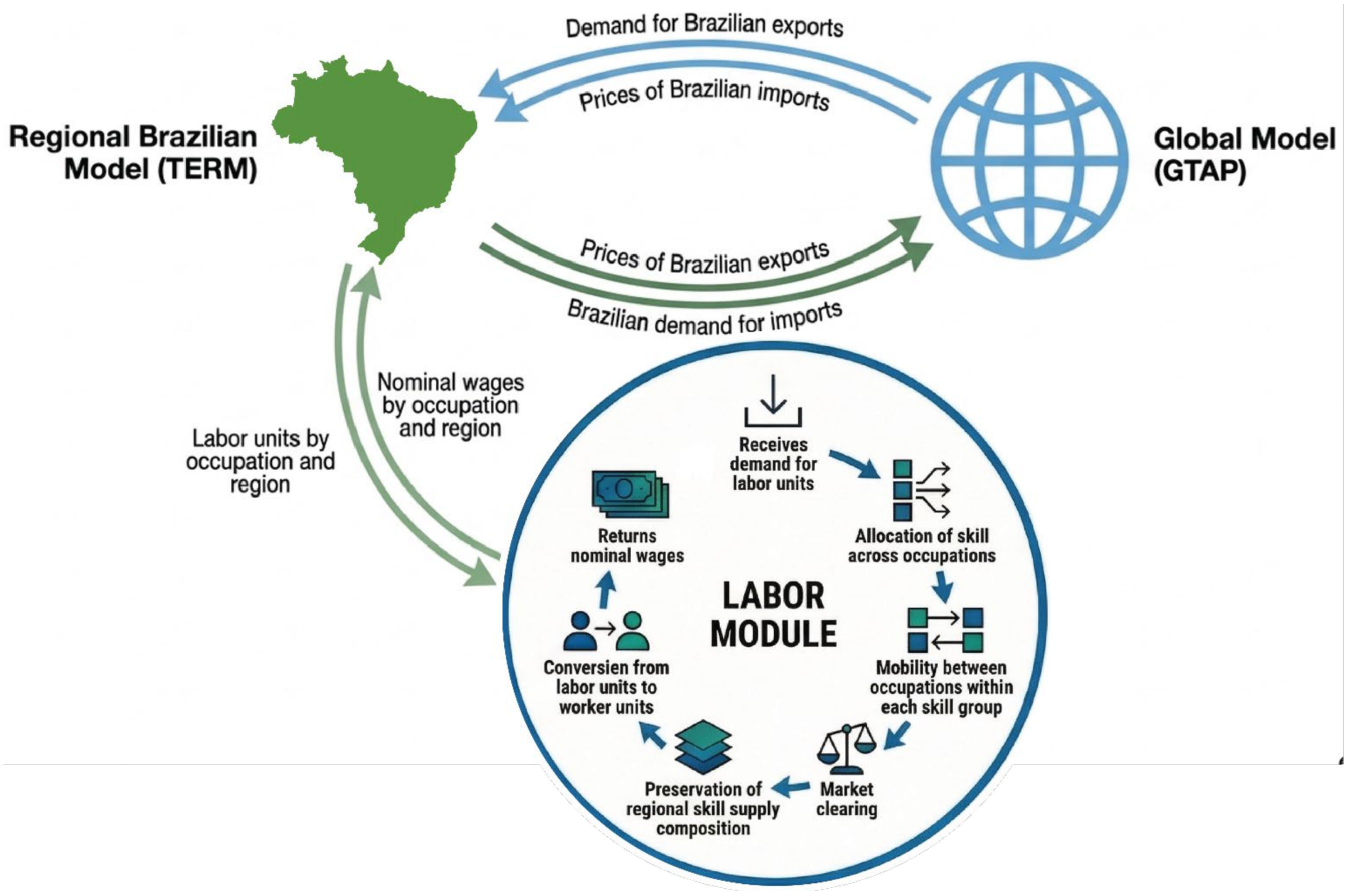

Figure 1: Transmission channels between the GTAP Global Model, the TERM Regional Model, and the Labor Market Module.

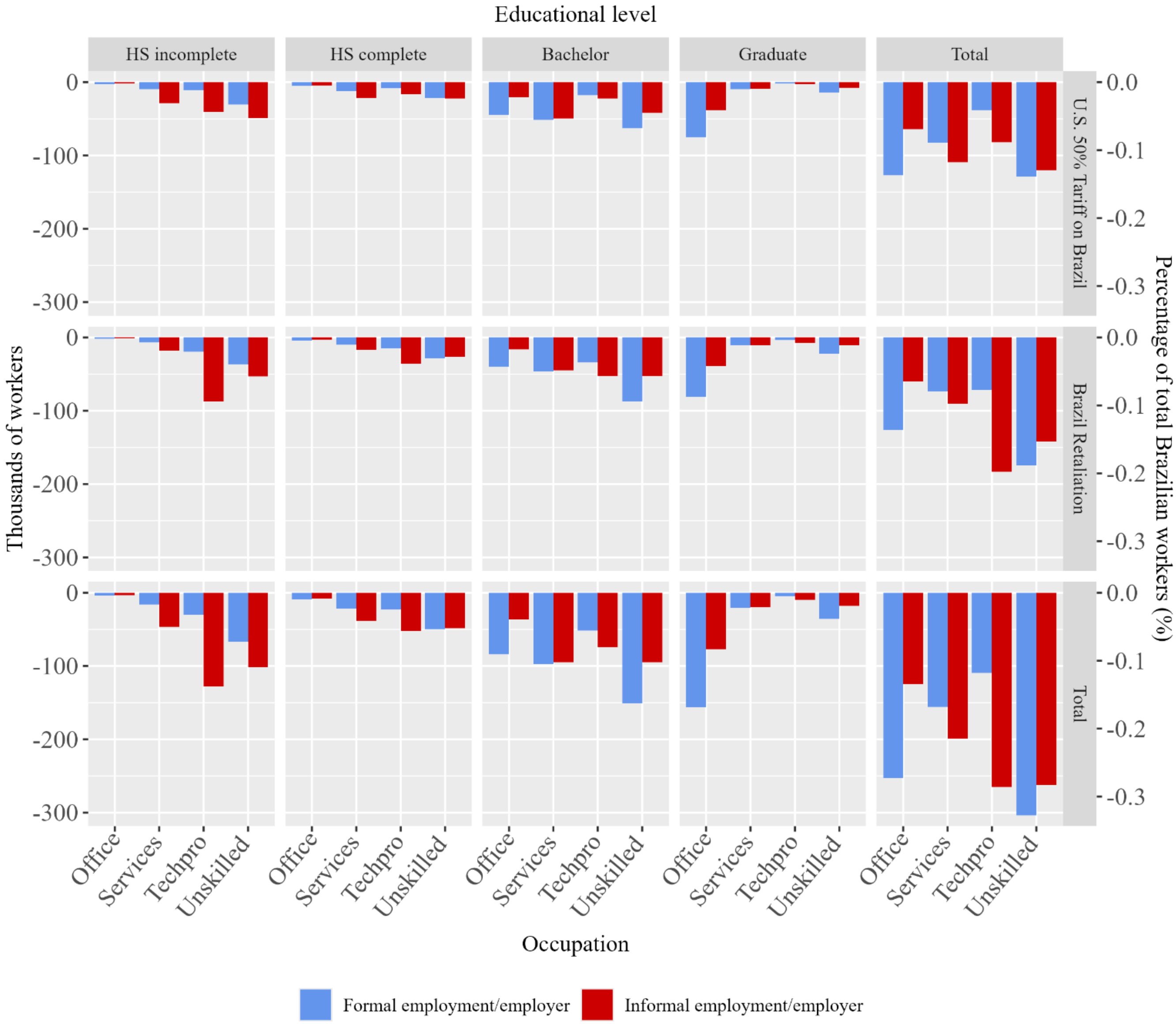

Figure 2 Impacts on the demand for workers by occupation category, educational level, and employment`s formality for Scenario 1 (thousands of workers).

