The Transmission of Commodity Price Super-Cycles

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Abstract

We examine two key channels through which commodity price super-cycles affect the economy: a *wealth* channel, through which higher commodity prices increase domestic demand, and a *cost* channel, through which they induce wage increases. By exploiting regional variation in exposure to commodity price shocks and administrative firm-level data from Brazil, we empirically disentangle these transmission channels. We introduce a dynamic model with heterogeneous firms and workers to further quantify the mechanisms and evaluate welfare. A counterfactual economy in which commodity booms are purely endowment shocks experiences only 30% of the intersectoral labor reallocation between tradables and nontradables, and 40% of the within-tradables labor reallocation between domestic and exported production. Finally, the consumption–equivalent welfare gain of a commodity super–cycle is twice as large in the counterfactual economy.

Keywords: Commodity shocks, local labor markets, skill premium, heterogeneous firms.

JEL classification: E32, F16, F41

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1 Introduction

Global commodity prices are a fundamental source of volatility for emerging markets. Commodity price super-cycles evolve at lower frequencies than regular business cycles with booms often lasting more than a decade. These super-cycles explain a third of the variance in output [Fernández et al., 2017b]. The literature has typically abstained from micro-founding their transmission channels to the economy. In this paper, we fill this gap by empirically identifying two key transmission channels of commodity super-cycles and studying their effects on labor reallocation and aggregate outcomes.

Firm and sector heterogeneity play a central role in our strategy to identify these transmission channels. First, during a commodity price boom, the increase in wealth leads to higher spending, and the response to this *wealth* channel is heterogeneous as it benefits more firms that sell their output locally (nonexporters and firms in low-tradability industries). Second, a commodity price boom induces a *cost* channel, operating through an increase in wages in response to an expansion in the labor demand of the commodity sector. Because the commodity sector in our setting is relatively unskilled-intensive, a commodity price boom lowers the skill premium, increasing the relative cost of less skill-intensive industries. While these two channels can be traced back to the characterization of the Dutch disease by Corden and Neary [1982], ours is the first study to introduce this heterogeneity and to exploit it to identify the existence of these channels using granular data for all sectors in the economy.[1]

Our empirical results are drawn from the experience of Brazil during 1999-2013, which is an ideal setting for understanding the mechanisms behind the transmission of commodity price cycles. During this period, the country faced large commodity price fluctuations. This economy has been historically characterized by substantial regional differences in the composition of commodity production. We exploit this regional variation and detailed administrative data for millions of firms to empirically identify the two channels. We motivate our identification strategy with a simple conceptual framework based on Jones [1975], Kovak [2013] and Dix-Carneiro and Kovak [2015], which delivers three testable results. First, an employment–weighted average of the prices of individual commodities is a sufficient statistic for the regional skill premium and employment

[1]Our cost channel is equivalent to Corden and Neary [1982]'s resource movement effect. In line with Alberola and Benigno [2017], we extend the original spending channel to allow for consumption smoothing with an endogenous current account and denote it wealth channel. The term 'Dutch disease' refers to the adverse effect of a boom in a resource sector on other sectors of the economy.

outcomes. Second, as a result of the cost channel, regions with a larger increase in this regional commodity price index will experience higher employment growth in high–skill relative to low–skill nontradable (i.e., service) industries. Third, as a result of the wealth channel, regions with a larger increase in the regional commodity price index face higher employment growth among firms selling their goods locally (nonexporters and firms in low–tradability industries) relative to exporters within the tradable (i.e., manufacturing) sector. We find strong evidence in favor of both channels in the data. We consider several alternative mechanisms as well as confounding shocks that may have affected manufacturing or service firms during this period. These include regional trends of trade liberalization, regional variation on import penetration from China, exchange rates dynamics, and intersectoral productions linkages, among several others. The magnitude and statistical significance of our main channels are robust to these other forces.

While these empirical results prove the existence of the cost and wealth transmission channels, they are silent about their aggregate implications. To assess these implications, we apply the intuition from our simple conceptual framework to a quantitative and dynamic general–equilibrium model. We introduce a three-sector (commodity, manufacturing, and services) small open economy model, which extends the quantitative international finance literature that studies commodity cycles (e.g., Alberola and Benigno [2017]) along two main dimensions. First, we deviate from the representative firm paradigm by including heterogeneous firms. Within the manufacturing sector, an export productivity cutoff divides firms into exporters and nonexporters, which allows us to capture the differential exposure to the wealth channel. Second, because the cost channel operates through differences in skill intensity across sectors, our model allows for heterogeneous workers (skilled and unskilled labor). The model is solved dynamically, taking into account the consumption smoothing behavior of the representative household, featuring endogenous trade balance and current account dynamics that are critical to account properly for the wealth channel.

We calibrate our model to the Brazilian economy. To discipline it, we explicitly target the heterogeneous skill intensities across sectors, the fraction of exporters in manufacturing, and several other firm-level and macroeconomic moments. We test the validity of the model by contrasting it to nontargeted outcomes. The model is able to replicate the dynamics of the regional skill premium, the reallocation of labor between sectors, and the differential evolution of employment in exporting versus nonexporting firms in response to a commodity price super-cycle. With the calibrated model, we perform a general equilibrium counterfactual to assess the importance of the labor market as a transmission mechanism. A counterfactual economy without transmission through the labor market (in which commodity booms are purely endowment shocks) sees 30% of the intersectoral labor reallocation between tradables and nontradables found in the baseline economy, and 40% of the within-tradables labor reallocation between domestic and exported production. From an aggregate perspective, the consumption–equivalent welfare gain of a commodity super–cycle is twice as large in the counterfactual economy relative to the baseline economy. Therefore, while the literature has frequently understood commodity price cycles as pure endowment shocks, our results show that incorporating contagion through the labor market is paramount. These quantitative results are robust to extending the model to a multiregion version with interregional trade and migration, and to using different modeling assumptions and parametrizations.

Related Literature. Our paper builds on the long-standing literature in international finance seeking to understand the impact of terms of trade on macroeconomic aggregates in emerging economies [Mendoza, 1995, Kose, 2002]. In particular, we contribute to the recent efforts to study and quantify the economic consequences of commodity price super-cycles [Reinhart et al., 2016, Shousha, 2016, Fernández et al., 2017a, Drechsel and Tenreyro, 2017, Alberola and Benigno, 2017, Fernández et al., 2020, Kohn et al., 2021].

On the empirical side, we identify the classic cost and wealth transmission channels proposed by Corden and Neary [1982]. To do so, we combine a novel empirical strategy, a quasi-natural experiment, and rich administrative microdata. Our empirical strategy extends previous studies that have focused on cross-country evidence [Sachs and Warner, 1995, Harding and Venables, 2016, Fernández et al., 2017b] and relies instead on variation in exposure to commodity price fluctuations across regions within a country. In addition, our identification strategy is based on the new insight that commodity price fluctuations have *heterogeneous* impacts across sectors and across firms. It is this heterogeneity, which we incorporate to the Dutch disease framework, that is key to the identification of the transmission mechanisms. A second useful element of our empirical work is the context. We study the large boom of the 2000s, during which Brazilian regions experienced different commodity prices due to differences in their economic structure. Finally, the microdata we use have the novelty of covering not only the manufacturing sector, but also the service and commodity sectors, left out in previous work on this topic but where most individuals are employed. Our identification strategy and microeconomic approach connects our work to the literature examining the consequences of local economic shocks [Autor et al., 2013, Dix-Carneiro and Kovak, 2017, Adão, 2015, Costa et al., 2016]. Closer to our study, Allcott and Keniston [2018] find a positive impact of local oil and gas booms in the U.S. on the manufacturing sector. In their paper, the positive effect on the manufacturing sector is driven by locally-traded subsectors and those with upstream linkages to oil and gas. We find a similar pattern in the manufacturing sector in the Brazilian data and show that our main results are robust to controlling for these mechanisms. Also related to our work, Faber and Gaubert [2019] study the impact of the expansion of tourism in Mexico on local manufacturing.

Our quantitative model features the same heterogeneity that enables our empirical identification. The international finance elements of our model are mostly related to Alberola and Benigno [2017]. They extend the framework of Corden and Neary [1982] to a dynamic multisector model with representative firms featuring endogenous growth to study structural long-run changes driven by temporary commodity booms. We abstract from endogenous growth and extend their framework by allowing heterogeneous firms and selection into exporting in the spirit of Ghironi and Melitz [2005] and Alessandria and Choi [2007].[2]

The rest of the paper is structured as follows. Section 2.1 describes the data used in our empirical analysis. Section 2.3 documents the empirical findings that guide our theory. Section 3 outlines the model, and Section 4 describes the results of our quantitative analysis. Section 5 concludes.

2 Empirical Analysis

2.1 Data Description

Our empirical analysis is carried out using linked employer-employee data from Brazil for the period 1999-2013. This dataset –Relação Anual de Informações Sociais (RAIS)– is an administrative census collected for social security purposes by Brazil's Labor Ministry.[3] It encompasses the

[2]More broadly, our paper belongs to the recent literature that uses dynamic heterogeneous-firms models and/or firm-level information to study classical problems in international economics such as the consequences of financial integration [Gopinath et al., 2017, Varela, 2015], the response of trade flows to devaluations [Alessandria et al., 2013], sudden stops [Ates and Saffie, 2021], and the effect of news shocks arising from commodity discoveries [Arezki et al., 2017].

[3]Differently than recent papers that have used worker-level records from these data [Alvarez et al., 2018, Dix-Carneiro and Kovak, 2017, Helpman et al., 2017], we use it to construct a comprehensive dataset of millions of firms in all sectors of the economy. No other such data exists for Brazil.

universe of formal-sector employees. The longitudinal information allows us to track both workers and firms over time. We observe detailed worker characteristics including educational attainment, age, gender, and occupation. The data also report each firm's industry and geographic location at the municipality level.[4] This allows us to exploit regional variation in exposure to commodity price changes in our empirical analysis.

For each job spell in each year, we observe the exact starting and ending day of a worker's employment in a firm. Based on this information, we compute quarterly indicators of employment. The data report individuals' mean monthly earnings in each job spell in each year, as well as earnings each December. In our analysis below, we use both annual earnings and monthly December earnings.

Regional Units. We define regional units that are a close approximation to the concept of local labor markets. While in the raw data we observe the municipality of each worker's employer, these municipalities are geographically too small to be considered a local labor market. Instead, we use 558 microregions as the regional unit that best reflects a local labor market. Throughout the paper we refer to microregions simply as regions. These units are defined by Brazil's Statistical Institute (IBGE) and are similar to U.S. commuting zones.[5] They are large enough such that commuting across them is fairly small. Aggregating the individual-level data, we compute sectoral and total regional employment, and regional measures of the skill premium.

Economic Sectors. The three sectors of interest to our paper are commodity, tradable, and nontradable. The commodity sector includes agriculture, mining, and fuels. The tradable sector includes all manufacturing industries. Nontradables include retail and wholesale trade, hospitality, construction, transportation, finance and real estate, among others.[6]

Heterogeneity in Skill Intensity. We divide workers into skilled and unskilled categories based on their educational attainment. The raw data records nine groups of attainment ranging from no formal education to tertiary education. We classify as unskilled workers those with at most

[4] Industry categories follow Brazil's National Classification of Economic Activities (CNAE).

[5] Commuting zones have been widely used as approximations to local labor markets in the US for the analysis of regional shocks, such as in Autor et al. [2013]. Brazil is divided into about 5500 municipalities, 558 microregions, 137 mesoregions, 27 states, and 5 macroregions.

[6] We exclude from our analysis government and quasi-public sectors. This includes federal and local governments, education and healthcare. We also exclude domestic service.

complete secondary education, and as skilled workers those with at least some tertiary education. Nationally, unskilled workers represent about 80 percent of total employment.

Differences in skill intensity across industries are key to our identification strategy, so we start by describing the distribution of skill intensity across industries within the commodity, tradable, and nontradable sectors. This allows us to characterize both the relative ordering of sectors as well as the variation in skill intensity within sectors. We measure an industry's skill intensity as the share of skilled workers in total employment using cross-sectional data in year 2000.[7] The distribution of skill intensity across industries for each sector is displayed in Figure 1 and moments of this distribution are reported in Appendix Table A3. Two observations emerge. First, the commodity sector is the most unskilled-intensive, followed by tradables and then nontradables. Second, while the distribution of skill intensity in commodity industries (and to a lesser extent within tradables) is fairly homogeneous, it varies substantially within the nontradable sector. This wide variation within the nontradable sector is exploited in our subsequent analysis to identify the transmission of commodity price cycles.

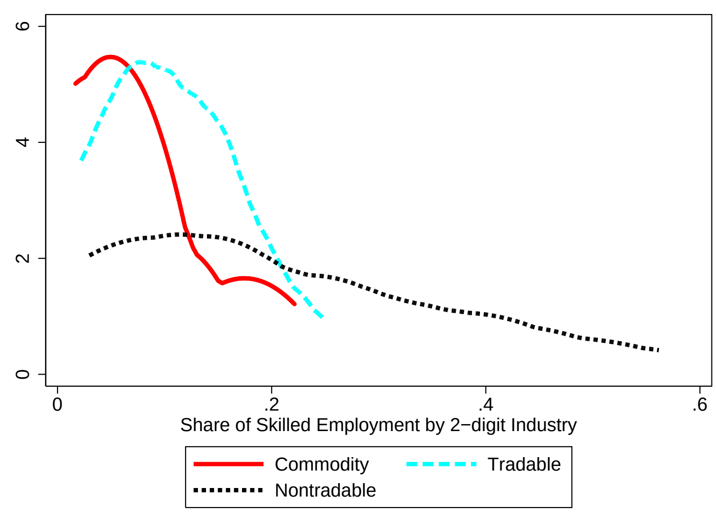


Figure 1: Skill Intensity Across Industries

NOTE: This figure displays kernel density estimates of the distribution of skill intensity (measured as the share of skilled workers in year 2000) of two-digit industries in the commodity, tradable, and nontradable sectors.

Firm-Level Panel. We construct a firm-level panel by aggregating our worker-level records. The panel consists of 2.3 million firms operating in the three sectors of interest. We compute firms'

[7] We have verified that these statistics are stable over time. While we report these distributions using data from RAIS, data from Brazil's demographic census show similar patterns.

quarterly employment in the last month of each quarter.[8] We complement our firm-level panel with additional information on exporting and importing firms obtained from Brazil's Secretariat of Foreign Trade (SECEX). We assign each firm in our panel a dummy variable for exporting and importing status at an annual frequency.

Commodity Prices. We use data on 14 commodity goods that capture the majority of commodity employment in Brazil. These commodities span agriculture, mining, and fuel industries and are chosen based on the following criteria: i) we must be able to match these categories to employment data to construct regional employment weights, and ii) we must be able to match these categories to data on commodity prices in world markets. The list of 14 commodities consists of cereals, cotton, sugarcane, soybeans, citrus, coffee, cacao, bovine meat, ovine meat, poultry meat, coal, oil and gas, a basket of metallic minerals, and a basket of precious metals. The largest commodities in terms of employment are cereals, bovine meat, coffee, sugarcane, and soybeans. There is considerable variation in the geographic distribution of employment in these commodities across Brazil. There is also geographic variation in the share of employment in commodities in each region as is illustrated in Figure A1 in Appendix A.1.2.

We obtain commodity prices for the period 1999-2013 from the World Bank's Global Economic Monitor - Commodities. This dataset has the advantage of tracking prices for a wide number of commodities over a long period of time and with systematic criteria. These prices are in nominal U.S. dollars, which we deflate using the U.S. Consumer Price Index. The data are reported at a monthly frequency, and we construct quarterly price indices based on the last month of each quarter.

Additional Data Sources. We complement our data with information from multiple additional sources. These include Brazil's Demographic Census, data on international trade flows, import tariffs, Brazil's input-output table, data on interregional trade flows, and industry-level measures of tradability and income elasticities. All of these are described in Appendix A.1.1.

Descriptive Statistics. Appendix A.1.2 provides descriptive statistics on the variation of employment, number of firms, and share of exporters across regions and sectors. It also discusses the

[8] In the case of multiplant firms, we define a firm's sector as that in which the firm has a majority of employment. Similarly, we define a firm's region as that in which most of the firm's employment is concentrated.

geographic variation in the skill premium and regional specialization in commodities.

Having described our data sources, we now proceed to the empirical analysis.

2.2 Conceptual Framework

We first provide a simple analytical framework to guide our empirical analysis. The quantitative model in Section 3 relaxes many of the assumptions used here. We use a specific factors model along the lines of Jones [1975], Kovak [2013] and Dix-Carneiro and Kovak [2015].[9] Consider a country with regions indexed by r and industries indexed by i. Production requires skilled and unskilled labor, and a specific factor. Each type of labor is mobile across industries and immobile across regions. The specific factor is immobile across industries and regions. There is perfect competition in all goods and factor markets.

The economy is comprised of I industries such that $\mathcal{I} = \{i = 1, \ldots, I\}$. The commodity sector is the subset of industries $C = \{i = 1, \ldots, I-3\}$. The nontradable sector has only 2 industries ($I-2$ and $I-1$), and the tradable sector has a single industry (I). This is the simplest setup under which we can derive our testable implications.

For simplicity and without loss of generality, we assume the cost share of the specific factor, θ_R, is common across all industries. Skill intensities, on the other hand, vary across industries following the patterns described earlier in Figure 1. The commodity sector is the most unskilled intensive, with cost shares (θ_u^C, θ_s^C). We assume these are constant across industries within the commodity sector, which is consistent with the small amount of variation in skill intensities across commodity industries documented in Figure 1. The tradable sector, with cost shares (θ_u^T, θ_s^T), is skill intensive relative to the commodity sector. Finally, consistent with the larger amount of variation in skill intensity within the nontradable sector in Figure 1, we assume there is a low–skill nontradable industry with cost shares ($\theta_u^{N\ell}$, $\theta_s^{N\ell}$) and a high–skill nontradable industry with cost shares (θ_u^{Nh}, θ_s^{Nh}). To be able to compare industries based on their tradability (keeping everything else constant) we assume that the low–skill nontradable industry has the same skill intensity as the tradable industry:

$$\frac{\theta_s^C}{\theta_u^C} < \frac{\theta_s^T}{\theta_u^T} = \frac{\theta_s^{N\ell}}{\theta_u^{N\ell}} < \frac{\theta_s^{Nh}}{\theta_u^{Nh}} \tag{1}$$

Commodity output is sold in Brazil and the rest of the world, with prices that are exogenous to

[9] This type of model also motivates the empirical work in Dix-Carneiro and Kovak [2017].

the domestic economy. Output of the tradable industry is exported and faces a foreign demand with finite price elasticity. Prices in each nontradable industry are endogenous and clear the domestic market. In line with the literature, hats represent proportional changes.[10] We omit region subscripts for the sake of clarity. Our key results are the following.

Proposition 1: The change in the regional skill premium $\hat{w}_s - \hat{w}_u$ can be written as $\hat{w}_s - \hat{w}_u = \left(\sum_i \kappa_i \lambda_i \hat{P}_i\right)$, where $\lambda_i = \frac{L_i}{L}$ is the employment share of each industry in each region and $\hat{P}_i$ is the change in the price of industry i. Given that price changes in the tradable and nontradable industries can themselves be written as a function of commodity prices $\left(\hat{P}_T = \left(\sum_{i \in C} \zeta_i^T \hat{P}_i\right),\right.$ $\hat{P}_{Nh} = \left(\sum_{i \in C} \zeta_i^{Nh} \hat{P}_i\right)$, and $\left.\hat{P}_{N\ell} = \left(\sum_{i \in C} \zeta_i^{N\ell} \hat{P}_i\right)\right)$, we can approximate the change in the skill premium as $\hat{w}_s - \hat{w}_u \approx \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$, with $\kappa_C < 0$ due to the fact that commodities are unskilled intensive relative to the rest of the economy.

Proof: See Appendix C.

The mechanism behind this result is that an increase in commodity prices leads to an expansion in the commodity sector's labor demand. Because the commodity sector is relatively unskilled-intensive, this implies an increase in the relative demand for unskilled labor, and consequently, a decline in the skill premium. Thus, this proposition leads to the following testable implication:

Testable Implication 1: Regions with a larger increase in a regional commodity price index $\left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$ will experience a larger decline in the skill premium $(\hat{w}_s - \hat{w}_u)$.

Proposition 2 (cost channel): We can write the relative change in employment between the high– and low–skill industries in the nontradable sector as: $\hat{L}_{Nh} - \hat{L}_{N\ell} = \left(\eta_U^{Nh} - \eta_U^{N\ell}\right)(\hat{w}_S - \hat{w}_U)$, where η_U^{Nh} and $\eta_U^{N\ell}$ are measures of the skill intensity in the high– and low–skill industries in the nontradable sector, respectively. Using Proposition 1, we can write $\hat{L}_{Nh} - \hat{L}_{N\ell} \approx \left(\eta_U^{Nh} - \eta_U^{N\ell}\right) \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$.

Proof: See Appendix C.

The increase in wages during a commodity boom represents a negative cost shock for all industries. Given that the unskilled wage increases more than the skilled wage, this cost shock is larger for unskilled-intensive industries, which in consequence face lower employment growth. This proposition leads to the following testable implication:

[10] Specifically, the proportional change in a variable x is denoted as $\hat{x}$ and is equal to $\frac{dx}{x}$, considering a small change dx.

Testable Implication 2: Regions facing higher relative growth in a regional commodity price index $\left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$ will experience higher employment growth in high–skill relative to low–skill nontradable industries.

Proposition 3 (wealth channel): Let $\hat{L}_T$ be the employment change in the tradable industry. We can write the relative change in employment between the tradable industry and the low–skill nontradable industry (which by assumption have the same skill intensity) as: $\hat{L}_T - \hat{L}_{N\ell} = -\hat{m}$, where $\hat{m}$ is the change in the region's income. We can write the change in income as $\hat{m} = \sum_i \varphi_i \hat{P}_i$, where φ_i is the share of regional production in each industry. In consequence, $\hat{L}_T - \hat{L}_{N\ell} \approx \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$.

Proof: See Appendix C.

A positive commodity price shock triggers a wealth effect increasing the local demand for goods.[11] This wealth channel benefits producers of nontradables, which sell their goods locally. Since by assumption the tradable industry and the low–skill nontradable industry in the model have the same technology, we can interpret them as representing the export–oriented and domestically–oriented segments of a same manufacturing industry in the data. This proposition then leads to a final testable implication:

Testable Implication 3: Regions facing higher relative growth in a regional commodity price index $\left(\sum_{i \in C} \lambda_i \hat{P}_i\right)$ will experience higher employment growth among nonexporters relative to exporters within the manufacturing sector.

2.3 Empirical Characterization of Transmission Channels

Based on the testable implications of our simple framework, we now empirically identify the cost and wealth channels that transmit changes in commodity prices through the economy. But first, we discuss the construction of a regional commodity price index.

Regional Commodity Price Index. Following Proposition 1, we can define a regional commodity price index which drives labor market outcomes. This is defined as the weighted average of individual commodity prices. In each region, the weights are the base-period shares of employment

[11] The quantitative model in the next section features consumption smoothing with an endogenous current account in a dynamic setting, and thus we refer to a wealth effect.

in each individual commodity over total employment in the commodity sector. Formally,

$$p_{rt} = \frac{\sum\limits_{i \epsilon C} p_{it} \times e_{ir}}{\sum\limits_{i \epsilon C} e_{ir}}, \tag{2}$$

where p_{it} stands for the price of commodity i in period t, and e_{ir} represents the base-year employment of commodity i in region r.[12] We obtain employment data for these weights from Brazil's Demographic Census of year 2000, the earliest available year that is close to the start of our sample period. By using the Demographic Census for these weights instead of RAIS, we are using a wider measure of employment, including informal employment. This regional commodity price index is similar to the one used by Adão [2015], who exploits it for the different goal of quantifying the effects of global shocks on between– and within–group inequality.

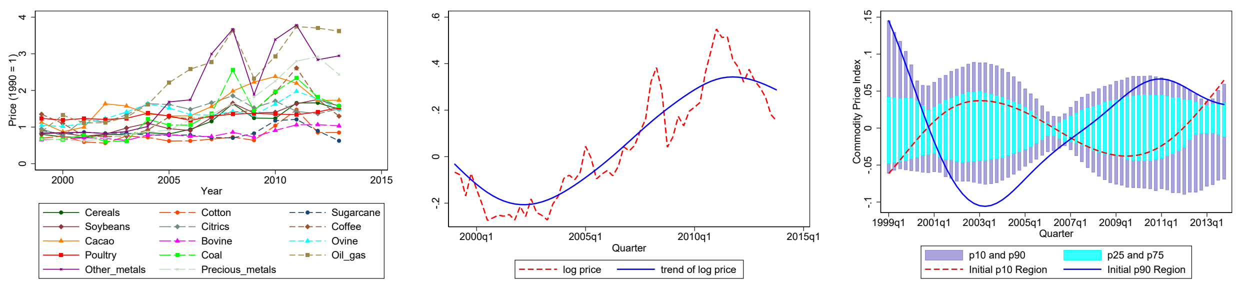
Commodity super-cycles are low-frequency phenomena where most of the time series variation is explained by medium to long-run movements. Therefore, to better capture super-cycles, we use the trend of this price index rather than the short run deviations from it. We compute the logarithm of the price index in equation (2) and we extract the trend for each region's log price index using the Hodrick-Prescott filter, based on quarterly data for 1990-2015.

This regional price index varies across regions and time due to the interaction of (time-invariant) differences in the base-year composition of the commodity sector and the variation over time in the prices of individual commodities. Figure 2a depicts the evolution of the individual commodity price series over time. To a large extent, this period has seen a commodity price boom, but there is widespread variation, with for instance large growth in metal prices and fairly stable prices in cotton or sugarcane. At the national level, our 1999-2013 window captures falling prices up to mid-2002 followed by a commodity price boom with the price index at its peak in 2011 and the start of a bust in the last two years of our sample. This is shown in Figure 2b, which displays an aggregate commodity price index based on nation-wide employment weights. Figure 2c illustrates the variation in the residual regional price index after extracting region and time fixed effects, which is the source of our identification in the next section. The outer bars show the 10th and 90th percentiles of the residual price across regions in each quarter, and the inner bars show the 25th and 75th percentiles. The dashed (solid) line shows the path of the price for the

[12] For each region, there is a fraction of employment in commodity-related activities that we cannot directly link to one of the 14 commodities for which we have price data. In these cases, we distribute those workers equally across the commodities for which we do have price data found within the same 2-digit industry.

region with the price at the 10th (90th) percentile in the initial period.

We now proceed to examine our testable implications.



a) Individual Commodity Prices b) Aggregate Commodity Price Index c) Regional Commodity Prices

Figure 2: Commodity Prices

NOTE: The graph on the left shows the path of the prices in real U.S. dollars of the 14 commodities included in our commodity price index. These prices are normalized to one in 1990. The graph on the middle shows the path of the commodity price index for Brazil (dashed line) and its trend (solid line). The graph on the right shows the percentiles of the distribution of the residual regional commodity price index after extracting region and time fixed effects. The outer bars mark the 10th and 90th percentiles and the inner bars mark the 25th and 75th percentiles. The dashed (solid) line marks the path of the residual price for the region at the 10th (90th) percentile in the initial period.

Testable Implication 1: The Skill Premium and Commodity Prices. To establish the relationship between commodity prices and the regional skill premium, we estimate the following equation through OLS:

$$\text{SP}_{rt} = \pi_1 \cdot \text{Price}_{rt} + \gamma_r + \delta_{tm} + v_{rt} \,, \tag{3}$$

where SP_{rt} denotes the skill premium in region r in macroregion m at time t and v_{rt} is an error term. We use annual observations for each region during the period 1999-2013, with commodity prices measured in the last month of the year. The regional commodity price index (Price_{rt}) is the HP filtered trend of the log of the employment weighted index defined in equation (2). We measure the skill premium as the (log) difference in mean skilled and unskilled earnings in each region, for workers employed in the last month of the year. We report our results using both annual and monthly (December) earnings.[13] The regression includes region fixed effects as well as macroregion × year fixed effects. Observations are unweighted and standard errors are clustered by region.

[13] We estimate the regression with annual observations given the nature of how wage data are reported. As described in more detail in Section 2.1, we observe the annual earnings per job spell in each year as well as December earnings. Employment regressions below are estimated using quarterly data.

The results are reported in Table 1. Consistent with Testable Implication 1, the sign on the regional commodity price index is negative, such that a region experiencing a larger increase in the regional commodity price index will experience a larger decline in the skill premium.[14] Specifically, a region facing a one log point larger increase in the regional commodity price index experiences a 0.14 log point relative decline in the skill premium based on annual wages (column 1) and a 0.13 log point relative decline based on monthly wages (column 2). These are large elasticities; if a region faces an increase in commodity prices such as that seen in Brazil between the second quarter of 2002 and the last quarter of 2011 (a 55 log point trough-to-peak increase), it would experience a 7 log point relative decline in the skill premium (based on column 2). In Appendix A.1.4, we report the impact of commodity prices on the wages of unskilled and skilled workers separately, finding that the response of the skill premium is driven primarily by an increase in unskilled workers' wages.

Table 1: Commodity Prices and the Skill Premium

	(1)	(2)
Price_{rt}	-0.140**	-0.128***
	(0.057)	(0.058)
Observations	8363	7912
R^2	0.694	0.687

NOTE: This table reports the results of the estimation of equation (3). Column 1 corresponds to annual earnings. Column 2 corresponds to monthly (December) earnings. Each regression includes region as well as macroregion × time (year) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

Testable Implication 2: The Cost Channel. We now document that higher commodity prices lead to employment losses in unskilled relative to skilled industries. We estimate the following regression, linking firm–level employment to the regional commodity price index and its interaction with industry–level skill intensity:

$$\log(\text{Emp})_{ft} \;=\; \alpha_0 \cdot \text{Price}_{rt} + \alpha_c \cdot [\text{Price}_{rt} \times \text{Skill Intensity}_i] + \gamma_f + \delta_{st} + \epsilon_{ft}\;, \tag{4}$$

[14] These elasticities do not allow us to infer aggregate effects, which are absorbed by the intercept or time fixed effects. This limitation is common to the empirical literature exploiting within–country variation to identify the effects of various shocks on relative regional outcomes [Autor et al., 2013, Faber and Gaubert, 2019].

where Emp_{ft} denotes employment of firm f in quarter t located in region r, Price_{rt} is the commodity price index of region r in period t, and Skill Intensity_i is the skill intensity of firm f's industry i measured in the baseline period. We include firm fixed effects (γ_f) as well as state × time (year–quarter) fixed effects (δ_{st}) to control for confounding time-varying shocks. Observations are unweighted and standard errors are clustered by region. We use the quarterly firm panel described in Section 2.1.[15] The parameter of interest is α_c. Testable Implication 2 entails $\alpha_c > 0$.

Note that following our conceptual framework, the wealth channel has a homogeneous impact across nontradable industries, so any variation in the impact of commodity prices on employment as a function of industries' skill intensity can be attributed to the cost channel. For this reason, and in line with Testable Implication 2, we estimate equation (4) for firms in the nontradable sector. This mechanism should still apply in the commodity and tradable sectors. Although in these two sectors we cannot necessarily isolate other mechanisms, we also report results for them for the sake of completeness.

Table 2 displays the results.[16] We find that in regions facing larger increases in the regional commodity price index, high–skill industries experience higher employment growth relative to low–skill industries, which is consistent with Testable Implication 2. For the nontradable sector (in column 1), the elasticity of firm employment to commodity prices for firms at the 25th and 75th percentiles of skill intensity is -0.039 and 0.005, respectively.[17,18] For the tradable and the commodity sectors (in columns 2 and 3, respectively), we also find a statistically significant and positive interaction term. Overall, our findings confirm that higher commodity prices lead to larger employment losses in relatively unskilled industries, a result consistent with the cost channel.[19]

Testable Implication 3: The Wealth Channel. The third testable implication predicts a gain

[15]Employment and commodity prices are measured in the last month of each quarter.