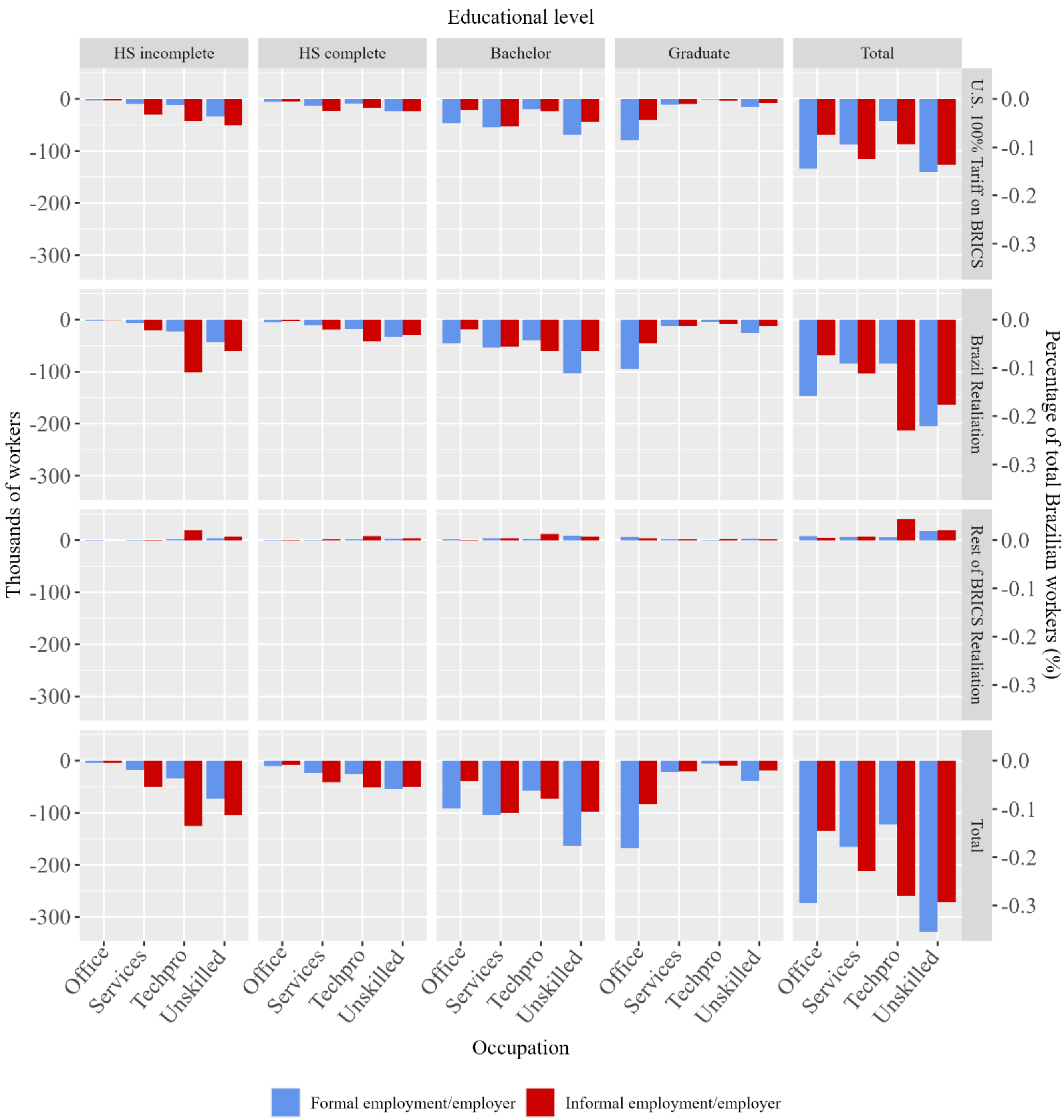

Figure 3 Impacts on the demand for workers by occupation category, educational level, and employment`s formality for Scenario 2 (thousands of workers).

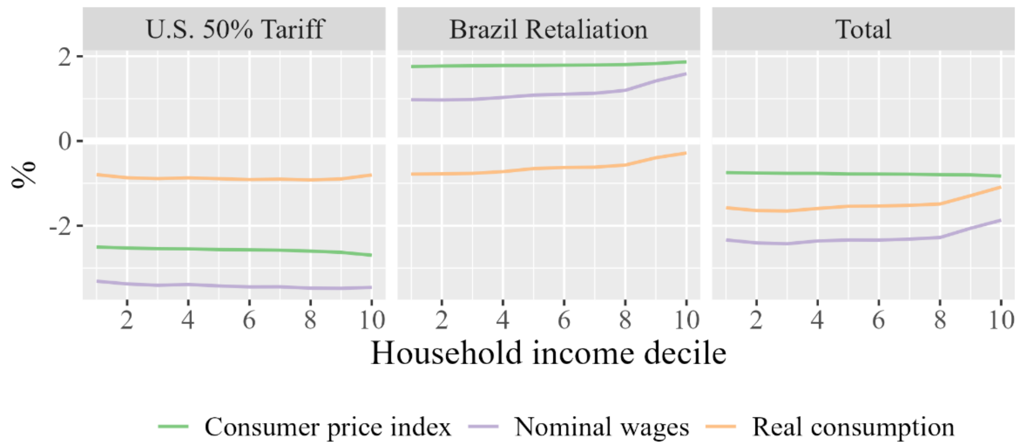

Figure 4: Impacts on the nominal wages, CPI and real consumption by household income decile in Scenario 1 (percentage changes).

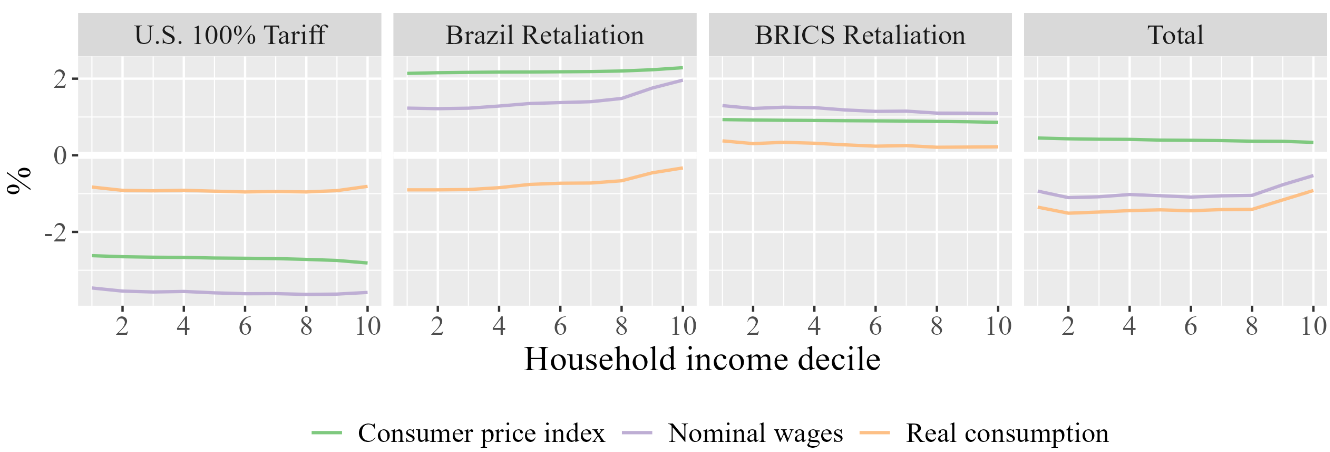

Figure 5: Impacts on the nominal wages, CPI and real consumption by household income decile in Scenario 2 (percentage changes).