[16]Note that we demean the commodity price index and the measure of skill intensity.

[17]To benchmark this, note that if a region faces an increase in commodity prices such as that seen in Brazil between the second quarter of 2002 and the last quarter of 2011 (a 55 log point trough-to-peak increase), it would experience a 2.1 log point relative decline in employment for firms at the 25th percentile of skill intensity and a 0.4 log point relative increase for firms at the 75th percentile of skill intensity.

[18]Table A8 in Appendix A.1.5 reports the impact of the regional commodity price index on the employment in each sector without including interaction terms. We find that a one log point increase in the regional commodity price index is associated with a 0.13 log point increase and a 0.14 log point decline in employment for firms in the commodity and tradable sectors respectively. For firms in the nontradable sector, the impact is small and not statistically different from zero. The same appendix also provides an analysis of sectoral employment shares in each region.

[19]In Appendix Table A14 (column 2) we show these results hold when we identify them based on variation across three-digit industries within broader two-digit industries, which reduces concerns about unobserved industry characteristics shaping the response to commodity price shocks.

Table 2: Commodity Prices and Firm-Level Employment: The Cost Channel

	Nontradable Sector (1)	Tradable Sector (2)	Commodity Sector (3)
Price_{rt}	0.014	-0.136***	0.100*
	(0.021)	(0.030)	(0.056)
Skill Intensity_i x Price_{rt}	0.845***	0.795***	3.467***
	(0.114)	(0.205)	(0.476)
Observations	30,453,457	8,007,422	1,007,570
R^2	0.849	0.873	0.908

Note: This table reports the results of the estimation of equation (4) by sector. Each regression includes firm and state × time (year–quarter) fixed effects. Note we estimate equation (2) demeaning the commodity price index and skill intensity variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

in employment among nonexporters relative to exporters within the tradable sector. Exporter status, however, does not account for trade across regions within a country. For this reason, we provide further evidence in favor of this channel by also comparing industries with different degrees of tradability within the tradable sector, under the assumption that firms in low-tradability manufacturing industries are more likely to sell their output locally.

To identify the wealth channel, we estimate the following linear regression model:

$$\begin{aligned} \log(\text{Emp})_{ft} &= \beta_0 \cdot \text{Price}_{rt} + \beta_1 \cdot \text{Exporter}_{ft} + \beta_{w1} \cdot \left[\text{Exporter}_{ft} \times \text{Price}_{rt}\right] \\ &+ \beta_{w2} \cdot \left[\text{Tradability}_i \times \text{Price}_{rt}\right] + \gamma_f + \delta_{st} + u_{ft} \,, \end{aligned} \tag{5}$$

where Exporter_{ft} is a dummy variable taking a value of one if firm f operating in industry i exports in period t, Tradability_i is an industry-level measure of the extent to which a firm's output is tradable, and u_{ft} is the error term. We estimate (5) only for the tradable sector. We also control for firm and state × time fixed effects. As before, observations are unweighted and standard errors are clustered by region. The parameters of interest are β_{w1} and β_{w2}. The existence of a wealth channel (Testable Implication 3) implies $\beta_{w1} < 0$ and $\beta_{w2} < 0$.

We use a measure of industry tradability constructed by Holmes and Stevens [2014] and used in a similar context by Allcott and Keniston [2018].[20] Specifically, Holmes and Stevens [2014]'s measure, η, captures the transportation cost of different industries and is constructed based on data on shipment distances. For ease of interpretation, in our estimation of (5) we define $Tradability = -\eta$, such that highly tradable industries have low η values.

Table 3 displays the results for the estimation of equation (5). Column 1 includes only the interaction between the regional price index and the exporter dummy, and excludes the tradability measure. Given the well-documented link between exporting status and firm size, we additionally include interaction terms between firm–size bin dummies and the price index.[21] We find that in regions facing larger increases in the regional commodity price index, nonexporters experience higher employment growth relative to exporters, which is consistent with Testable Implication 3. Specifically, we find a much larger negative elasticity of firm employment to commodity prices for exporters (-0.10) than nonexporters (-0.042) in the tradable sector (see column 1). In column 2, we include the interaction term between the regional commodity price index and the industry-level tradability measure, and exclude the interaction of the price index with the exporter dummy. We find that the total elasticity of firm employment to commodity prices is -0.026 for firms at the 75th percentile of tradability and -0.007 at the 25th percentile. Finally, in column 3 we include both interaction terms, finding very similar coefficients to those in the previous two columns. These large and statistically significant differences illustrate the relevance of the wealth channel in the transmission of commodity price shocks.

Next, we verify the robustness of our findings to the existence of alternative transmission mechanisms and to other potentially confounding factors. We also provide further evidence in favor of the cost and wealth channels.

2.4 Alternative Transmission Mechanisms

Upstream and Downstream Linkages. A complementary transmission mechanism consists of upstream and downstream linkages between the commodity sector and other industries. This mechanism has been explored by Allcott and Keniston [2018] in the context of oil and gas booms in the U.S. We explore this mechanism in Appendix A.2.3. Based on Brazil's 2005 input-output table, we construct measures of these vertical linkages, categorizing manufacturing industries as

[20] Details on the tradability measure and summary statistics are provided in Appendix A.1.6.

[21] We include the interaction between the regional commodity price index and the following firm–size bin dummies: 5 to 50 workers, 50 to 100 workers, 100 to 500 workers, 500 to 1000 workers, and 1000 or more workers.

Table 3: Firm-Level Employment and Export Status in the Tradable Sector: The Wealth Channel

	(1)	(2)	(3)
Price_{rt}	-0.042*	-0.046**	-0.044**
	(0.022)	(0.022)	(0.022)
Exporter_{ft}	0.135***	0.135***	0.134***
	(0.005)	(0.005)	(0.005)
Exporter_{ft} x Price_{rt}	-0.058***		-0.055***
	(0.015)		(0.015)
Tradability_{i} x Price_{rt}		-0.042**	-0.039**
		(0.017)	(0.017)
Observations	8,086,964	8,005,174	8,005,174
R^2	0.909	0.909	0.909

NOTE: This table reports the results of the estimation of equation (5). Each regression includes firm and state × time (year–quarter) fixed effects. We include (but do not display) the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

upstream, downstream, or unlinked to the commodity sector. We show that upstream and downstream linkages are relevant: an increase in commodity prices leads to an increase in employment in upstream industries, and a decline in employment in downstream industries. We also find that the coefficients estimated in equations (4) and (5) are robust to including interaction terms between the commodity price index and upstream and downstream dummy variables.

Interest Rates and Financial Conditions. Shousha [2016] and Fernández et al. [2017a] suggest that commodity cycles can affect the economy through an interest rate channel as spreads seem to be lower during booms and higher during busts. While we control for economy-wide shocks using state × time fixed effects, the pass-through of interest rates to firm-level employment could have a different impact on different firms. Although our data do not include financial information, the literature on financial frictions has documented that borrowing constraints are strongly tied to firm size [Gopinath et al., 2017]; small firms are more likely to be constrained and therefore less likely to benefit from the boom. Appendix Table A14 and Table 3, for the cost and wealth channels respectively, confirm our findings hold even after we control for the interaction between firm–size bin dummies and the regional commodity price index.

Political Economy. Commodity prices could potentially impact labor market outcomes through various political economy mechanisms. A first such channel could consist in increased revenue by local governments leading to increases in social transfers or a larger demand for employment associated with public works. Caselli and Michaels [2013] find a small (if at all) increase in social transfers and public goods provision to increases in oil-related revenue to regions. A second channel is that local governments could adjust the minimum wage in response to commodity prices. The following facts suggest our results are robust to these mechanisms. First, while oil resources might lead to local government revenue, other commodities do not. We find that our results are robust to excluding oil and gas from the commodity price index (Appendix A.2.4). Second, in Brazil the minimum wage is primarily defined at the national level. Although a handful of states have state-level minimum wages (that must be higher than the national-level minimum), Engbom and Moser [2022] argue that minimum wages vary little across states. Our firm-level regressions include state × time fixed effects, which would absorb changes in state-level minimum wages, alongside any other policies determined at this level of regional aggregation. Policies determined at more local levels are also controlled for with region × time fixed effects used in robustness checks.

2.5 Robustness Checks

Market Power in Commodity Markets. Our identification strategy for the cost and wealth channels in equations (4) and (5) does not rely on a lack of market power of the Brazilian economy (or specific Brazilian regions) on world markets for individual commodities. The reason is that these regressions exploit firm–level variation in the tradable (i.e., manufacturing) or nontradable (i.e., service) sectors. Thus, the identifying assumption is that unobserved shocks to the commodity sector that could impact world prices do not simultaneously have i) a differential impact on skilled– versus unskilled–intensive nontradable industries (in the case of the cost channel) or ii) a differential impact on exporting vs nonexporting firms in the manufacturing sector (in the case of the wealth channel).

Nevertheless, in Appendix A.1.7 we document that Brazil holds a relatively small world market share in each of the commodities used in the construction of this index. In addition, Appendix A.1.8 shows that employment in each of these commodities is regionally dispersed: in each commodity, even regions at the right tail of the distribution represent a small share of aggregate employment. Going further, Appendix A.2.4 shows that the regressions for the cost and wealth channels are robust to excluding the commodities in which Brazil has a larger world market share (soybeans, sugarcane, and coffee) from the regional commodity price index.[22] Furthermore, Appendix A.2.5 confirms that our results for the cost and wealth channel regressions are robust to excluding the states with larger world market shares of soybeans, sugarcane, and coffee. Thus, we use a sample in which no state has more than a 2% world market share in any commodity.

Another potential concern is that depending on the market structure of the commodity sector in Brazil, the prices received by commodity producers could differ from the world price. In Appendix A.1.9, we compare producer prices and world prices for important commodities in our sample, and find an extremely high correlation between them. Further, we document there are only small regional differences in the evolution of producer prices. Finally, we show that there is no concentration of employment among commodity producers, suggesting that these firms are price takers.

Trade Shocks. Brazil faced a large increase in imports from China in the period under study [Costa et al., 2016]. In Appendix A.2.6, we construct a measure of regional exposure to the increase in Chinese competition and show that our estimates are not confounded by this shock. Additionally, in the late 1980's and early 1990's, Brazil reduced its import tariffs substantially [Dix-Carneiro and Kovak, 2017]. While this occurred earlier than our sample period, the impacts could potentially be long-lasting. In Appendix A.2.7, we construct a measure of regional exposure to trade liberalization and show our estimates are robust to controlling for the effect of tariff liberalization.

Informality. While Brazil has a large share of informal labor, our firm-level data are limited to the formal sector of the economy. Because informality is more common among unskilled workers, a transition of informal workers toward the formal sector in response to an increase in commodity prices would bias our results against finding a decline in the skill premium. Thus, we interpret our results for the skill premium, and the consequent reallocation of labor, as lower bounds. Despite this point, in Appendix A.2.8 we construct regional measures of informal employment and show that our identification of the cost and wealth channels is not driven by regional variation in informality.

[22] We show equivalent results for the skill premium regression in Appendix Table A20.

Geographic Spillovers. We extend our empirical strategy to capture geographic spillovers through general equilibrium effects. These spillovers could occur due to trade linkages, migration, or other geographic linkages. Following Allcott and Keniston [2018], we assume that these spillovers are mostly local, meaning that a given region is only impacted by commodity price shocks to other regions within a certain radius. In Appendix A.2.4, we construct a commodity price index that takes into account the prices faced by nearby regions. The estimated impact of commodity prices on employment is very similar to that reported earlier, which suggests the magnitude of these spillovers is small. Moreover, in Appendix B.1 we develop a version of our quantitative model with interregional trade and migration to fully take into account these general equilibrium effects. The results from this model are similar to those from its more parsimonius version in Section 3.

Exchange Rates. Exchange rate fluctuations could impact employment of exporting and non-exporting firms in the tradable sector differentially. Several conditions would have to be met for exchange rate fluctuations to confound our estimates of the impact of regional commodity prices on firm-level employment in equation (5). While our regressions include time fixed effects that capture aggregate shocks, a spatial correlation between the share of exporters and the local composition of commodity baskets, however, could confound our results. Note that this spatial correlation would have to occur within states, as we include state $\times$ time fixed effects. We show in Appendix A.2.9 that this is not the case.

Regional Commodity Price Index: Trend vs. Cyclical Component. Our baseline empirical analysis is carried out using the trend of the regional commodity price index obtained with the Hodrick-Prescott (HP) filter. Tables A19 and A20 in the Appendix show our results are similar when using the raw price index instead of its trend. Moreover, by including both the trend and cyclical components simultaneously, we conclude that the trend of the price index is the source of variation driving our main findings.

Unobservable Regional or Region by Sector Shocks. Finally, we can modify equations (4) and (5) to include region $\times$ time (year–quarter) fixed effects. These control for any unobserved regional shock. In this case, the first term in each equation (the regional commodity price index by itself) is absorbed by these fixed effects. Further, we also include region $\times$ time $\times$ 2–digit industry fixed effects, absorbing regional shocks that vary by region and broad industries. Our regression for the cost channel is still feasible with these fixed effects given that we measure skill intensity at the 3–digit level. The results, in Appendix Sections A.2.1 (for the cost channel) and A.2.2 (for the wealth channel) show our results remain robust.

Standard Errors. Our approach consists of a shift-share design as we construct regional shocks weighting individual commodity price time series with initial regional employment shares. Adão et al. [2019] propose a correction to standard errors in this type of regression. In Appendix A.2.10, we report standard errors following this method. Because these corrected standard errors are smaller, we conservatively leave them to the Appendix and report the standard errors clustered by region in the main text.

2.6 Further Evidence in Favor of the Cost and Wealth Channels

Identification of the Wealth Channel based on Variation in Income Elasticities. An alternative approach to identifying the wealth channel could exploit variation across nontradable industries in income elasticities. If a commodity price increase leads to an increase in wealth and, consequently, an increase in the local demand for nontradables, this should lead to a relative expansion in industries with a higher income elasticity. Appendix A.2.11 shows that this is indeed the case. It also confirms that the identification of both the cost and wealth channels in equations (4) and (5), respectively, is robust to the inclusion of these income elasticities.

Importing Firms. Commodity prices could have a differential impact not only on exporters but also on importing firms. One would expect a positive impact of commodity prices on importers relative to nonimporters because importers purchase inputs instead of producing them, and are thus less exposed to the increase in labor costs induced by the cost channel. Appendix A.2.9 shows that this is the case. We also report that the negative coefficient on the interaction between the regional commodity price index and the exporter dummy variable is even larger in magnitude after controlling for an importer dummy variable. Finally, we also show that the response of importers to exchange rate movements does not confound our results.

3 Model

The stylized framework in the previous section allowed us to clearly lay out the conditions behind the identification of the cost and wealth channels. In this section, we develop a quantitative multisector small open economy model. The main differences with the previous framework are adding heterogeneous firms and a dynamic setting which allows for consumption smoothing with an endogenous current account. These features bring us closer to the data, and allow us to quantify the mechanisms involved in the transmission of commodity price super-cycles and to assess welfare.

The economy consists of commodity, nontradable (services), and tradable (manufacturing) sectors. In the commodity sector, a representative firm produces a homogeneous good using a scarce natural resource in fixed supply. The commodity price is exogenously determined in the world market. The commodity good can be exported. In the tradable and nontradable sectors, heterogeneous firms produce differentiated product varieties in a monopolistic competition setting.[23] Nontradable goods are consumed only domestically. Firms in the tradable sector can sell their varieties domestically or they can export subject to a fixed cost.[24] Firms in all sectors use both skilled and unskilled labor.

Skilled and unskilled labor are supplied inelastically by a representative household. This household demands the commodity good, the bundle of tradable varieties, the nontradable good, and an imported good; and it can borrow freely from the world.