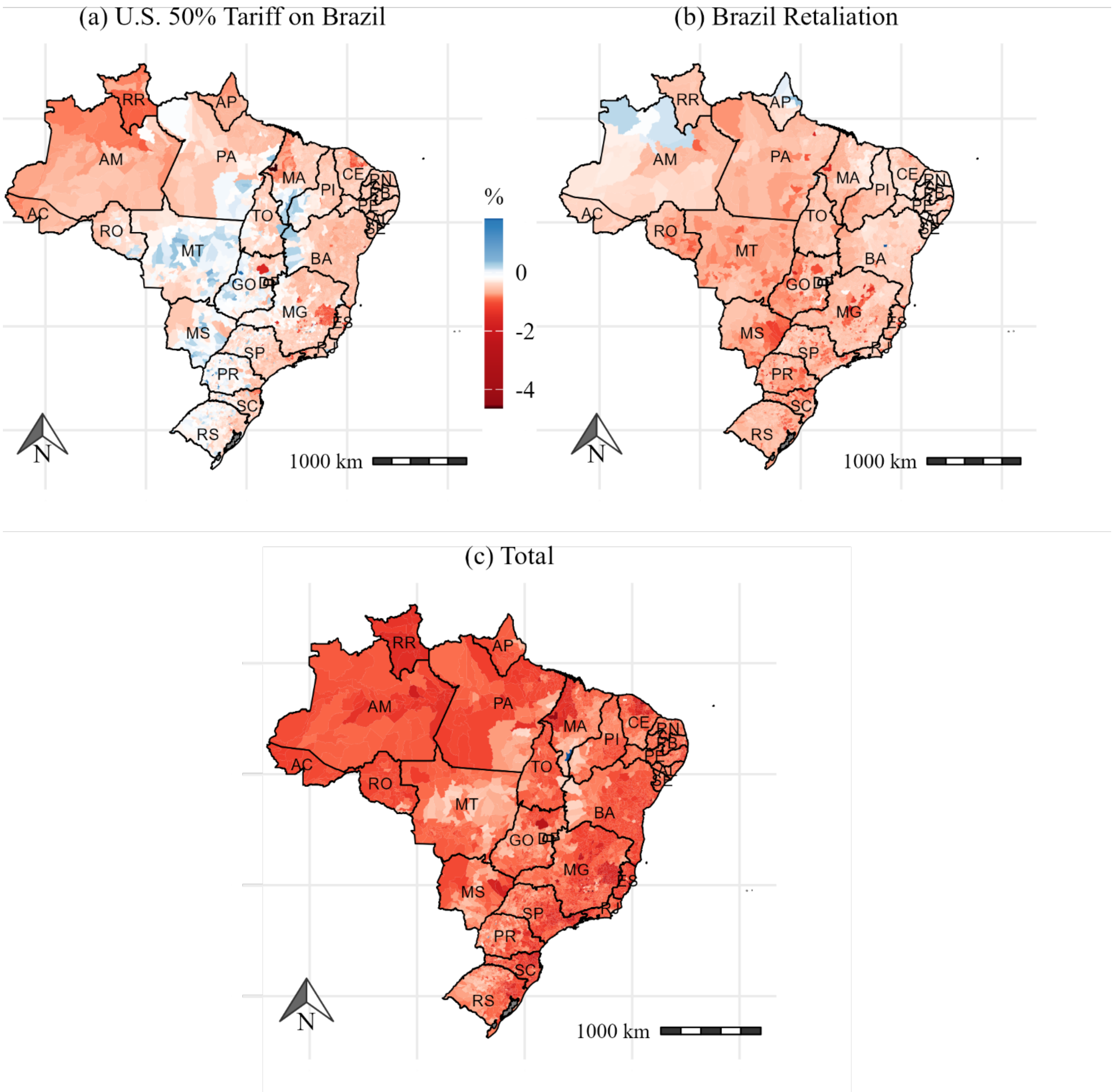

Figure 6: Regional impacts on Real GDP in Scenario 1, by trade shock and total (percentage changes).

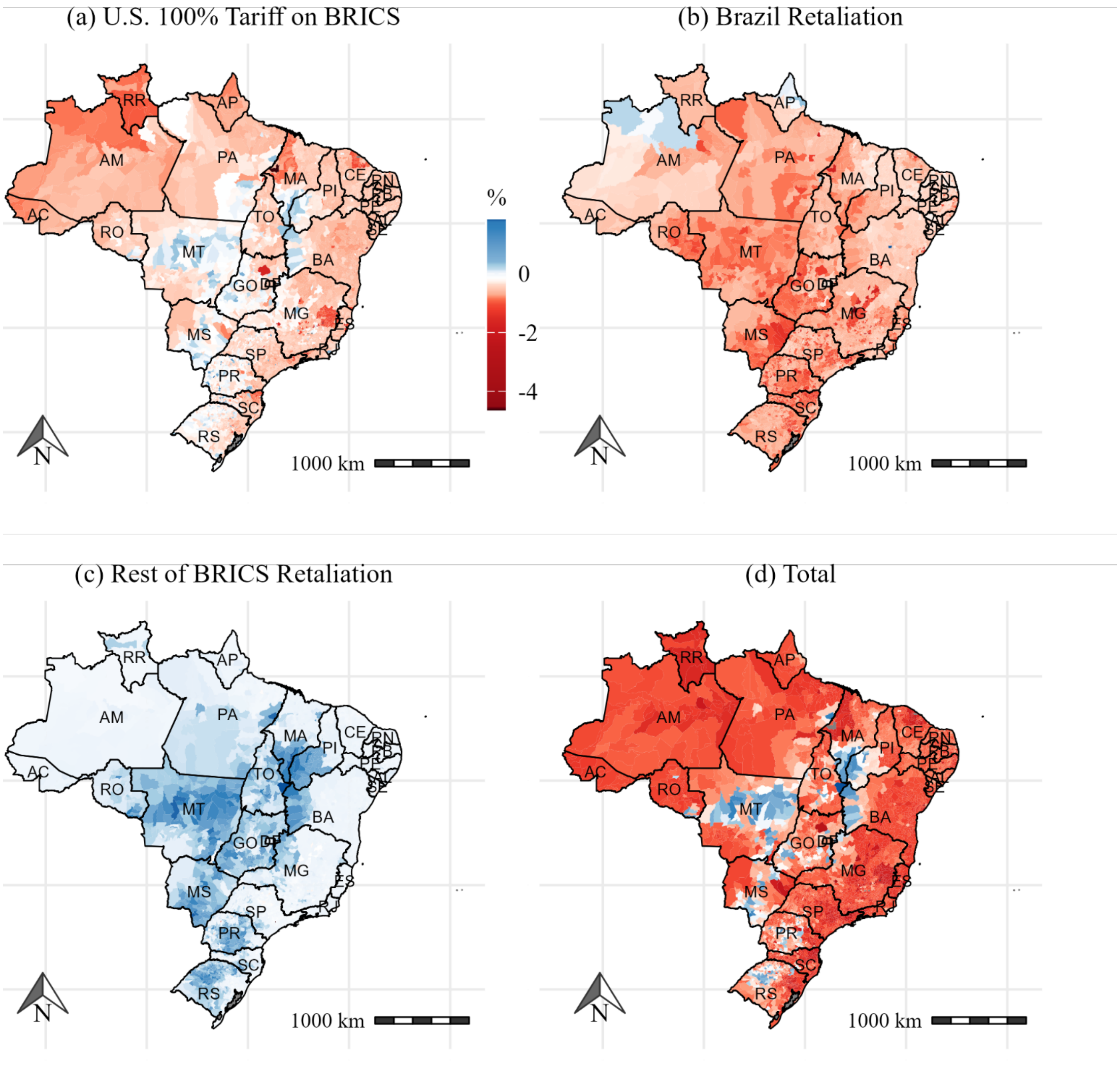

Figure 7: Regional impacts on Real GDP in Scenario 2, by trade shock and total (percentage changes).

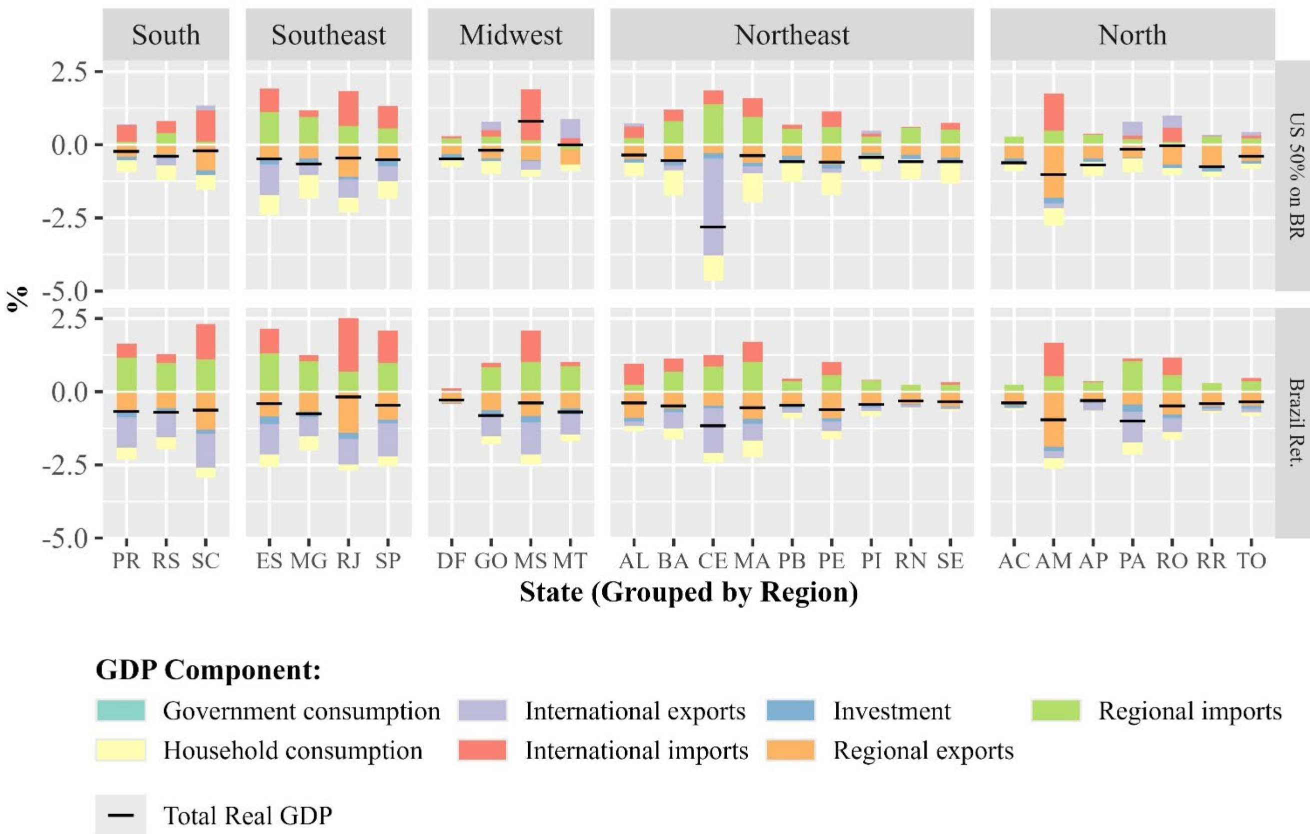

Figure 8: Contribution to regional GDP % changes by expenditure components in Scenario 1 (contribution to percentage changes).

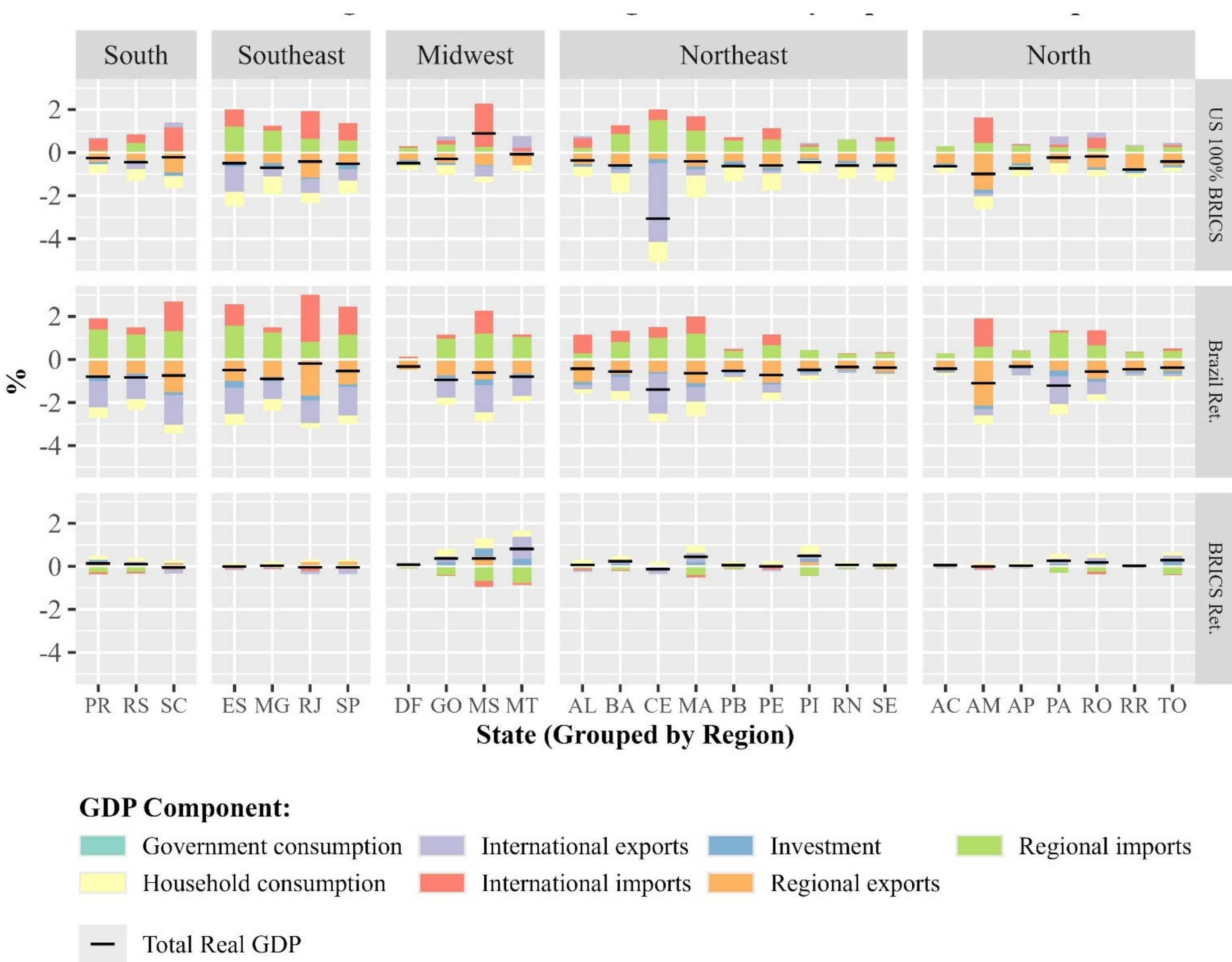

Figure 9: Contribution to regional GDP % changes by expenditure components in Scenario 2 (contribution to percentage changes).

Table 1: Impacts on GDP Components and Their Contribution to Total GDP Changes in Scenario 1.

	Macroeconomic Indicators					
	C	I	G	X	M	GDP
% change	-1.36	-1.63	0	-7.50	-6.79	-1.15
Contribution to GDP % changes	-.87	-.29	0	-.96	.96	-1.15

Authors' elaboration.

Table 2: Impacts on GDP Components and Their Contribution to Total GDP Changes in Scenario 2.

	Macroeconomic Indicators					
	C	I	G	X	M	GDP
% change	-1.23	-1.44	0	-9.01	-7.04	-1.19
Contribution to GDP % changes	-.79	-.26	0	-1.15	.99	-1.19

Authors' elaboration.

Table 3: Sectoral impacts in Scenario 1 on Total output (Y), Household consumption (C), Investment (I), Government expenditure (G), Exports (X), Imports (M) and Prices (P) (percentage changes).