We use the imported good as the numeraire. We index sectors by $k \in \{C, N, T\}$ (for commodity, nontradable, and tradable), skill types by $d \in \{U, S\}$ (for unskilled and skilled), and firms by f.

3.1 Representative Household

The representative household consumes imported (M), commodities (C^d), nontradable (N), and tradable (T) goods. It supplies skilled ($\bar{L}^s = (1-\kappa)\bar{L}$) and unskilled ($\bar{L}^u = \kappa\bar{L}$) labor inelastically.

[23] Because our results concern employment reallocation between the nontradable and tradable sectors, we impose the same market structure across them. In this way, the only differences between these two sectors are tradability and skill intensity in production. Note also that the two key differences between the commodity sector and the tradable (manufacturing) sector are the constant returns to scale (with a representative firm) in the commodity sector and that the commodity good is traded costlessly. These assumptions are immaterial to our results.

[24] In Appendix A.1.10 we document that fluctuations in regional commodity prices have an impact on firm entry and exit in the commodity, tradable and nontradable sectors, as well as on entry and exit in and out of exporting within the tradable sector. This motivates the inclusion of the entry and exit margins in the model.

Lifetime utility is:

$$U = \sum_{t=0}^{\infty} \beta^t \frac{(C_t)^{1-\nu}}{1-\nu}\,, \tag{6}$$

where $\nu > 1$ is the intertemporal elasticity of substitution and C_t is the final consumption bundle that is a nested-CES aggregate of M_t, C_t^d, N_t, and T_t:

$$C_t = \left\{ \left[\left[(M_t)^{\theta_1} + \alpha_T (T_t)^{\theta_1} \right]^{\frac{\theta_2}{\theta_1}} + \alpha_N (N_t)^{\theta_2} \right]^{\frac{\theta_4}{\theta_2}} + \alpha_C \left[C_t^d \right]^{\theta_4} \right\}^{\frac{1}{\theta_4}}\,. \tag{7}$$

The tradable bundle T_t and nontradable bundle N_t are both CES aggregators of individual varieties according to:

$$T_t = \left[\int_{\zeta \in \mathfrak{Z}_t} t_t(\zeta)^{\rho} d\zeta \right]^{\frac{1}{\rho}} \qquad \text{and} \qquad N_t = \left[\int_{\varphi \in \mathfrak{P}_t} n_t(\varphi)^{\rho} d\varphi \right]^{\frac{1}{\rho}}\,,$$

where ζ and φ are indices for individual varieties and $\mathfrak{Z}_t$ and $\mathfrak{P}_t$ denote the respective sets of individual varieties sold at time t.

Let P_t^C be the exogenous price of the commodity good, P_t^R the price of the fixed natural resource, P_t^N the price of the nontradable bundle, and P_t^T the price of the tradable bundle. With the exogenous price of the imported good normalized to one and used as the numéraire, the representative household budget constraint becomes:

$$M_t + P_t^N N_t + P_t^T T_t + P_t^C C_t^d + B_{t+1} \leq w_t^s \bar{L}^s + w_t^u \bar{L}^u + P_t^R \bar{R} + (1+r)\, B_t + \Pi_t\,, \tag{8}$$

where bonds are in units of the imported good and the interest rate r is exogenous. Π_t collects total profits from firms in the commodity, nontradable, and tradable sectors.

Therefore, the representative household takes as given the sequence $\{P_t^C, P_t^N, P_t^T, P_t^R, \Pi_t, w_t^s, w_t^u\}$ and chooses $\{B_t, N_t, C_t^d, N_t, T_t\}$ to maximize lifetime utility (equation (6)) subject to the budget constraint (equation (8)). Finally, we use the Euler equation for bonds to define the household's stochastic discount factor $\Lambda_{t,t+1}$:

$$\Lambda_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} = \frac{1}{1+r}\,. \tag{9}$$

Here λ_t is the marginal utility of consumption in period t. When equation (9) holds, $\Lambda_{t,t+1}$ is constant. When the household is surprised by a new sequence of commodity prices revealed at period $\tilde{t}$, the Euler equation does not hold in that period and the marginal utility experiences a discrete jump before reaching a new constant level in $\tilde{t}+1$. In other words, the permanent income hypothesis holds implying that the household decides a new constant level of consumption immediately after a change in the present value of its income. This optimal re-balancing of consumption is critical for characterizing the wealth channel.

3.2 Production

Labor Input. Firm f in each sector $k \in \{C, N, T\}$ uses a composite labor input that combines skilled and unskilled labor according to the following CES function:

$$l_f^k\left(l_{f,t}^{u,k}, l_{f,t}^{s,k}\right) \equiv \left[(\phi^k)^{\frac{1}{\gamma}}(l_{f,t}^{u,k})^{\frac{\gamma-1}{\gamma}} + (1-\phi^k)^{\frac{1}{\gamma}}(l_{f,t}^{s,k})^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{10}$$

where $l_{f,t}^{s,k}$ and $l_{f,t}^{u,k}$ are the skilled and unskilled labor inputs, respectively. We assume that the relative use of these two types of labor varies across sectors (ϕ^k), while the elasticity of substitution between skill types is constant across them. We can define the effective labor cost of sector k as:

$$\hat{w}_t^k = \left[\frac{\phi^k}{(w_t^u)^{\gamma-1}} + \frac{1-\phi^k}{(w_t^s)^{\gamma-1}}\right]^{-\frac{1}{\gamma-1}}. \tag{11}$$

Note that as the skill premium falls sectors with higher skill intensity (lower ϕ^k) see a decrease in their effective labor cost relative to low skill intensity sectors.

Commodity Sector. A representative firm produces the commodity good that can be sold domestically and exported internationally. To produce the commodity good, the representative firm combines the composite labor input L_t^C and a resource input R_t according to the following production function:

$$Y_t^C = \left(L_t^C\right)^{\eta} \cdot (R_t)^{1-\eta}.$$

The price of the commodity good, P_t^C, is determined exogenously in the international market. After the domestic demand is met, the remaining output is exported internationally.

Nontradable Sector. The nontradable sector is composed of a continuum of firms heterogeneous in productivity z each producing a differentiated variety φ under monopolistic competition. Each firm's permanent productivity type z is drawn upon entry from a log-normal distribution g with mean μ_N and standard deviation σ_N. A type-z firm produces its variety using the composite labor as the only input according to the following production function:

$$q_{Nt}(z) = z \cdot (l_{Nt}(z) - f_N) \ ,$$

where f_N is a fixed per-period production cost in terms of the labor input. In every period, all continuing firms are subject to an i.i.d. exit shock with probability δ_N. Potential entrants can enter the market by paying an entry cost consisting of a fixed and a convex component in terms of the composite labor input:

$$f_{Net} = f_{Ne} + \xi_{Ne} \left[\exp \left(\frac{\mathcal{M}_{Net} - \overline{\mathcal{M}}_{Ne}}{\overline{\mathcal{M}}_{Ne}} \right) - 1 \right] \ ,$$

where $\mathcal{M}_{Net}$ is the mass of potential entrants that pay the entry cost to observe their permanent individual productivity. The convex component of the entry cost captures congestion externalities or competition for a fixed resource at entry.[25] After paying the entry cost, the productivity type of the firm is revealed.

Tradable Sector. The production technology of the tradable sector is identical to that of the nontradable sector. There is a continuum of firms heterogeneous in productivity z, each producing a differentiated variety ζ using the following production function:

$$q_{Tt}(z) = z \cdot (l_{Tt}(z) - f_d) \ ,$$

where f_d is a fixed per-period production cost in terms of the composite labor input. Akin to the nontradable sector, each firm's productivity type z is permanent and is drawn from a log-normal distribution g with mean μ_T and standard deviation Σ_T upon entry.

Unlike the nontradable sector, firms in the tradable sector can export subject to a per-period

[25] This assumption is standard in dynamic models of heterogeneous firms (see for example Jaef and Lopez [2014]). It is used to avoid corner solutions in the transition, and the size of the convex component of the cost is set to be small relative to the fixed component so its effects on dynamics are minimal.

fixed cost f_x expressed in terms of the composite labor input. The foreign demand for exports is:

$$q^x_{Tt}(z) = \Gamma \left[p_{Tt}(z)\right]^{-\sigma} ,$$

where Γ is exogenous and fixed throughout the commodity super-cycle. In each period, all continuing firms face an exogenous exit risk that occurs with probability δ_T that is i.i.d. across firms and time. Meanwhile, potential entrants can enter the market subject to a fixed entry cost:

$$f_{Tet} = f_{Te} + \xi_{Te} \left[\exp\left(\frac{\mathcal{M}_{Tet} - \overline{\mathcal{M}}_{Te}}{\overline{\mathcal{M}}_{Te}}\right) - 1\right] .$$

3.3 Equilibrium

We now describe some key aspects of the equilibrium. The full system of equations and the definition of the equilibrium are deferred to Appendix D.1 and the steady state is described in Appendix D.2.

Entry and Exit in the Nontradable Sector. Firms are subject to an exogenous exit probability δ_N in every period. In addition, firms exit endogenously when the present discounted value of profits is negative. Letting optimal profits of a nontradable firm i be denoted by π_t, the value function of a firm with productivity z is:

$$W_t(z) = \max\left\{0, \pi_t(z) + \beta(1-\delta_N)W_{t+1}(z)\right\} .$$

The domestic productivity cutoff $\bar{z}_t$ is implicitly defined by the productivity level that solves $W_t(\bar{z}_t) = 0$.

In each period, potential entrants may pay the fixed entry cost to draw their permanent productivity levels z. If the realized draw is higher than the domestic cutoff, the firm will enter the market and produce. Potential entrants will pay to get their productivity draws until the present discounted value of entry is equal to the fixed entry cost:

$$\hat{w}_{Nt} \cdot f_{Net} = \int_{\bar{z}_t}^{\infty} W_t(z) g(z) dz \,.$$

Entry, Exit, and Exporting in the Tradable Sector. Entry and exit decisions in the tradable sector are identical to those in the nontradable sector. However, in the tradable sector, firms make the additional decision of whether or not to export.

Let $\pi_{m,t}$ denote the static profits associated with each sales mode $m \in \{d, x\}$ (selling domestically and exporting internationally, respectively). The value functions corresponding to each of these modes are:

$$W_{d,t}(z) = \max\{0, \pi_{d,t}(z) + \beta(1-\delta_N)W_{t+1}(z)\} \text{ , and}$$
$$W_{x,t}(z) = \max\{0, \pi_{d,t}(z) + \pi_{x,t}(z) + \beta(1-\delta_N)W_{t+1}(z)\} \text{ .}$$

The continuation value is given by: $W_{t+1}(z) = \max\{W_{d,t}(z), W_{x,t}(z)\}$. The domestic ($\bar{z}_{d,t}$) and export cutoffs ($\bar{z}_{x,t}$) are implicitly defined by $W_{d,t}(\bar{z}_{d,t}) = 0$ and $\pi_{x,t}(\bar{z}_{x,t}) = 0$. Finally, the free entry condition is:

$$\hat{w}_{Tt} \cdot f_{Tet} = \int_{\bar{z}_t}^{\infty} W_t(z)g(z)dz\,.$$

4 Quantitative Analysis

We calibrate the model with the goal of quantifying the mechanisms that propagate commodity price super-cycles throughout the economy. We use counterfactual simulations to determine the extent to which the labor market is a relevant channel of transmission to other sectors of the economy. This is relevant given the common assumption in the literature that commodity booms are purely endowment shocks. We proceed as follows. First, we describe the calibration of the model to the Brazilian economy. We then validate the calibration by simulating data from the model and replicating regressions results in Section 2.3 for outcomes which were not targeted in the calibration. Finally, we use the calibrated model to quantify transmission mechanisms.

4.1 Calibration

We calibrate two sets of parameters. The calibration is done at an annual frequency and uses data for the year 2001.[26]

[26] We choose 2001 because it is the year right before the start of the boom. The model is calibrated to the exact same sample used in the empirical analysis.

Externally Calibrated Parameters. Table 4 shows a first set of parameters that are either normalized or externally calibrated to values in the literature and to regional outcomes computed using the data described in Section 2.1. The discount factor (β) is consistent with an annual interest rate of 4%. The parameters governing risk aversion (υ), substitution between sectoral goods (θ's), substitution between tradable varieties (σ), and substitution between skilled and unskilled labor (γ) are taken from the international trade and international finance literatures. The exogenous sectoral exit rates (δ^N and δ^T) are computed directly from RAIS.

Because we study a small open economy that faces an exogenous interest rate, an initial condition for bond holdings is needed to solve the model. Without loss of generality, we assume that the economy starts with zero net foreign assets.[27] We normalize the total population of the economy to be 100. In addition, we set $\alpha_T = \alpha_M = 1$ and $P_T^l = P_M^l = 1$ such that importables and domestic tradables are symmetric in the initial steady state.

Table 4: Externally–Calibrated Parameters

Parameter	Description	Value	Source
r^*	Interest rate	0.04	Macroeconomic data
ν	Discount factor	1.5	Literature
σ	Elast. of substitution between varieties in T and N	4	Simonovska and Waugh [2014]
ρ	Inverse of markup in T and N	0.75	$\sigma = \frac{1}{1-\rho}$
γ	Elast. of subs. between skilled and unskilled labor	1.41	Katz and Murphy [1992]
η	Labor share in C	0.5	Gollin et al. [2014]
δ_T	Exogenous exit probability in T	0.14	Firm-level data (RAIS)
δ_N	Exogenous exit probability in N	0.18	Firm-level data (RAIS)
θ_1	Elast. of subs. between importables and domestic tradables	$\frac{1}{1-0.85}$	Corsetti et al. [2008]
θ_2	Elast. of subs. between tradables and nontradables	$\frac{1}{1-0.74}$	Mendoza [1995]
θ_3	Elast. of subs. between commodities and non-commodities	$\frac{1}{1-0.50}$	Buera and Kaboski [2009]
μ_T	Mean of productivity distribution in T	0	Normalization
$\bar{B}$	Steady state debt	0	Normalization
$\bar{H}$	Total inelastic labor supply	100	Normalization
α_T	Weight on T good in utility function	1	Normalization
P_T	Steady state price of T good	1	Normalization

NOTE: This table shows the values and sources of the externally-calibrated parameters. The abbreviations C, T and N stand for the commodity, tradable and nontradable sectors. Note that the elasticity of substitution between regional commodity goods is assumed to be the same than that between importables and domestic tradables.

[27]The model is solved using a shooting algorithm, in the spirit of Alberola and Benigno [2017], extended to our setting with heterogeneous firms. We show in Appendix B.3 that the quantitative results of the model are robust to alternative initial conditions or to including a bond–holding cost.

Internally Calibrated Parameters. Table 5 displays the set of 16 parameters that are internally calibrated. Twelve of these parameters are calibrated in the steady state. The initial price level of the commodity good (P_C) is used to match the commodity output share, while the weight on the nontradable good in the utility function (α_N) is used to target the nontradable output share. Because all commodity output in excess of domestic demand is exported, the weight on the commodity good (α_C) can be identified by the share of commodities in total exports. The fixed cost of exporting in the tradable sector (f_x) is calibrated to match the fraction of exporting firms. The firm size distributions in the tradable and nontradable sectors are used to discipline the fixed operating costs (f_d,f_N) and the variance of the productivity distributions (Σ_T,Σ_N). Having normalized μ_T (the mean of the productivity distribution in the tradable sector) to 0, the mean of the productivity distribution in the nontradable sector (μ_N) captures the relative differences in average size between the tradable and nontradable sectors. As such, we calibrate this parameter to the relative mass of firms between the two sectors. The size of foreign demand for exports (Γ) targets the export to GDP ratio. The endowment of the natural resource ($\bar{R}$) is used to match the commodity sector's share of total employment. We observe a close match between the model's moments and the target moments.[28]

The next set of parameters is calibrated to match perfectly macroeconomic ratios of the Brazilian economy. The share of unskilled labor in the model economy (κ) is set to generate the skill premium observed in Brazil. The skill intensities in each sector (ϕ_C, ϕ_T, ϕ_N) are chosen to replicate the share of unskilled labor in each sector.