Sector	Macroeconomic indicators						
	Y	C	I	G	X	M	P
Agriculture							
rice_wheat	.14	-1.52	.58	.00	4.83	-1.66	.52
cereal_gra	.10	-1.47	.40	.00	.95	-1.97	.42
vegetables	.04	-1.55	.29	.00	1.81	-2.26	.03
rest_agric	.75	-1.04	-3.16	.00	.45	-5.79	-1.91
soy	.04	-1.45	.11	.00	.66	-1.95	.27
orange	.89	-1.14	-3.61	.00	-3.77	-4.28	-1.85
coff_grain	-1.23	.96	-4.68	.00	-1.67	.00	-2.34
livestock	.61	.69	-1.29	.00	-7.62	-22.63	.96
Industry							
min_other	.14	.00	.39	.00	.84	-13.84	.53
oil_gas	.31	.00	.93	.00	.85	-3.12	.30
bovine_mea	.47	.83	.75	.00	1.77	-2.39	.88
meat_produ	.28	.91	.43	.00	2.40	-2.52	.78
other_food	.89	-1.06	-1.48	.00	-1.27	-3.38	.93
dairy_food	.78	.93	-1.32	.00	-1.38	-3.56	.97
bev_toba	.87	-1.19	-2.21	.00	-3.28	-3.65	-1.49
rest_manuf	-1.88	-1.10	-2.98	.00	-13.65	-4.16	.94
petroleum	.87	-1.21	-4.25	.00	-22.39	-12.09	.49
bio_ethanol	-1.43	-1.02	-1.90	.00	-15.91	-6.90	-1.26
chemical	-1.52	-1.16	-3.07	.00	-15.68	-4.26	.21
ferrous_me	-9.69	.73	-16.90	.00	-25.58	-6.69	-2.60
metals_nec	-2.99	-1.03	-6.51	.00	-3.79	-4.35	-1.07
metal_prod	-2.39	-1.05	-3.74	.00	-21.03	-4.88	-1.51
eletronics	-2.63	-1.22	-3.72	.00	-20.61	-3.56	.52
machinery	-2.78	-1.25	-3.46	.00	-19.22	-3.43	.70
motor_vehi	-4.14	-3.14	-5.17	.00	-12.39	-4.88	.53
Services							
rest_serv	-1.02	-1.41	-1.56	.00	-11.62	-13.92	-1.12
constr	-1.49	.00	-2.87	.00	6.17	-3.78	-1.55
finan_busi	.29	-1.65	.60	.00	-10.19	-12.16	-1.10

Authors' elaboration.

Table 4: Sectoral contribution to aggregate macroeconomic impacts on Household consumption (C), Investment (I), Government expenditure (G), Exports (X), Imports (M) and Prices (P) in Scenario 1 (contribution to percentage changes).

Sector	Macroeconomic indicators					
	C	I	G	X	M	P
Agriculture						
rice_wheat	0	0	0	.01	-.01	0
cereal_gra	0	0	0	.02	0	0
vegetables	0	0	0	.01	0	0
rest_agric	-.03	0	0	0	-.05	-.04
soy	0	0	0	.05	0	0
orange	0	0	0	0	0	0
coff_grain	0	0	0	-.03	0	0
livestock	0	-.02	0	-.02	-.01	-.01
Industry						
min_other	0	0	0	.05	-.20	0
oil_gas	0	-.01	0	-.03	-.15	0
bovine_mea	-.03	0	0	.04	0	-.03
meat_produ	-.01	0	0	.07	0	-.01
other_food	-.08	0	0	-.11	-.06	-.06
dairy_food	-.02	0	0	0	-.01	-.02
bev_toba	-.03	0	0	-.04	-.06	-.03
rest_manuf	-.13	-.05	0	-1.33	-.56	-.07
petroleum	-.05	0	0	-.45	-.51	-.01
bio_ethanol	-.01	0	0	-.06	-.01	-.01
chemical	-.03	0	0	-.62	-.56	.02
ferrous_me	0	0	0	-1.16	-.10	0
metals_nec	0	0	0	-.12	-.07	0
metal_prod	-.01	-.02	0	-.18	-.08	-.01
eletronics	-.03	-.29	0	-.76	-.54	0
machinery	-.01	-.04	0	-.23	-.11	0
motor_vehi	-.13	-.16	0	-1.04	-.43	-.01
Services						
rest_serv	-.58	-.11	0	-1.23	-1.67	-.39
constr	0	-.86	0	.04	-.01	0
finan_busi	-.18	-.07	0	-.35	-1.59	-.11
Total	-1.36	-1.63	0	-7.50	-6.79	-.80

Authors' elaboration.

Table 5: Sectoral impacts in Scenario 2 on Total output (Y), Household consumption (C), Investment (I), Government expenditure (G), Exports (X), Imports (M) and Prices (P) (percentage changes).

Sector	Macroeconomic indicators						
	Y	C	I	G	X	M	P
Agriculture							
rice_wheat	.44	-1.31	-1.42	.00	5.01	-2.53	.31
cereal_gra	.62	-1.57	2.72	.00	3.11	-1.93	2.20
vegetables	.29	-1.33	.72	.00	1.50	-1.54	.82
rest_agric	.81	.94	-3.14	.00	-1.04	-6.18	.71
soy	3.62	-2.94	15.77	.00	8.41	4.54	8.07
orange	-1.29	.93	-4.89	.00	-5.17	-4.63	-1.26
coff_grain	-1.71	.71	-6.13	.00	-2.30	.00	-1.82
livestock	.85	.64	-1.31	.00	-10.89	-26.94	.39
Industry							
min_other	.22	.00	.67	.00	.61	-17.11	.45
oil_gas	.25	.00	.65	.00	.24	-3.09	1.05
bovine_mea	.83	.76	-1.35	.00	.44	-1.95	.37
meat_produ	.20	.83	.32	.00	1.17	-2.46	.48
other_food	-1.74	-1.03	-2.85	.00	-5.52	-3.16	.73
dairy_food	.86	.87	-1.39	.00	-5.68	-3.62	.33
bev_toba	.97	-1.10	-2.39	.00	-5.33	-3.86	.29
rest_manuf	-2.40	.92	-3.69	.00	-17.60	-3.43	.05
petroleum	.87	-1.14	-4.20	.00	-25.46	-13.72	.88
bio_ethanol	-1.59	.97	-2.17	.00	-19.31	-5.98	.09
chemical	-1.91	-1.04	-3.74	.00	-19.11	-3.97	1.26
ferrous_me	-11.53	.53	-19.82	.00	-29.83	-6.24	-1.85
metals_nec	-3.98	.87	-8.54	.00	-5.20	-5.08	.17
metal_prod	-2.98	.86	-4.53	.00	-25.39	-3.90	.66
eletronics	-3.28	.97	-4.58	.00	-23.36	-3.08	.10
machinery	-3.82	-1.02	-4.72	.00	-24.96	-2.30	.11
motor_vehi	-4.66	-2.65	-5.71	.00	-14.87	-4.52	.38
Services							
rest_serv	-1.09	-1.28	-1.59	.00	-14.88	-15.63	.05
constr	-1.33	.00	-2.40	.00	4.74	-2.53	.34
finan_busi	.21	-1.56	.27	.00	-13.25	-13.73	.25

Authors' elaboration.

Table 6: Sectoral contribution to aggregate macroeconomic impacts in Household consumption (C), Investment (I), Government expenditure (G), Exports (X), Imports (M) and Prices (P) in Scenario 2 (contribution to percentage changes).

Sector	Macroeconomic indicators					
	C	I	G	X	M	P
Agriculture						
rice_wheat	0	0	0	.01	-.02	0
cereal_gra	0	0	0	.07	0	0
vegetables	0	0	0	.01	0	0
rest_agric	-.03	0	0	-.01	-.05	-.01
soy	0	0	0	.69	0	0
orange	0	0	0	0	0	0
coff_grain	0	0	0	-.04	0	0
livestock	0	-.02	0	-.03	-.01	0
Industry						
min_other	0	0	0	.04	-.25	0
oil_gas	0	-.01	0	-.01	-.15	0
bovine_mea	-.02	0	0	-.03	0	.01
meat_produ	-.01	0	0	.03	0	0
other_food	-.07	0	0	-.47	-.05	.05
dairy_food	-.02	0	0	-.01	-.01	.01
bev_toba	-.03	0	0	-.07	-.06	0
rest_manuf	-.11	-.05	0	-1.70	-.46	.04
petroleum	-.05	0	0	-.51	-.58	.05
bio_ethanol	-.01	0	0	-.08	-.01	0
chemical	-.02	0	0	-.75	-.53	.04
ferrous_me	0	0	0	-1.35	-.09	0
metals_nec	0	0	0	-.17	-.08	0
metal_prod	0	-.01	0	-.22	-.06	0
eletronics	-.02	-.26	0	-.86	-.47	.01
machinery	-.01	-.04	0	-.30	-.07	0
motor_vehi	-.11	-.14	0	-1.24	-.40	.03
Services						
rest_serv	-.53	-.09	0	-1.59	-1.88	.11
constr	0	-.75	0	.03	-.01	0
finan_busi	-.17	-.06	0	-.45	-1.79	.03
Total	-1.23	-1.44	0	-9.01	-7.04	.37

Authors' elaboration.

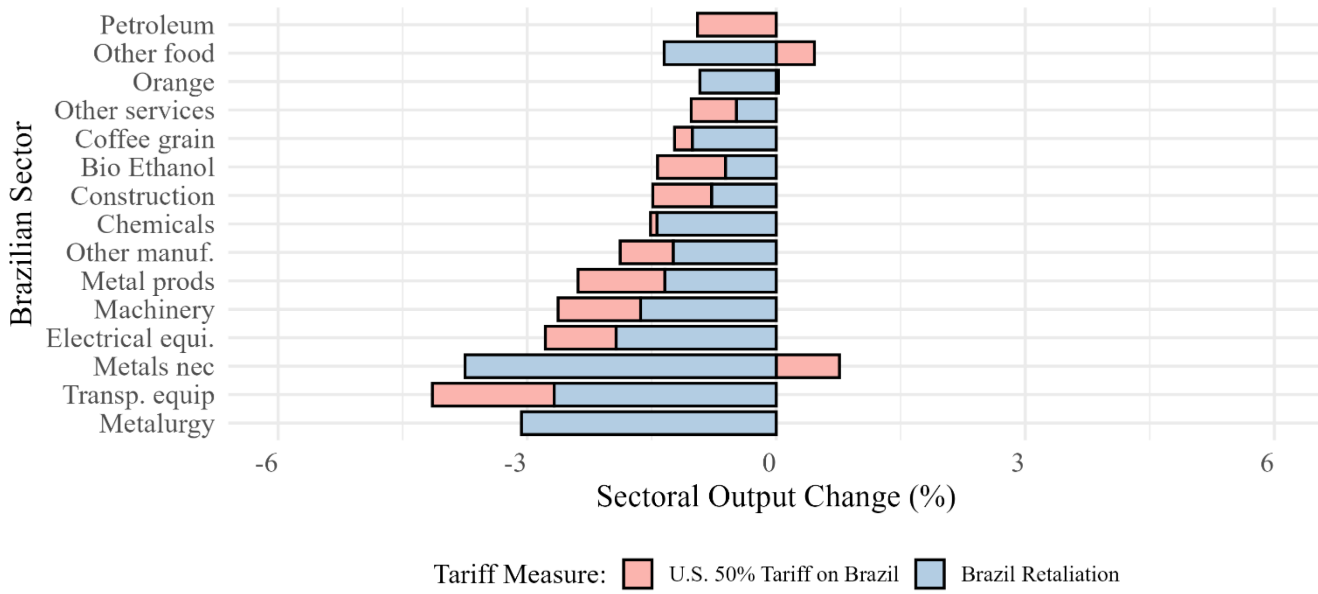

Figure 10 Main Sectoral Impacts of U.S.–Brazil Tariff Policies on Brazil's Economy in Scenario 1 (percentage changes).

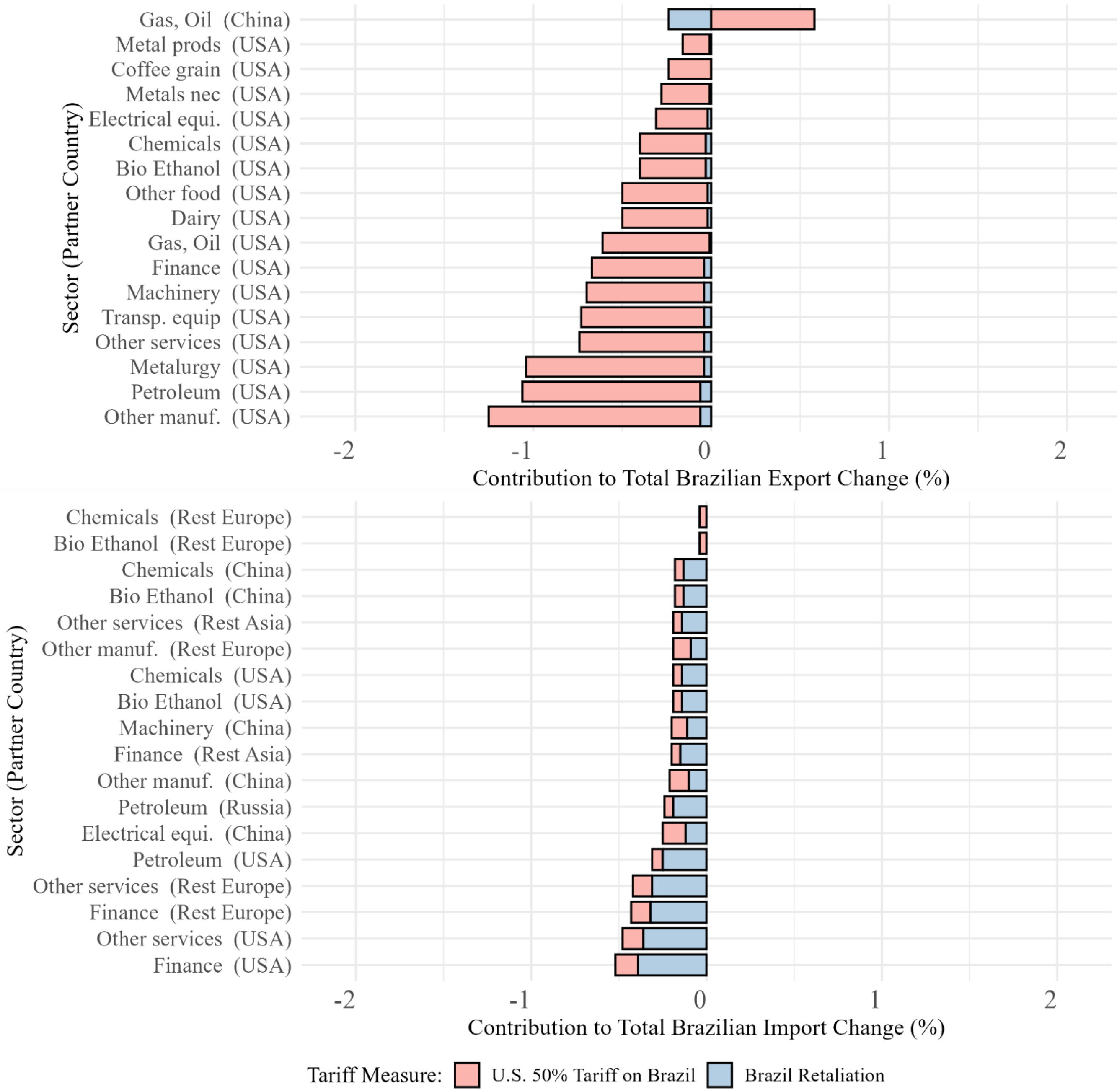

Figure 11: Main contributions to changes in Brazilian exports and imports by partner country and sector in Scenario 1 (contribution to percentage changes).