The entry congestion elasticity (ξ_e) is calibrated using the transition over the commodity super-cycle. It is chosen such that at the peak of the boom, the convex component of the entry cost is 20% of the fixed component.

As Table 5 shows, the commodity sector in the Brazilian economy concentrates a modest share of firms and workers (commodity production represents only 12% of output). This means powerful internal amplification and propagation mechanisms must be present to generate the aggregate effects of a commodity price super-cycles documented in the literature.

Simulation. In the following exercises, we assume that the economy starts in a steady state in period 0. In period 1, a commodity price super-cycle is revealed to the agents. As Figure

[28] The only exception is the share of nontradable employment by the largest firms which can be attributed to the fact that the log normal productivity distribution used does not have fat tails.

Table 5: Internally–Calibrated Parameters

Parameter	Description	Moment Targeted	Moment (Data)	Moment (Model)	Param. Value
P_C	Commodity price	C share in GDP	0.14	0.13	26.86
α_N	Weight on N good in utility	N share in GDP	0.55	0.56	8.40
α_C	Weight on C good in utility	Share of C in exports	0.32	0.34	0.54
f_d	Production fixed cost in T	Share of T emp. in 20% smallest firms	0.02	0.03	0.06
f_x	Fixed cost of exporting in T	Fraction of exporting firms in T	0.09	0.08	1.40
Σ_T	St. dev. of productivity distribution in T	Share of T emp. in 10% largest firms	0.68	0.71	0.91
Γ	Foreign demand	Export to GDP ratio	0.15	0.19	281.16
$\bar{R}$	Resource endowment	C share in employment	0.08	0.08	3.63
f_N	Production fixed cost in N	Share of N emp. in 20% smallest firms	0.04	0.03	0.03
μ_N	Mean of productivity distribution in N	Relative mass of firms: M_T/M_N	0.27	0.27	0.25
Σ_N	St. dev. of productivity distribution in N	Share of N emp. in 10% largest firms	0.66	0.56	0.79
κ	Aggregate share of unskilled labor	Skill premium (w^s/w^u)	3.16	3.16	0.83
ϕ^C	Skill intensity in C	Shared of unskilled labor in C ($L^{u,C}/L^C$)	0.92	0.92	0.69
ϕ^N	Skill intensity in N	Shared of unskilled labor in N ($L^{u,N}/L^N$)	0.79	0.79	0.43
ϕ^T	Skill intensity in T	Shared of unskilled labor in T ($L^{u,T}/L^T$)	0.88	0.88	0.59
ξ_e	Entry congestion elasticity	Fraction of entry cost: $\max\{\frac{\text{cong. term}}{f_e}\}$	0.20	0.19	1

NOTE: This table shows the values of internally-calibrated parameters. The abbreviations C, T and N stand for the commodity, tradable and nontradable sectors.

3 shows, the price of the commodity good increases steadily for ten years (period identified by the darker gray area in each graph) and reaches a cumulative increase slightly above 70%. This trough-to-peak amplitude is obtained from the increase in commodity prices observed in Brazil between 2002 and 2011, as measured with employment-weighted prices at the national level. The commodity price then decreases steadily after the peak of the boom, reverting to the initial level after ten years. The price dynamic during the bust is extrapolated from the data in a symmetric fashion.

4.2 Model Validation

Prior to quantifying the mechanisms of the model, we perform a validation exercise focusing on key nontargeted moments. Using simulated data based on the model's response to the price sequence used in our quantitative analysis (shown in Figure 3), we estimate regressions that are analogous

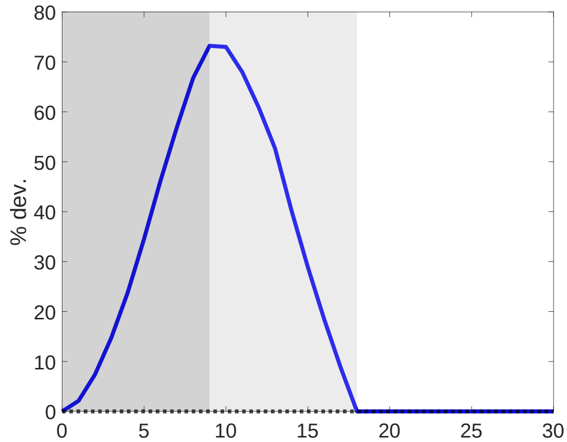


Figure 3: Commodity Price Super-Cycle

NOTE: This figure shows the path of the price of the commodity good used in the quantitative analysis.

to those estimated in the empirical section.

First, we show that the model can replicate the evolution of the skill premium. We estimate the following regression of the (log) skill premium on the (log) commodity price sequence using the simulated data:

$$\mathrm{SP}_t = \beta_1 \cdot \mathrm{Price}_t + \epsilon_t \,. \tag{12}$$

Since our model has a single region, we exclude the regional fixed effects from equation (3) when using the simulated data. The results are displayed in column 1 of Table 6. In column 2 we report equivalent results for the skill premium estimated using the actual data. To match the model calibration, we use annual data. In addition, we use state–level data because some of the data used to calibrate the model varies at the state–level.[29] This comparison indicates that the model matches very closely the skill premium dynamics triggered by the commodity price super-cycle.[30]

The intersectoral reallocation of labor between the tradable and nontradable sectors lies at the core of the transmission of commodity price super-cycles in our framework. Therefore, this is another important dimension along which to test the calibrated model. To this end, we estimate the following equation of sectoral employment shares (Emp. Share$_{rst}$) on an interaction term

[29]Specifically, in Appendix B.1 we develop a multiregion version of the model which we calibrate using state–level domestic trade flows.

[30]The simulated price series fed into the model (shown in Figure 3) is based on the bust to boom commodity price increase in each state from 2002 to 2013, with 2002 corresponding to the initial steady state in the model. In this subsection, we contrast data and model using in both cases the “transition years” 2003-2013.

Table 6: Model Validation: Skill Premium and Regional Employment

	(1)	(2)	(3)	(4)
	Skill Premium		Regional Employment	
	Model	Data	Model	Data
Price	-0.085***	-0.221***		
	(0.003)	(0.087)		
Price $\cdot T_s$			-0.053***	-0.199***
			(0.002)	(0.026)
Observations	11	267	22	594

Note: The first two columns report the results of the estimation of equation (12). Column 1 includes year fixed effects; column 2 includes state and year fixed effects. The last two columns report the results of the estimation of equation (13). Column 3 includes sector and year fixed effects; column 4 includes sector and state × year fixed effects. Columns 1 and 3 use simulated data. Columns 2 and 4 use the actual data. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

between the commodity price and a tradable sector dummy (T_s), and sector and time fixed effects:

$$\text{Emp. Share}_{st} = \beta_1 \cdot \text{Price}_t \cdot T_s + \gamma_s + \delta_t + \epsilon_{st}\,. \tag{13}$$

In the regression estimated with the actual data, we replace the sector and time fixed effects by a set of region × time and sector fixed effects. The coefficient β_1 measures the differential employment response in the tradable sector relative to the nontradable sector. As before, to match the model closely, we use data at an annual frequency with each observation corresponding to a state, although we find similar patterns using data at the microregion level. We compare the estimated parameters obtained using the simulated data with those obtained based on the actual data. The results are reported in columns 3 and 4 in Table 6. We observe a close match between model and data in the reallocation of employment across sectors.

Finally, we compare the model-generated firm-level employment responses to the commodity price super-cycle to those estimated from the actual data to distinguish between the impact of prices on exporting and nonexporting firms in the tradable sector. Specifically, we estimate the following equation:

$$\log(\text{Emp})_{ft} = \beta_1 \cdot \text{Exporter}_{ft} + \beta_2 \cdot \text{Exporter}_{ft} \cdot \text{Price}_t + \gamma_f + \delta_t + \epsilon_{ft}\,. \tag{14}$$

This equation is analogous to equation (5) estimated in the empirical section. Once again, we use actual data with prices defined at the state level at an annual frequency to be consistent with the model calibration. The results are displayed in Table 7, and again show a close parallel between the behavior of the model and the empirical results.

Table 7: Model Validation: Firm-Level Employment

	(1)	(2)
	Tradable	
	Model	Data
Exporter$_{ft}$ x Price$_{rt}$	-0.264***	-0.094***
	(0.000)	(0.024)
Observations	1,315,872	1,538,219

NOTE: Columns 1 and 2 in this table reports the results of the estimation of equation (14) using the simulated and actual data respectively. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

It is worth noting that when using the actual data we estimate cross-regional regressions. In contrast, the simulated data are based on a single–region model. Appendix B.1 presents the extension to the multiregion setting, which includes interregional trade and migration. Given that the multiregion model is closer to the empirical design, it is not surprising that with this framework we find an even closer fit between the regression results obtained using model–simulated and actual data. Nonetheless, to a large extent our more parsimonious model captures the key features of the data.

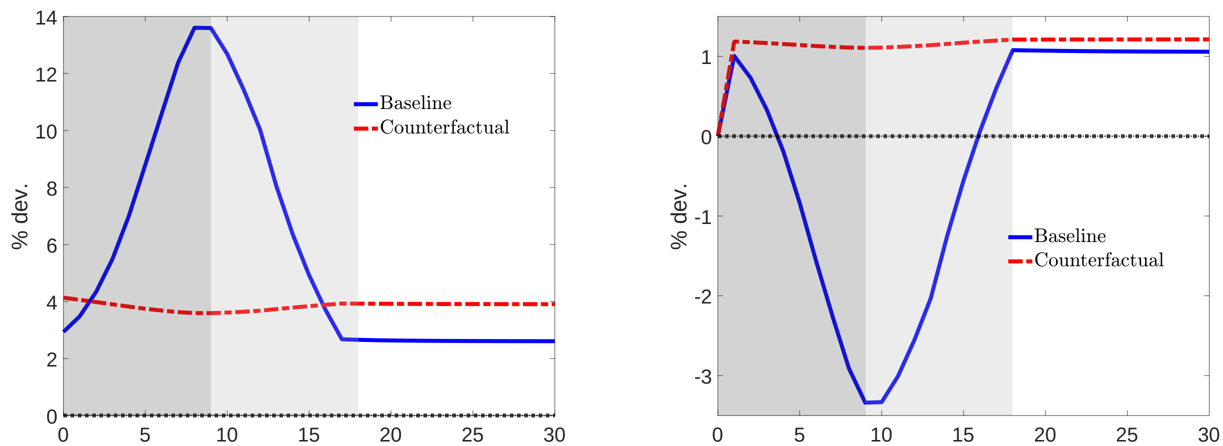
4.3 Transmission Mechanisms

We first use the calibrated model to analyze the extent to which the labor market is a relevant channel of transmission to other sectors of the economy. We first focus on labor reallocation, including both intersectoral reallocation between the tradable (i.e., manufacturing) and nontradable (i.e., service) sectors as well as on reallocation within the tradable sector. Having a calibrated model allows us to document general equilibrium effects, furthering our understanding of the role of labor markets in the transmission of a commodity boom.

For this purpose, we compare the baseline economy to a counterfactual economy in which the commodity sector's labor demand does not change in response to commodity price fluctuations, thus shutting down transmission through the labor market. Therefore, in the counterfactual economy, a commodity boom becomes purely an endowment shock. To construct this counterfactual economy, we fix the commodity sector's employment at the initial steady-state level. We calculate and feed to it a path for the natural resource stock such that commodity output follows the same trajectory in the counterfactual and baseline economies. Thus, commodity prices, output, and revenue are also identical in both economies. In the counterfactual economy, by construction, the commodity super-cycle has no direct impact on wages. Second–order wage movements in the counterfactual economy are the result of general equilibrium effects due to increases in wealth.

Consider first the reallocation of labor between the tradable and nontradable sectors. In the baseline economy, the commodity boom raises the demand for labor in the commodity sector, leading to an increase in wages during the boom (see Figure 4a), which implies a cost increase in both the tradable and nontradable sectors. Given that the tradable sector is unskilled intensive relative to the nontradable sector, the skill premium falls (see Figure 4b) and the cost increase in the baseline economy is larger in the tradable sector. In addition, the increase in wages during the boom raises the prices of all goods, lowering the domestic demand for output, which has a negative impact on sales for the nontradable sector and on domestic sales for the tradable sector. Overlapping these mechanisms, the commodity price boom leads to a decline in employment in tradables relative to nontradables, as shown in Figure 5a. In contrast, in the counterfactual economy, the expansion of the commodity sector leads to changes in wages only through general equilibrium effects, so the reallocation of labor is driven primarily by changes in spending. It is worth noting that in the counterfactual economy the increase in wealth leads to more demand for both tradable and nontradable goods. Given that only tradables can be imported, there is an increase in the production of nontradables relative to tradables. Because the nontradable sector is relatively skilled intensive, this leads to a (small) increase in the skill premium, in contrast to the large decline in the skill premium seen in the baseline economy.

By comparing the baseline and counterfactual economies, we find that about 70% (measured at the peak of the boom) of the intersectoral reallocation in labor between tradables and nontradables is due to changes in wages resulting from the increased labor demand from the commodity sector. The remaining reallocation can thus be attributed to the overall wealth increase in the economy due to the commodity boom, which causes a disproportionate increase in the demand for nontradables. It is worth noting that in the first periods, both the baseline and counterfactual economies behave similarly, and the difference appears gradually over time. The reason is that both economies immediately adjust to the increase in permanent wealth resulting from the anticipated boom, while only the baseline economy faces a gradual reallocation of labor as a result of the transmission occuring through the labor market as the boom develops.



a) Unskilled Wage

b) Skill Premium

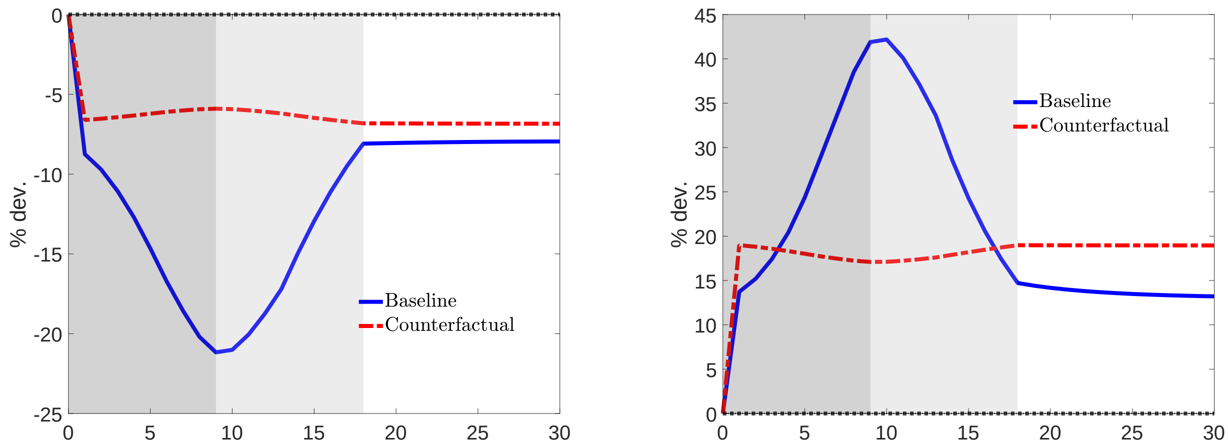
Figure 4: Wage Dynamics in the Baseline and Counterfactual Economies

NOTE: This figure shows the response of the unskilled wages and the skill premium to the commodity price super-cycle shown in Figure 3. The blue solid line corresponds to the baseline economy and the red dashed line corresponds to the counterfactual economy described in Section 4.3.

The second outcome on which we focus is the intrasectoral reallocation of labor within the tradable sector, distinguishing between workers producing output for domestic sales versus exports. In the baseline economy, the commodity boom raises local spending, which benefits goods sold locally relative to goods that are exported. In the tradable sector, this leads to an increase in employment oriented toward domestic relative to export sales during the boom.