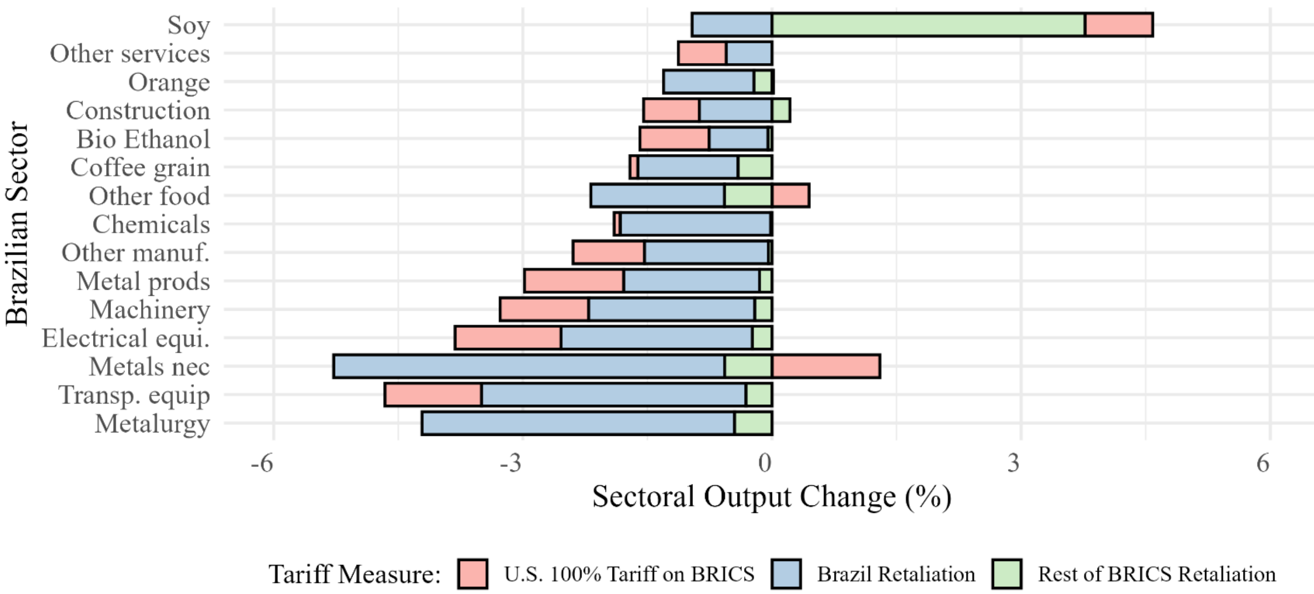

Figure 12: Main Sectoral Impacts of U.S.–BRICS Tariff Policies on Brazil's Economy in Scenario 2 (percentage changes).

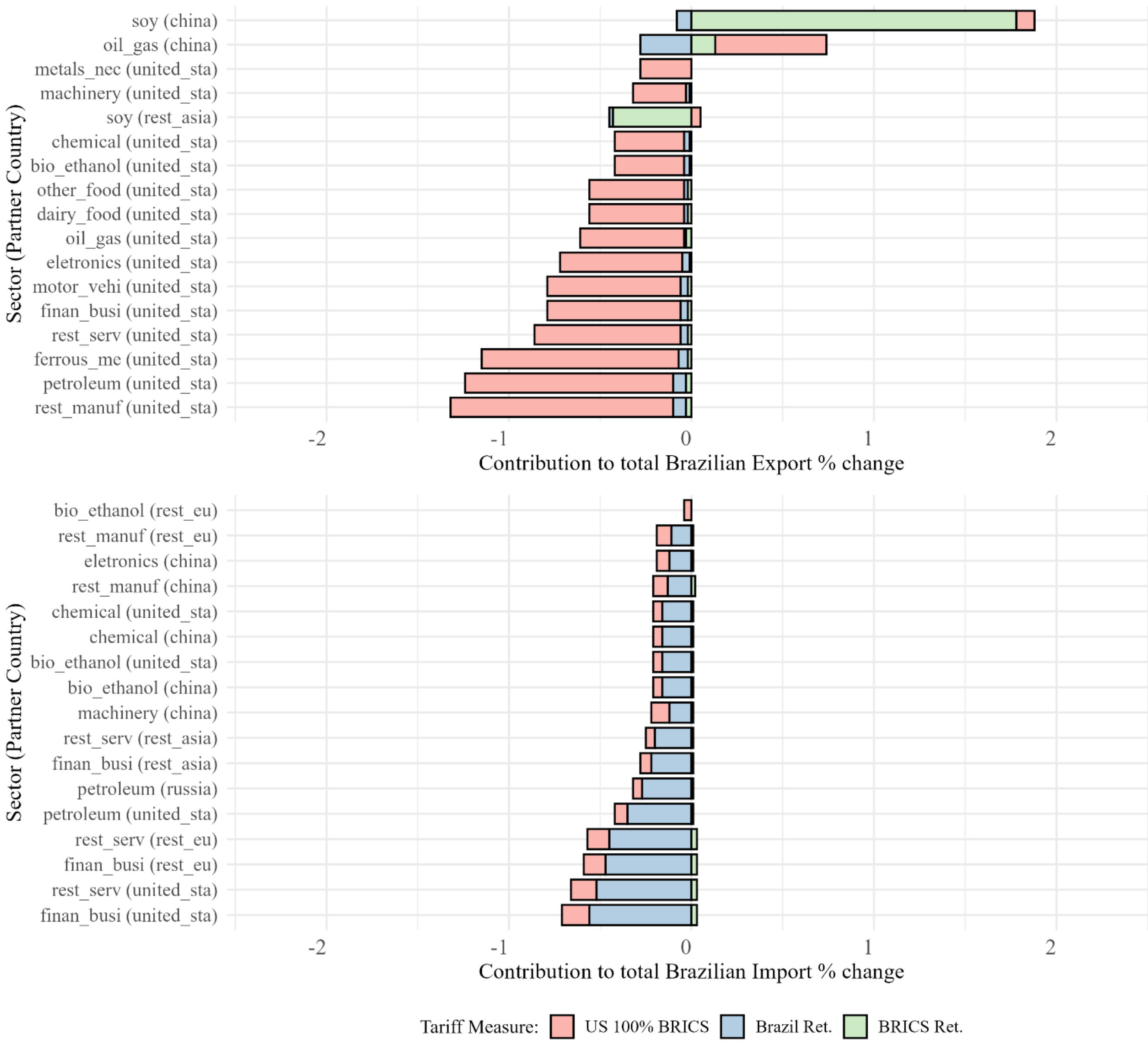

Figure 13: Main contributions to changes in Brazilian exports and imports by partner country and sector in Scenario 2 (contribution to percentage changes).

Appendix

Table A.1: GTAP Regional Concordance.

No.	Countries/regions represented in this study	Disaggregated GTAP countries/regions
1	Oceania	Australia, New Zealand, Rest of Oceania
2	China	China
3	Rest Asia	China, Hong Kong SAR, Japan, Republic of Korea, Mongolia, Chinese Taipei, Rest of East Asia, Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic, Malaysia, Philippines, Singapore, Thailand, Viet Nam, Rest of Southeast Asia, Afghanistan, Bangladesh, Nepal, Pakistan, Sri Lanka, Rest of South Asia, Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Rest of Former Soviet Union, Armenia, Azerbaijan, Georgia, Bahrain, Iran (Islamic Republic of), Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syrian Arab Republic, Türkiye, United Arab Emirates, Rest of Western Asia
4	India	India
5	Canada	Canada
6	USA	United States of America
7	Mexico	Mexico
8	Rest America	Rest of North America, Ecuador, Venezuela (Bolivarian Republic of), Rest of South America, Costa Rica, Guatemala, Honduras, Nicaragua, Panama, El Salvador, Rest of Central America, Dominican Republic, Haiti, Jamaica, Puerto Rico, Trinidad and Tobago, Caribbean
9	Argentina	Argentina
10	Bolivia	Bolivia (Plurinational State of)
11	Brazil	Brazil
12	Chile	Chile
13	Colombia	Colombia
14	Paraguay	Paraguay
15	Peru	Peru
16	Uruguay	Uruguay
17	Rest Europe	Austria, Belgium, Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom of Great Britain and Northern Ireland, Switzerland, Norway, Rest of EFTA, Albania, Serbia, Belarus, Ukraine, Rest of Eastern Europe, Rest of Europe
18	Russia	Russian Federation

19	Rest Africa	Algeria, Egypt, Morocco, Tunisia, Rest of North Africa, Benin, Burkina Faso, Cameroon, Côte d'Ivoire, Ghana, Guinea, Mali, Mauritania, Niger, Nigeria, Senegal, Togo, Rest of Western Africa, Angola, Central African Republic, Chad, Congo, Democratic Republic of the Congo, Equatorial Guinea, Gabon, Sao Tome and Principe, Burundi, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Sudan, United Republic of Tanzania, Uganda, Zambia, Zimbabwe, Rest of Eastern Africa, Botswana, Eswatini, Namibia, Rest of Southern African Customs Union
20	South Africa	South Africa
21	Rest World	Rest of the World

Authors' elaboration based on the model sector aggregation used in this study.