We focus on a single firm that sells domestically and exports in every period, and compute the ratio between employment oriented to domestic versus export sales.[31] In Figure 5b, we plot this ratio in the baseline and counterfactual economies. Comparing both economies, we find that about 60% (measured at the peak of the boom) of the reallocation of labor within this marginal exporter in the tradable sector is due to changes in wages resulting from the increased labor demand from the commodity sector. Note that wages impact changes in the proportion of employment producing output for domestic versus export sales through general equilibrium

[31]We choose a "marginal exporter" that is the least productive exporter at the peak of the boom (i.e., the least productive firm that exports in every period). In the counterfactual economy, we focus on a firm with the same productivity than this marginal exporter in the baseline economy.



a) Relative T to N Employment (L^T/L^N)

b) Relative Employment in Domestic to Exported Production for Marginal Exporter in T (L_d^T/L_x^T)

Figure 5: Employment Reallocation in the Baseline and Counterfactual Economies

NOTE: This figure shows the response of the relative tradable to nontradable sector employment (left) and the ratio of labor employed in the production of tradables for the domestic market to labor employed in the production of tradables for the foreign market in the marginal exporter defined in the text (right) to the commodity price super-cycle shown in Figure 3. The blue solid line corresponds to the baseline economy and the red dashed line corresponds to the counterfactual economy described in Section 4.3.

effects. Higher wages in the domestic economy lead to an increase in prices, which, aggregated in the price index, lead to changes in demand for domestic relative to exported output. The remaining reallocation is caused by the wealth increase in the economy due to the commodity boom, which causes a disproportionate increase in the demand for local sales. As in the case of intersectoral reallocation, we document a similar behavior of the baseline and counterfactual economies in the initial period and a subsequent divergence for the same reason discussed earlier.

Overall, the findings on labor reallocation highlight the first order role played by the labor market in propagating commodity price cycles throughout the economy.

4.4 Aggregate Impact and Welfare

We now evaluate the macroeconomic effects of a commodity price super-cycle. We motivated this section arguing that standard models in the literature view commodity booms as endowment shocks, abstracting from the transmission through the labor market. We showed earlier that labor markets are quantitatively important when studying the impact of a commodity price cycle on the reallocation of labor across and within sectors. We now conclude by asking what are the aggregate impacts of acknowledging labor markets as a transmission mechanism.

In Figure 6a, we plot GDP (measured in units of the consumption basket). In the counterfactual economy, the increase in GDP is more than twice as large, foreshadowing larger welfare gains as well. The reason is that in this case the expansion of the commodity sector is driven by an increase in the resource endowment instead of by absorbing labor from the tradable and nontradable sectors. Thus, the other sectors do not contract to fuel the commodity boom.

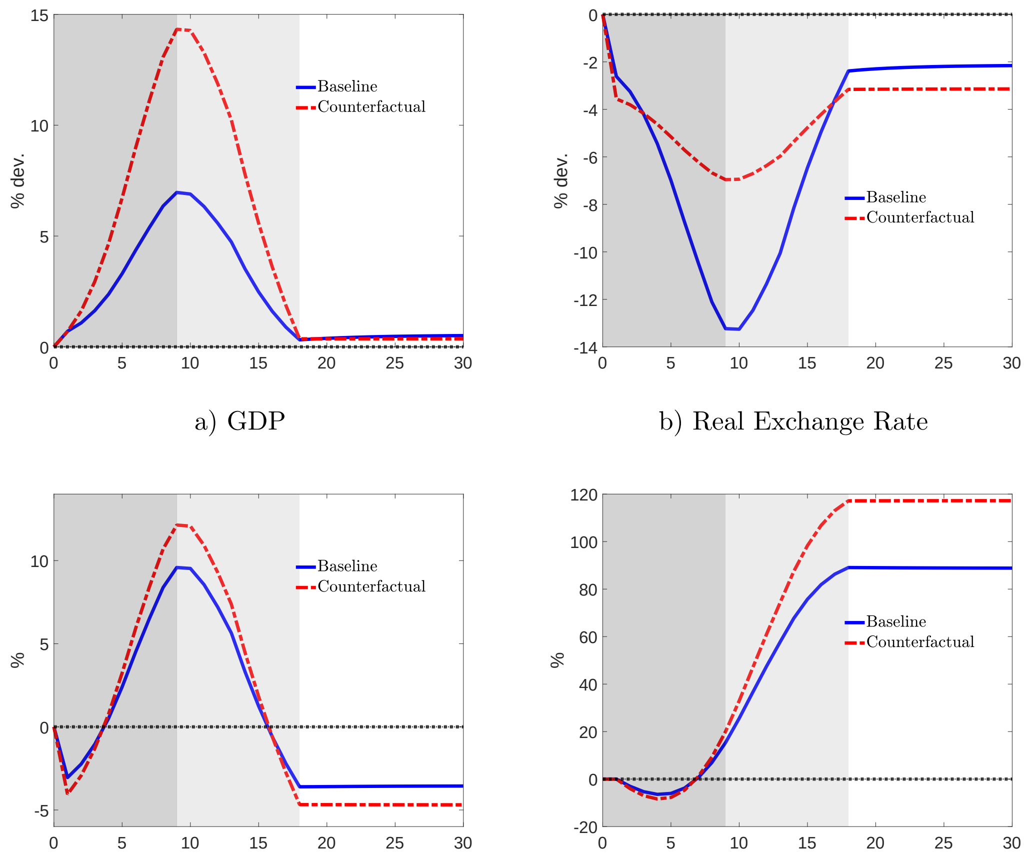
Figure 6b plots the path of the real exchange rate. Consistent with the empirical cross-country literature, the real exchange rate appreciates persistently (domestic prices increase as the economy is permanently wealthier).[32] Interestingly, the counterfactual economy has a weaker appreciation of the real exchange rate. The domestic consumption basket faces the same increase in commodity prices in both economies. However, in the baseline economy, the increase in wages following rising labor demand in the commodity sector leads to an increase in the cost of tradable and nontradable production. This supply–side effect dominates differences in the demand for these goods between both economies, and leads to a larger increase in the price of tradable and nontradable output in the baseline case.

Next, Figure 6c describes the evolution of the trade balance. In line with the permanent income hypothesis, the representative household adjusts its permanent consumption level on impact and chooses a new and higher level of consumption. Thus, the trade balance follows a countercyclical path. The difference between the baseline and counterfactual economies is due to two opposite forces. First, the larger increase in wealth in the counterfactual economy leads to a larger rise in consumption, which worsens the trade balance relative to the baseline economy. Second, in the counterfactual economy the commodity sector does not draw labor from the tradable sector. In addition, the smaller adjustment in wages leads to a smaller increase in the price of tradable output. Thus, tradable exports fall less in the counterfactual economy, improving the trade balance relative to the baseline economy.

In addition, Figure 6d plots the path of net foreign assets, showing larger wealth accumulation in the counterfactual economy. The reason is that the expansion of the commodity sector in counterfactual economy is driven by an expansion of the natural resource, without drawing labor from other sectors.

To conclude, we analyze the impact of the commodity cycle on welfare and on the long–

[32]The real exchange rate is defined as the inverse of the ideal price index of the consumption bundle.



a) GDP

b) Real Exchange Rate

c) Trade Balance to GDP ratio

d) Net Foreign Assets to GDP ratio

Figure 6: Response of Macroeconomic Outcomes to a Commodity Price Super-Cycle

NOTE: This figure shows the response of consumption-deflated GDP (top left), the real exchange rate (top right), the trade balance to GDP ratio (bottom left), and the net foreign assets to GDP ratio (bottom right) to the commodity price super-cycle shown in Figure 3. The blue solid line corresponds to the baseline economy and the red dashed line corresponds to the counterfactual economy described in Section 4.3.

run steady state of net foreign assets.[33,34] The first row in column 1 in Table 8 indicates that

[33]To assess the impact of the commodity price super-cycle on welfare we calculate the consumption-equivalent welfare gain from the episode. This is the difference between the welfare gain of an economy exposed to the cycle (W_{cycle}) versus that of one not exposed (W_0), measured as the amount of consumption the representative household would have to receive to be indifferent between experiencing the cycle and remaining in the initial steady state. This is:

$$\text{Consumption-Equivalent Welfare Gain} = \left(\frac{W_{cycle}}{W_0}\right)^{\frac{1}{1-\upsilon}} - 1\,. \tag{15}$$

[34]There are two sources of inefficiency in the model. First, the standard inefficiency of Melitz [2003] type models arising from markups, which does not vary during the commodity price cycle as markups are constant. Second, the cycle ends with net savings and a permanently appreciated real exchange rate (relative to the original steady-state level). This long-run effect on prices leads to a permanent change in production allocation between sectors, which is not internalized by the firms or the representative household. This is akin to the long-run effect of a financial liberalization analyzed by Saffie et al. [2020] and can be traced back to the immiserating growth result in Bhagwati [1958]. Note that a bond–holding cost (an extension discussed later in this section) eliminates this

consumption–equivalent welfare in the baseline economy is 2.27%, implying that the representative household should receive at least a 2.27% permanent increase in steady–state consumption to be willing to forgo the commodity boom–bust cycle. We compare this to the counterfactual economy (shown in the second row), which features nearly twice the amount of consumption–equivalent welfare from the commodity cycle and which accumulates 30% more wealth than the baseline economy. The reason is that, in the counterfactual economy, the lack of transmission through the labor market eliminates the contraction in tradable and nontradable output.

Next, we explore whether some of our key modeling assumptions also impact welfare and wealth accumulation. To this end, we refer to the extensions of our model presented in Appendix B.[35] In the case of the multiregion model developed in Appendix B.1 (see the third row), consumption–equivalent welfare from the commodity cycle is 0.41 percentage points lower than in the baseline economy, given that it is costly to move goods and workers across regions. At the same time, wealth accumulation is only slightly below the baseline economy. We also consider a model with a representative firm, which is much closer to the model of Alberola and Benigno [2017] (see Appendix B.2). As seen in the fourth row, this model has a 0.26 percentage point lower consumption–equivalent welfare from the commodity cycle than the baseline economy. We also see in rows five and six that assumptions about initial household debt have a small impact on welfare and wealth accumulation. Similarly, introducing a bond–holding cost that forces the economy to converge to the original steady state in the long run does not significantly impact welfare, as seen in the seventh row (see Appendix B.4). Finally, given the role played by the trade balance, it is also worth assessing whether changes in trade costs impact welfare. However, changes in export fixed costs only have minor effects, as seen in the last two rows.[36]

Summing up, the most important determinant of consumption–equivalent welfare and wealth accumulation is whether the labor market is allowed to play a role in the transmission of the commodity cycle. To a smaller extent, modeling assumptions such as interregional trade and migration (featured in the multiregion model) as well as firm heterogeneity also have an effect on welfare calculations.

long–run inefficiency by forcing the economy to return to its original steady state after the commodity cycle.

[35] In Appendix B we also report the robustness of other outcomes to the alternative modeling assumptions and parametrizations discussed in these paragraphs.

[36] We explore further model simulations in the Appendix. Specifically, given that the literature has established that commodity booms are often accompanied by reductions in interest rates [Shousha, 2016, Fernández et al., 2017a] in Appendix B.6 we use the calibrated model to contrast the response of the economy to a commodity cycle versus a temporary reduction in the real interest rate.

Table 8: Welfare and Long–Run Net Foreign Assets

	CEQ Welfare (%)	Long Run B/Y
Baseline	2.27	0.89
GE Counterfactual	4.38	1.17
Multiregion Model (Appendix B.1)	1.86	0.84
Rep. Firm Model (Appendix B.2)	2.02	1.06
$B_0/Y = 0.20$ (Appendix B.3)	2.19	1.07
$B_0/Y = -0.20$ (Appendix B.3)	2.37	0.71
Bond-holding cost (Appendix B.4)	2.25	0
High f_x (Appendix B.5)	2.10	0.92
Low f_x (Appendix B.5)	2.49	0.85

Note: This table reports consumption–equivalent welfare (column 1) and the long–run value of the net foreign assets to GDP ratio (column 2) to the commodity price super-cycle shown in Figure 3. The rows correspond to the baseline economy (first row), the counterfactual economy described in Section 4.3 (second row), the model with a representative firm in the tradable and nontradable sectors (third row), the multiregion model (fourth row), the baseline economy with an initial value of net foreign assets to GDP equal to 0.2 or -0.2 (fifth and sixth rows), the baseline economy adding a bond–holding cost (seventh row), and the baseline economy with a higher or lower value of the fixed cost of exporting (eighth and ninth rows).

5 Conclusions

In this paper, we study the transmission of commodity price super-cycles throughout the economy. We combine rich administrative microdata, a novel empirical strategy, and a quantitative multi-sector model of firm dynamics to identify and quantify key transmission channels in the context of a large commodity boom in Brazil.

We focus on two key transmission channels that were originally proposed by Corden and Neary [1982]'s analysis of the Dutch disease. In response to a commodity boom, an increase in wealth boosts local demand. In addition, an increase in the commodity sector's labor demand generates a cost increase for all sectors of the economy. We extend this framework by studying the heterogeneous impact of each of these mechanisms across firms and sectors, depending on their exposure to local demand (in the case of the wealth channel) and on their skill intensity (in the case of the cost channel). This heterogeneity is the key to the empirical strategy we design to identify the existence of these channels in the data. Our empirical work exploits variation across Brazilian regions in terms of their exposure to the large commodity boom in the 2000s. Using unique microdata on the universe of formal-sector firms across the commodity, manufacturing, and services sectors, we provide robust evidence of the existence of these two transmission channels. We then build and calibrate a multisector model that fits the empirical setting tightly. This model allows us to quantify the transmission mechanisms, study counterfactuals, and assess welfare. We find that transmission through the labor market is crucial. A counterfactual economy which abstracts from it experiences only 30% of the intersectoral labor reallocation between tradables and nontradables, and 40% of the labor reallocation between domestic and exported production within the tradable sector. From an aggregate perspective, the consumption–equivalent welfare gain obtained from a commodity super–cycle is twice as large in the counterfactual economy.

Given the importance of the labor market in the transmission of commodity price super–cycles, one can imagine that labor market frictions can lead to recessions and unemployment during the bust. Future work could extend our framework to study the optimal policy response to commodity cycles under such frictions.

6 Data Availability Statement

Part of the data used in this article consist of confidential administrative records from Brazil, which cannot be shared publicly. A replication package including codes, instructions on how to access the confidential data, and the part of the data that can be shared publicly, are available on Zenodo at https://doi.org/10.5281/zenodo.8118050

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Online Appendix To:

The Transmission of Commodity Price Super-Cycles

Felipe Benguria Felipe Saffie Sergio Urzua

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A Empirical Appendix

A.1 Data and Additional Results

A.1.1 List of Data Sources.

In what follows we describe each of the additional data sources used in the paper. Our two main data sources (RAIS and commodity prices from the World Bank's Global Economic Monitor - Commodities) are described in the main text.

Demographic Census. We use the long forms of Brazil's Demographic Census in year 2000 to i) construct weights for the commodity price index as defined in Section 2.1; ii) compute regional informality shares as described in Appendix A.2.8; iii) create the map of regional specialization in commodities in Appendix A.1.2; iv) construct weights for the import penetration measures in Appendix A.2.6; and v) compute shares of commodity employment concentration examined in Appendix A.1.8. Additionally we use the 1991 Census to construct weights for regional tariffs as described in Section A.2.7. Weights are computed based on employed individuals aged 20-60.

Trade Flows. We use the United Nations' COMTRADE database to construct measures of Chinese imports used in Appendix A.2.6 and to compute Brazil's market shares in commodities in world markets examined in Appendix A.1.7. Industry-level trade data are originally reported in COMTRADE according to the ISIC revision 3 classification, and converted to three-digit level CNAE industries using a cross-walk provided by Brazil's Statistical Institute (IBGE).

Firm-level Exporter and Importer Status. We obtain a list of the universe of exporting and importing firms from Brazil's Secretariat of Foreign Trade (SECEX), which we match to RAIS. This is available at a yearly frequency.

Import Tariffs. We obtain industry-level tariffs in 1990 and 1995 from Kovak [2013]. We compute the change in industry-level tariffs as described in Appendix A.2.7.

Input-Output Table. We use Brazil's 2005 input-output table with 56 sectors and 110 products to identify tradable industries with upstream or downstream linkages to the commodity sector in

Appendix A.2.3. This input-output table is produced by Brazil's Statistical Institute (IBGE).

Interregional Trade Patterns. We use data on interstate trade flows for 1999 compiled by Vasconcelos [2001] and recorded as a result of Brazil's state tax on the movement of goods and services (Imposto sobre Circulacao de Mercadorias e Servicos - ICMS). These data have also been used by Morten and Oliveira [2016].

Tradability Measure. We use a measure of industries' tradability constructed by Holmes and Stevens [2014] for the U.S. based on the Commodity Flow Survey. We map this to the Brazilian CNAE classification. Appendix A.1.6 provides more details and descriptive statistics.

Income Elasticities. We obtain industry-level measures of income elasticities from Borusyak and Jaravel [2018], estimated using the US consumer expenditure survey (CEX).

Geographic data. We obtain data on administrative regional units from Brazil's Statistical Institute (IBGE). These allow us to match municipalities to microregions, macroregions and states.

A.1.2 Descriptive Statistics.

This section reports a set of descriptive statistics on the firm panel across regions and sectors and on the skill premium across regions.

There is wide variation across regions and sectors in the number of firms, firm employment, and the share of exporting firms, as Table A1 shows. In all five Brazilian macroregions, commodity firms are fewer than those in the tradable and nontradable sectors and are also substantially larger. The share of exporters in the tradable sector varies from 3 percent in the *South* to 10 percent in the *North*.[4] Table A2 illustrates the regional variation in the relative wage of skilled to unskilled workers, which ranges from 2.64 in the *Southeast* to 3.57 in the *South* in the middle of our sample period (2006).

Figure A1 illustrates the regional variation in the degree of specialization in commodity production. For each region, we compute the share of employment in the commodity sector as a share

[4]The shares of exporting firms reported in Appendix Table A1 are low in comparison to those reported in the literature for other countries. Part of the reason is that we restrict our sample to firms with 5 or more workers, whereas datasets used in the literature have a higher threshold. In addition larger economies typically have smaller shares of exporters.

Table A1: Summary Statistics by Macroregion and Sector - Firm Panel

Macroregion	Sector	Number of Firms	Mean Employment	Share of Exporters
North	Commodity	1088	68.3	0.04
	Tradable	4144	53.9	0.10
	Nontradable	18416	27.0	0.00
Northeast	Commodity	3312	81.3	0.06
	Tradable	14909	46.5	0.04
	Nontradable	69301	25.6	0.00
Central-West	Commodity	7647	116.9	0.03
	Tradable	71720	46.9	0.09
	Nontradable	262454	29.3	0.01
Southeast	Commodity	3490	73.5	0.02
	Tradable	36754	45.4	0.09
	Nontradable	88162	22.1	0.01
South	Commodity	1782	138.3	0.02
	Tradable	7467	34.3	0.03
	Nontradable	37178	24.7	0.00

Note: This table reports the number of firms, mean firm employment, and the share of exporting firms, by macroregion and sector in the first quarter of 2006, which is the year in the middle of our sample. These statistics are computed from the sample of firms with at least 5 workers used in the firm-level regressions in the main text.

Table A2: Summary Statistics by Macroregion: Wages and Skill Premium

Macroregion	Mean Skilled Wage	Mean Unskilled Wage	Skill Premium
North	1541.66	517.82	2.98
Northeast	1229.50	412.70	2.98
Central-West	1707.46	582.50	2.93
Southeast	1396.16	528.77	2.64
South	2120.77	594.73	3.57

Note: This table reports the mean monthly wage for skilled and unskilled workers and the skill premium by macroregion in 2006, which is the year in the middle of our sample. Wages are reported in real *Reais* of 2000.

of regional employment using Brazil's Demographic Census in year 2000. The map shows four shades that correspond to quartiles of the distribution of the share of regional employment in the commodity sector. Darker shades reflect a larger share of employment in commodities. As the figure shows, we find a larger degree of specialization in commodities in the *North* and *Northeast*, and a lower degree of commodity specialization in the *Southeast*.

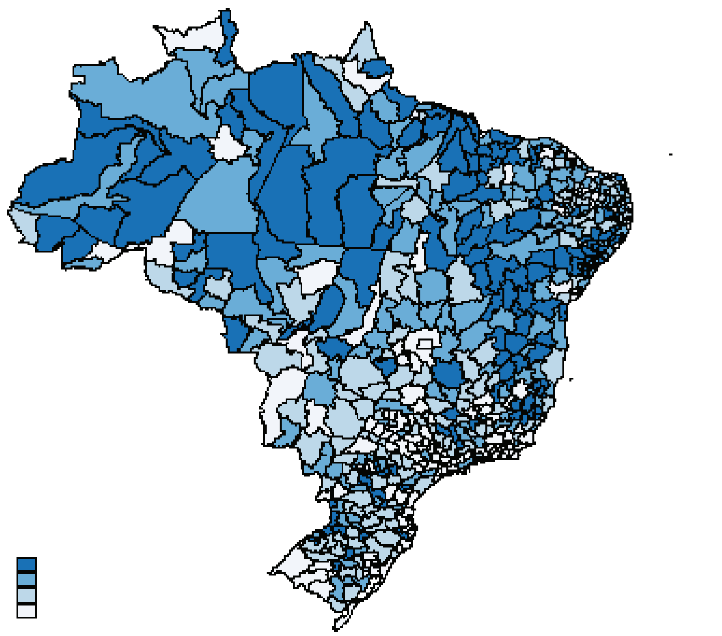


Figure A1: Regional Specialization in Commodities

A.1.3 The Distribution of Skill Intensity across Sectors.

Table A3 represents the means, standard deviations, and various percentiles of the distribution of skill intensity across two-digit industries for the commodity, tradable, and nontradable sectors.

Table A3: Distribution of Skill Intensity Across Industries

	Commodity	Tradable	Nontradable
Mean	0.074	0.107	0.199
St. Dev.	0.075	0.064	0.162
p10	0.017	0.028	0.033
p25	0.025	0.052	0.057
p50	0.048	0.105	0.146
p75	0.127	0.149	0.307
p90	0.221	0.185	0.398

NOTE: This table reports the mean, std. deviation, and various percentiles of the distribution of skill intensity across two-digit industries for the commodity, tradable, and nontradable sectors..

A.1.4 Regional Commodity Prices and Skilled and Unskilled Wages

In this section we report results regarding the impact of commodity prices on wages of unskilled and skilled workers. In the main text, equation (3) captures the relationship between the regional skill premium and the regional price index. Here, we replace the dependent variable by the log of the average skilled or unskilled wage. As in column 2 in Table 1, wages correspond to monthly (December) earnings. The results are shown in Table A4. They indicate that an increase in commodity prices leads to a large increase in unskilled wages. A one log point increase in the regional commodity price index is associated with a 0.163 log point increase in unskilled wages.[5] The coefficient for skilled wages is also positive but smaller in magnitude and not statistically significant.

Table A4: Commodity Prices and Regional Wages

	(1) Unskilled Wage	(2) Skilled Wage
Price_{rt}	0.163***	0.032
	(0.039)	(0.071)
Observations	7919	7912
R^2	0.925	0.841

NOTE: This table reports the results of the estimation of equation (3) with (log) unskilled wages (column 1) or (log) skilled wages (column 2) as the dependent variable. Wages correspond to monthly (December) earnings. Each regression includes region as well as macroregion × time (year) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

[5]Note that this elasticity implies that an increase in commodity prices such as that seen in Brazil between the second quarter of 2002 and the last quarter of 2011 (a 55 log point trough-to-peak increase) would lead to an 8.97 log point increase in unskilled wages.

A.1.5 Regional Employment and Commodity Prices

In this section we report additional results on the impact of commodity prices on regional employment. First, we show that commodity price fluctuations reallocate regional employment across sectors. Second, we measure the impact on a region's total employment in all sectors.

To measure how commodity price fluctuations reallocate regional employment across sectors we estimate equation (A1) for each sector at a time:

$$\text{Emp. Share}_{rt} = \beta \cdot \text{Price}_{rt} + \gamma_r + \delta_t + \epsilon_{rt}\,. \tag{A1}$$

We take advantage of the availability of quarterly employment data and use 60 observations for each of the 558 regions. Employment and commodity prices are measured in the last month of each quarter. The dependent variable is the share of employment in each sector in total regional employment. Using these shares rather than total sectoral employment prevents our results from being driven by an impact of commodity prices on total regional employment.[6] As in the skill-premium regression from the main text, we include region fixed effects as well as macroregion × time (year–quarter) fixed effects. We cluster standard errors by region.

The results are reported in Table A5. A one log point increase in the regional commodity price index is associated with an increase of 0.069 percentage points (p.p.) in the regional share of commodity employment (column 1), a 0.027 p.p. decline in the share of tradable employment (column 2), and a 0.012 p.p. positive but not statistically significant change in the share of nontradable employment. The 55 log point increase in commodity prices in Brazil during 2002q2 and 2011q4 would then be associated with a 3.78 p.p higher share of employment in the commodity sector, and a 1.5 p.p. lower share in the tradable sector. The reallocation of labor across sectors is driven primarily by changes in unskilled employment shares, as we show below.

To measure the impact on employment levels, we re-estimate equation (A1) but using total regional employment as the right-hand side variable. We find a large increase in regional employment: a one log point increase in the regional commodity price index is associated with a 0.288 log point increase in employment.

Finally, to quantify the impact on sectoral employment by skill category we repeat the analysis but now separately by sector and skill type. The results are displayed in Table A7. As suggested by

[6] We show below that in fact commodity prices are positively correlated with total regional employment.

Table A5: Commodity Prices and Shares of Sectoral Employment

	(1) Commodity	(2) Tradable	(3) Nontradable
Price_{rt}	0.069***	-0.027*	0.012
	(0.018)	(0.017)	(0.020)
Observations	33480	33480	33480
R^2	0.895	0.916	0.875

NOTE: This table reports the results of the estimation of equation (A1). Column 1 corresponds to the commodity sector. Column 2 corresponds to the tradable sector. Column 3 corresponds to the nontradable sector. Each regression includes region as well as macroregion × time (year–quarter) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

Table A6: Total Regional Employment

	(1)
Price_{rt}	0.288***
	(0.068)
Observations	33480
R^2	0.986

NOTE: This table reports the results of the estimation of equation (A1) using total regional employment as the dependent variable. This regression includes region as well as macroregion × time (year–quarter) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

the economic mechanisms described in the main text, across all sectors, the impact of commodity prices is larger for unskilled employment.

Firm–level regressions. We also report here results of firm–level regressions on firm–employment by sector. These regressions are akin to equation (4) in the main text, but without the interaction term:

$$\log(\text{Emp})_{ft} = \alpha_0 \cdot \text{Price}_{rt} + \gamma_f + \delta_{st} + \epsilon_{ft} \,. \tag{A2}$$

These results, shown in Table A8, reflect the superposition of all transmission channels. The first column indicates that for firms in the commodity sector a one log point increase in the regional commodity price index is associated with a 0.13 log point increase in employment. Column 2

Table A7: Regional Employment by Skill Category

	(1)	(2)	(3)	(4)	(5)	(6)
	Commodity		Tradable		Nontradable	
	U	S	U	S	U	S
Price_{rt}	0.0767***	0.0127	-0.0341*	0.0185	0.0353*	-0.0723***
	(0.0192)	(0.0107)	(0.0183)	(0.0127)	(0.0209)	(0.0266)
Observations	33480	33455	33480	33455	33480	33455
R^2	0.898	0.671	0.916	0.850	0.887	0.683

NOTE: This table reports the results of the estimation of equation (A1). Columns 1 and 2 correspond to unskilled and skilled employment in the commodity sector. Columns 3 and 4 correspond to unskilled and skilled employment in the tradable sector. Columns 5 and 6 correspond to unskilled and skilled employment in the nontradable sector. Each regression includes region as well as macroregion × time (year–quarter) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

displays the results for the tradable sector, which indicate that commodity prices are negatively correlated with firm employment. A one log point price increase leads to a 0.14 log point decline in firm-level employment. Finally, in the nontradable sector (column 3) the impact is small and not statistically different from zero. Again, these responses result from the superposition of the cost and wealth channels and are consistent with the idea that in response to rising commodity prices, the cost channel hurts the tradable sector relatively more, while the wealth channel benefits the nontradable sector relatively more.

Table A8: Commodity Prices and Firm-Level Employment

	Commodity	Tradable	Nontradable
	(1)	(2)	(3)
Price_{rt}	0.131**	-0.136***	0.010
	(0.065)	(0.030)	(0.021)
Observations	1,007,633	8,086,964	30,453,468
R^2	0.907	0.873	0.849

NOTE: This table reports the results of the estimation of equation (A2) by sector. Each regression includes firm and state × time (year–quarter) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.1.6 Tradability Measure

In Section 2.3 we use an industry measure of transportation costs to capture differences in tradability constructed by Holmes and Stevens [2014]. This measure is defined for the manufacturing sector. Holmes and Stevens [2014] construct this measure based on shipment distances of U.S. plants using the U.S. Commodity Flow Survey. We map the measure originally reported by four-digit SIC codes to the Brazilian CNAE classification.[7] Our tradability measure is defined for 99 3-digit industries. Table A9 reports summary statistics of Holmes and Stevens [2014]'s transport cost measure, η, across industries. Figure A2 plots the kernel density across industries. Note that in the main text we define Tradability $= -\eta$ for ease of interpretation. This means highly tradable industries are those with low transportation costs.

Table A9: Summary Statistics of Holmes and Stevens [2014]'s Transportation Cost Measure η

Mean	Std. deviation	25th Pct.	50th Pct.	75th Pct.
0.65	0.33	0.41	0.58	0.86

Note: This table reports summary statistics of Holmes and Stevens [2014]'s measure of industry transportation costs across CNAE 3-digit industries.

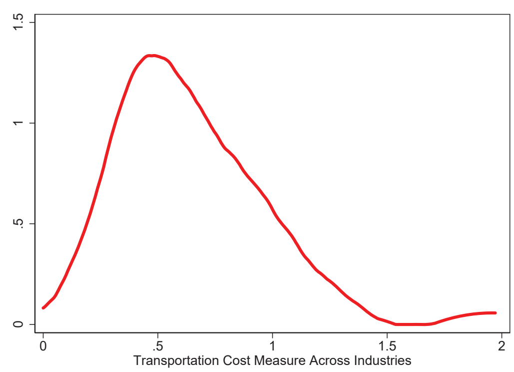


Figure A2: Kernel Density Estimate of Holmes and Stevens [2014]'s Transportation Cost Measure η

Note: This figure displays kernel density estimate of the distribution of Holmes and Stevens [2014]'s measure of industry transportation costs across CNAE 3-digit industries.

[7]For this purpose we use concordances from SIC to ISIC and from ISIC to CNAE.

A.1.7 Market Share of Brazil in World Commodity Markets.

Here we report the market share of Brazil in world markets for the largest 5 commodities (in terms of employment) used in the construction of our regional commodity price index. Due to the lack of comparable production data, we report market shares of Brazilian exports in total world exports. We obtain data on Brazil's and the world's exports by commodity from the United Nations' COMTRADE database for year 2000. Table A10 reports the results.

Table A10: Export Shares of Brazil by Commodity

	Share (%)
Bovine Meat	3.60
Cereals	5.19
Coffee	17.19
Soybeans	24.01
Sugarcane	23.75

NOTE: This table reports the share of value exported by Brazil as a fraction of world exports by commodity in year 2000, for the country's largest 5 commodities in terms of national employment. The data are obtained from COMTRADE.

A.1.8 Geographic Concentration of Commodity Employment.

In this section we report statistics on the distribution of regional employment shares for specific commodities. For each of the largest 5 commodities (defined in terms of national employment) included in our regional commodity price index, we compute the ratio of each microrregion's employment over national employment in the specific commodity industry. Table A11 reports various percentiles of these distributions. For example, in the case of coffee, the region at the 99th percentile concentrates 2.95 percent of national employment in the coffee industry. These ratios show that even the most specialized regions represent a small fraction of commodity employment.