Table A.2. GTAP Sectoral Concordance.

No.	**Activities represented in this study**	**Disaggregated GTAP sectors**
1	rest_agric	Paddy rice (PDR), Sugar cane, sugar beet (C_B), Plant-based fibers (PFB), Forestry (FRS), Fishing (FSH)
2	wheat	Wheat (WHT)
3	cereal_gra	Cereal grains nec (GRO)
4	vegetables	Vegetables, fruit, nuts (V_F)
5	oil_seeds	Oil seeds (OSD)
6	crops_nec	Crops nec (OCR)
7	livestock	Bovine cattle, sheep and goats, horses (CTL), Animal products nec (OAP), Raw milk (RMK), Wool, silk-worm cocoons (WOL)
8	other_extr	Coal (COA), Minerals nec (OXT)
9	oil_gas	Oil (OIL), Gas (GAS)
10	bovine_mea	Bovine meat products (CMT)
11	meat_produ	Meat products nec (OMT)
12	other_food	Vegetable oils and fats (VOL), Dairy products (MIL), Processed rice (PCR), Sugar (SGR), Food products nec (OFD)
13	bev_toba	Beverages and tobacco products (B_T)
14	rest_manuf	Textiles (TEX), Wearing apparel (WAP), Leather products (LEA), Wood products (LUM), Paper products, publishing (PPP), Basic pharmaceutical products (BPH), Rubber and plastic products (RPP), Mineral products nec (NMM), Manufactures nec (OMF)
15	petroleum	Petroleum, coal products (P_C)
16	chemical	Chemical products (CHM)
17	ferrous_me	Ferrous metals (I_S)
18	metals_nec	Metals nec (NFM)
19	metal_prod	Metal products (FMP)
20	eletronics	Computer, electronic and optical products (ELE), Electrical equipment (EEQ)
21	machinery	Machinery and equipment nec (OME)

22	motor_vehi	Motor vehicles and parts (MVH), Transport equipment nec (OTN)
23	rest_serv	Electricity (ELY), Gas manufacture, distribution (GDT), Water (WTR), Trade (TRD), Accommodation, Food and service activities (AFS), Transport nec (OTP), Water transport (WTP), Air transport (ATP), Warehousing and support activities (WHS), Insurance (INS), Real estate activities (RSA), Recreational and other services (ROS), Public Administration and defense (OSG), Education (EDU), Human health and social work activities (HHT), Dwellings (DWE)
24	constr	Construction (CNS)
25	finan_busi	Communication (CMN), Financial services nec (OFI), Business services nec (OBS)

Authors' elaboration based on the model sector aggregation used in this study.

Table A.3: TERM Sector Concordance.

No.	Activities represented in this study	Disaggregated Regional Sectors
1	rice_wheat	Paddy rice, wheat and other cereal grains
2	cereal_gra	Cereal grains nec (maize)
3	vegetables	Vegetables, fruit, nuts and temporary crop fibers
4	rest_agric	Sugar cane and sugar beet, Crops nec and related services, Permanent crops nec, Forestry, Fishing
5	soy	Oil seeds (soybeans)
6	orange	Citrus fruits (oranges)
7	coff_grain	Coffee beans
8	livestock	Bovine cattle and other live animals, Raw milk, Animal products nec (swine), Animal products nec (poultry and eggs)
9	min_other	Coal, Minerals nec (non-metallic), Iron ore, Non-ferrous metal ores
10	oil_gas	Oil and gas extraction
11	bovine_mea	Bovine meat products
12	meat_produ	Meat products nec (pork), Meat products nec (poultry)
13	other_food	Fish products, Sugar, Vegetable and fruit processing, Vegetable oils and fats, Processed rice, Cereal preparations and starch products, Prepared animal feeds, Food products nec
14	dairy_food	Dairy products (processed milk), Dairy products nec
15	bev_toba	Processed coffee, Beverages, Tobacco products
16	rest_manuf	Textiles, Wearing apparel, Textile products nec, Wearing apparel and accessories, Leather products and footwear, Wood products, Pulp, Paper products, publishing, Printing and reproduction services, Basic pharmaceutical products, Rubber products, Plastic products, Mineral products nec (cement), Mineral products nec (cement products), Mineral products nec (glass and ceramics), Furniture, Manufactures nec, Repair and installation of machinery and equipment
17	petroleum	Petroleum, coal products (aviation fuel), Petroleum products (gasohol), Petroleum products (naphtha), Petroleum products (fuel oil), Petroleum products (diesel and biodiesel), Petroleum, coal products nec
18	bio_ethanol	Biofuels (ethanol)

19	chemical	Chemical products (inorganic), Chemical products (fertilizers), Chemical products (organic), Chemical products (resins and synthetic fibers), Chemical products (agrochemicals), Chemical products nec, Chemical products (paints and varnishes), Chemical products (soap and cleaning preparations)
20	ferrous_me	Ferrous metals, Ferrous metal products (rolled steel), Ferrous metal castings
21	metals_nec	Metals nec (non-ferrous)
22	metal_prod	Metal products
23	eletronics	Computer, electronic and optical products, Computer and office machinery, Electronic and communication equipment, Medical and precision instruments, Agricultural machinery, Mining and construction machinery, Machinery and equipment nec
24	machinery	Electrical equipment, Household appliances
25	motor_vehi	Motor vehicles and parts (cars), Motor vehicles and parts (trucks and buses), Motor vehicles and parts (components), Transport equipment nec
26	rest_serv	Electricity, Water supply and waste management, Trade, Transport nec (freight), Transport nec (passenger), Water transport, Air transport, Warehousing and support activities, Postal and courier services, Accommodation services, Food service activities, Publishing services, Recreational and cultural services, Communication, Real estate activities, Dwellings (imputed rent), Research and development services, Architectural and engineering services, Administrative and support services, Administrative services nec, Security services, Public administration and defence, Social security services, Education (public), Education (private), Human health services (public), Human health services (private), Recreational and other services, Membership organisations, Repair of computers and household goods, Personal services, Domestic services
27	constr	Construction (buildings), Construction (infrastructure), Construction services nec
28	finan_busi	Business services nec (IT), Financial services nec and insurance, Business services nec (legal and consulting), Business services nec (advertising), Business services nec (rental and IP)

Authors' elaboration based on the model sector aggregation used in this study.

Table A.4. Labor Contract Concordance.

No.	Labor contract category represented in this study	Disaggregated employment categories
1	formal	Private sector employee with formal contract, Domestic worker with formal contract, Public sector employee with formal contract, Military personnel and statutory civil servant
2	informal	Private sector employee without formal contract, Domestic worker without formal contract, Public sector employee without formal contract, Employer, Underground worker, Unpaid family worker

Authors' elaboration based on the model sector aggregation used in this study.

Table A.5. Labor Occupation Concordance.

No.	Occupation category represented in this study	Disaggregated occupational categories
1	Office	Legislators, senior officials and managers, Professionals and intellectual occupations, Clerical support workers
2	Unskilled	Plant and machine operators and assemblers, Elementary occupations, Occupations not clearly defined
3	Services	Service workers and sales workers, Armed forces, police officers and military firefighters
4	Techpro	Skilled agricultural, forestry and fishery workers, Craft and related trades workers, Technicians and associate professionals

Authors' elaboration based on the model sector aggregation used in this study.

Table A.6. Educational Attainment (Skill) Concordance.

No.	Skill category represented in this study	Disaggregated education levels
1	HS Incomplete	No formal education or less than one year of schooling, Incomplete primary education, Complete primary education, Incomplete secondary education
2	HS Complete	Complete secondary education, Incomplete tertiary education
3	Bachelor	Completed undergraduate degree
4	Graduate	Postgraduate specialization, Master's degree, Doctoral degree (PhD)

Authors' elaboration based on the model sector aggregation used in this study.