Tables A10 and A11 suggest that none of Brazil's regions display the market power needed to set international prices. This supports our assumption that, when it comes to commodities, Brazilian regions are price takers.

Table A11: Distribution of Employment Share by Commodity Across Regions

Percentile	Cereals	Sugarcane	Soybeans	Coffee	Bovine Meat
p1	0.0000	0.0000	0.0000	0.0000	0.0000
p5	0.0000	0.0000	0.0000	0.0000	0.0001
p10	0.0001	0.0000	0.0001	0.0000	0.0002
p25	0.0003	0.0001	0.0001	0.0000	0.0005
p50	0.0008	0.0003	0.0006	0.0002	0.0010
p75	0.0023	0.0014	0.0040	0.0020	0.0025
p90	0.0046	0.0047	0.0124	0.0088	0.0045
p95	0.0066	0.0091	0.0256	0.0150	0.0061
p99	0.0142	0.0374	0.0492	0.0295	0.0085

NOTE: This table reports various percentiles of the distribution of regional shares of national employment by commodity, for the largest 5 commodities in terms of national employment. The data are based on the Demographic Census of year 2000.

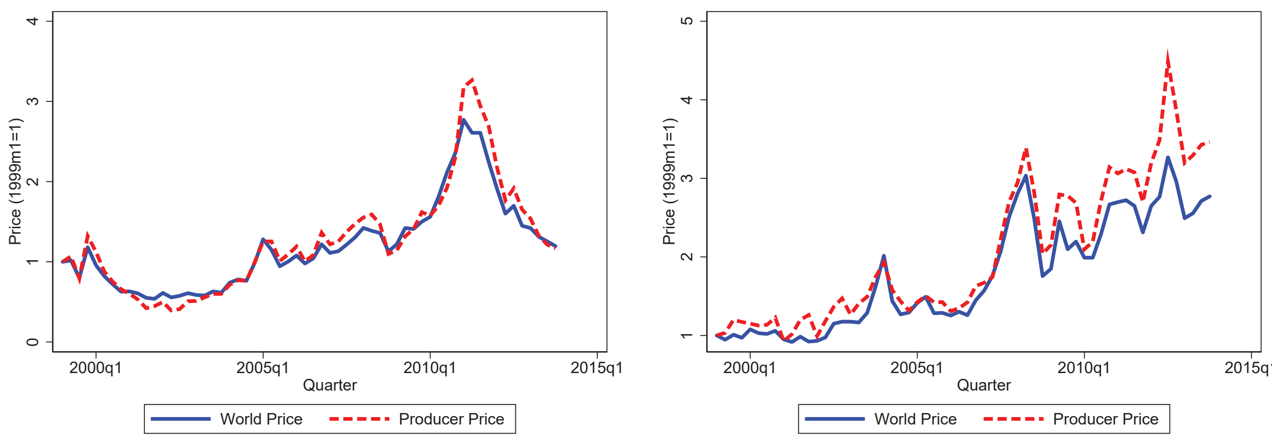
A.1.9 Producer Prices.

The regional commodity price index used in our paper is based on world prices of individual commodities. Depending on the market structure of the commodity sector in Brazil, the prices received by commodity producers could differ from the world price. For example, producers could export commodity goods indirectly through intermediaries. The market structure of the commodity sector does not affect our identification of the cost and wealth channels as long as rising commodity prices lead to an expansion in commodity employment. We show strong evidence of this in Table A5 in Appendix A.1.5.

Nevertheless, we collect data on producer prices to compare them to world prices. Figure A3 plots both series for coffee and soybeans. In both cases, the correlation between producer and world prices is higher than 0.98. This implies that the evolution of the world prices used in our regional commodity price index is also a good measure of the evolution of the prices received by producers.

In addition, Table A12 documents a lack of employment concentration among commodity producers, as measured by a Herfindahl–Hirschman index. This suggests that these firms are price takers.

Another concern could be that producers in different regions of Brazil face commodity prices that evolve differently. We use the case of soybeans (one of the most important commodities in our sample in terms of employment) to document that this is not the case. Figure A4 plots soybeans prices in five different states of Brazil with a relevant soybean production. The correlation between the prices in any pair of these states is above 0.97 in all cases.



a) Coffee

b) Soybeans

Figure A3: World Prices and Producer Prices

Note: This figure plots the world price and the producer price of coffee and soybeans. The world price is described in Section 2.1 and used in the regional commodity price index. The producer price is obtained from the Center for Advanced Studies in Applied Economics of the University of Sao Paulo. All series are indexed to 1 in 1999m1.

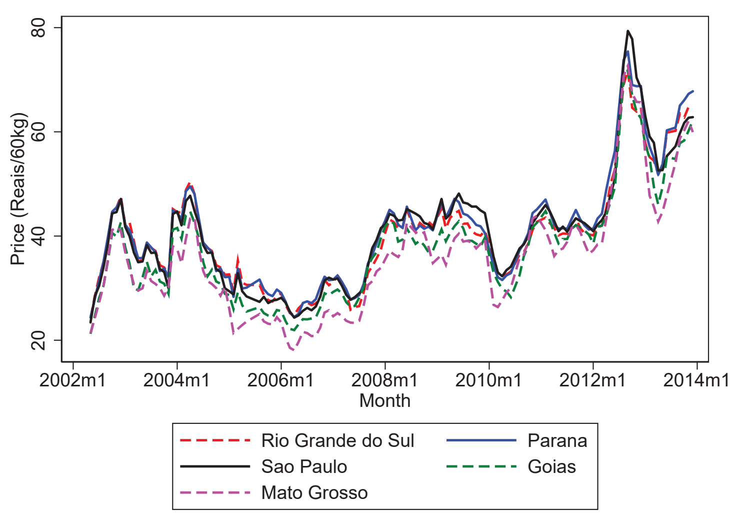


Figure A4: Soybean Producer Prices by State

Note: This figure displays monthly producer prices for soybeans in several Brazilian states. Producer prices are obtained from CONAB (a Brazilian government agency)'s Indicadores da Agropecuaria and are expressed in Reais.

Table A12: HHI of Main Agricultural Commodities

Commodity	HHI
Bovine meat	0.003
Cereals	0.012
Coffee	0.017
Soybeans	0.048
Sugarcane	0.007

Note: This table reports Herfindahl-Hirschman indices for the concentration of employment across firms in year 2000 computed separately for each of the 5 largest commodities in terms of national employment. The index goes from zero to one, with higher values indicating more concentration.

A.1.10 Heterogeneous Responses at the Extensive Margin.

We can use the rich firm-level information to determine the impact of regional commodity prices on the extensive margin (entry and exit of firms). To this end, we construct a balanced panel of all firms present at any point in our sample, and construct the categorical variable Present_{ft} which equals one when we observe firm f in the data in period t, and zero otherwise. We estimate a regression of commodity price shocks on this categorical outcome:[8] This procedure using firm-level regressions follows Bustos [2011], who examines the impact of trade barriers on export participation. Thus, we estimate:

$$\text{Present}_{ft} = \beta \cdot \text{Price}_{rt} + \gamma_f + \delta_t + \epsilon_{ft} .s \tag{A3}$$

Equation (A3) is estimated separately by sector. The empirical strategy, exploiting regional variation and including firm and state × time fixed effects, follows that used earlier for firm-level employment. We cluster standard errors at the firm level. We estimate this equation using annual data.[9]

Table A13 shows the results. In the commodity sector (column 1), a one log point increase in the regional commodity price index is associated with a 0.133 percentage point higher probability a firm is active. In the tradable sector, column 2 shows the results for firms in all industries, while column 3 excludes firms in three tradable industries with an intensive use of commodities as inputs. In both cases, commodity prices are negatively correlated with the probability a firm is active. Based on column 2, a one log point price increase is associated with a 0.052 p.p. lower probability a firm is active. Finally, in the nontradable sector (see column 4), a one log point increase in the regional commodity price index leads to a 0.0297 percentage point lower probability a firm is active.

Similarly, to quantify the impact of regional commodity prices on firms' exporting status in the tradable sector, we estimate a regression model in the same spirit of equation (A3) but with a dummy variable taking a value of one if the firm's exports in period t, and zero otherwise.

Table A13 reports the results. As column 5 indicates, higher commodity prices are correlated with a lower probability of exporting. A one log point increase in the price index leads to a 0.011

[8] We estimate a linear probability model rather than a probit model to avoid the incidental parameters problem given the large set of fixed effects included.

[9] We find similar effects using quarterly data.

p.p. lower probability a firm in the tradable sector exports.[10] These results are consistent with the combined effect of the cost and wealth channels.

Table A13: Commodity prices, Entry/Exit and Export Status

	Outcome: Present_{ft}				Outcome: Export_{ft}
	Commodity	Tradable		Nontradable	Tradable
	(1)	(2)	(3)	(4)	(5)
Price_{rt}	0.133***	-0.0519***	-0.0582***	-0.0297***	-.0107**
	(0.0194)	(0.00724)	(0.00782)	(0.00321)	(0.00537)
Observations	681,915	5,709,000	4,920,345	26,339,445	1,763,929
R^2	0.535	0.470	0.469	0.433	0.756

NOTE: This table reports the results of the estimation of equation (A3). Column 1 corresponds to the commodity sector. Column 2 and 3 corresponds to the tradable sector. Column 3 excludes commodity-intensive industries. Column 4 corresponds to the nontradable sector. Column 5 corresponds to the equation with export status as the dependent variable, estimated for firms in the tradable sector. Each regression includes firm as well as state × time fixed effects. Standard errors are clustered by firm. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

[10]To compare the magnitude of the effect of commodity prices on net entry and net entry into exporting, note that moving from the 25th to the 75th percentile in the regional commodity price leads to a 0.042 standard deviation lower probability of being active, and a 0.013 standard deviation lower probability of being an exporter.

A.2 Robustness Checks

A.2.1 Cost Channel

Controlling for Firm-Size Bin Dummies. We verify the robustness of our main results to different specifications of equation (4). Specifically, we first control for firm-size bin dummies and their interaction with the regional commodity price index. The results, shown in column 1 in Table A14 below, are similar to the baseline results discussed in the main text.

Identification *Within* Two-Digit Industries. In addition, we control for the interaction between the regional commodity price index and two-digit industry dummies. Here the identification of the cost channel is based on the variation in skill intensity across 3-digit industries (but *within* two-digit industries). The results, shown in column 2 in Table A14 below, are again similar to the baseline results discussed in the main text.

Controlling for Region × Time or Region × Time × Two-Digit Industry Fixed Effects We also verify the robustness of equation (4) to including region × time (year–quarter) fixed effects. These region × time fixed effects control for any region–specific shock and provide the strongest possible evidence of the robustness of our results. In this case, the first term in equation (4), the regional commodity price by itself, is absorbed by the fixed effects. In addition, we also include region × time (year-quarter) × two-digit industry fixed effects, absorbing regional shocks that vary by region and broad industries. Note that in this case our regression is still feasible because we measure skill intensity at the 3–digit level. The results, shown in column 3 in Table A14 below, represent even stronger evidence in favor of the cost channel.

A.2.2 Wealth Channel

Controlling for Skill Intensity We verify the robustness of equation (5) to including the interaction between commodity prices and the skill intensity of each tradable industry. The results, displayed in column 1 in Table A15 below, are similar to the baseline results in the main text.

Controlling for Region × Time or Region × Time × Two-Digit Industry Fixed Effects. We also verify the robustness of equation (5) to including region × time fixed effects. These region × time fixed effects control for any region-specific shock and provide the strongest possible evidence

Table A14: Commodity Prices and Firm-Level Employment: The Cost Channel

	Nontradable (1)	Nontradable (2)	Nontradable (3)	Nontradable (4)
Price_{rt}	0.033*	0.056		
	(0.018)	(0.056)		
Skill Intensity_i x Price_{rt}	0.485***	0.430***	0.844***	0.363***
	(0.069)	(0.094)	(0.117)	(0.077)
Observations	30,453,457	30,453,457	30,453,457	30,453,457
R^2	0.891	0.850	0.850	0.854

NOTE: This table reports the results of the estimation of equation (4) for the nontradable sector. Column 1 includes (but does not display) the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50 workers, 50 to 100 workers, 100 to 500 workers, 500 to 1000 workers, and 1000 and more workers. Column 2 includes the interaction between the regional commodity price index and two-digit industry dummy variables. Columns 1 and 2 include firm and state × time (year–quarter) fixed effects. Column 3 includes firm and region × time (year–quarter) fixed effects so the first term (the regional commodity price on its own) is absorbed by the fixed effects. Column 4 includes firm and region × time (year–quarter) × 2–digit industry fixed effects so the first term (the regional commodity price on its own) is absorbed by the fixed effects. Note we estimate equation (4) demeaning the commodity price index and skill intensity variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

of the robustness of our results. In this case, the first term in equation (5), the regional commodity price by itself, is absorbed by the fixed effects. Further, we include region × time (year-quarter) × two-digit industry fixed effects, absorbing regional shocks that vary by region and broad industries. The results, shown in columns 2 and 3 in Table A15 below, are consistent with those in the baseline case.

Table A15: Firm-Level Employment and Export Status in the Tradable Sector: The Wealth Channel

	Tradable (1)	Tradable (2)	Tradable (3)
Price_{rt}	-0.042*		
	(0.022)		
Exporter_{ft}	0.134***	0.134***	0.128***
	(0.004)	(0.005)	(0.004)
Exporter_{ft} x Price_{rt}	-0.060***	-0.046***	-0.057***
	(0.014)	(0.015)	(0.014)
Skill Intensity_i x Price_{rt}	0.278***		
	(0.108)		
Tradability_i x Price_{rt}	-0.043**	-0.057***	-0.181 ***
	(0.016)	(0.017)	(0.022)
Observations	8,005,174	8,005,174	8,005,174
R^2	0.909	0.910	0.914

NOTE: This table reports the results of the estimation of equation (5). Column 1 includes the interaction of the regional commodity price index and each industry's skill intensity. It includes firm as well as state × time (year–quarter) fixed effects. Column 2 includes firm and region × time (year–quarter) fixed effects so the first term (the regional commodity price on its own) is absorbed by the fixed effects. Column 3 includes firm and region × time (year–quarter) × 2–digit industry fixed effects so the first term (the regional commodity price on its own) is absorbed by the fixed effects. Note we demean the commodity price index and skill intensity variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.3 Upstream and Downstream Linkages.

In this section, we explore the role of upstream and downstream linkages in the transmission across industries of commodity price fluctuations. We establish that while this is a complementary transmission channel, it does not invalidate the results presented in the main text regarding the identification of the cost and wealth channels.

- First, following Allcott and Keniston [2018], we define industries with upstream and downstream linkages to the commodity sector, based on Brazil's input-output table. Details on this defintion are provided below.

- Next, we show that an increase in the regional commodity price leads to an increase in employment in industries that are defined as upstream from the commodity sector and a decline in employment in downstream industries. The results, discussed in more detail below, are shown in Table A16. In a nutshell, we find that the coefficients used to identify the cost and wealth channels (in equations (4) and (5)) remain essentially unchanged when we introduce interaction terms between the regional commodity price index and dummy variables capturing the upstream and downstream status of industries.

Definition and measurement of upstream and downstream industries. To construct a measure of commodity usage in manufacturing industries, we use Brazil's input-output table for year 2005, which reports the value of inputs used by 22 two-digit manufacturing industries. This table is obtained from Brazil's Statistical Agency, IBGE.

To define upstream industries we compute what fraction of output each industry ships to the commodity sector. We mark as upstream five industries that ship more than 5% of their output directly to the commodity sector. These upstream industries are *manufacture of chemicals and chemical products*, *food and beverages manufacturing*, *machinery and equipment manufacturing*, *coke, refined petroleum, and other fuels manufacturing*, and *manufacture of fabricated metal products*.

To define downstream industries, we compute the share of inputs sourced from the commodity sector. We mark as downstream industries that source more than 5% of their inputs from the commodity sector. These downstream industries are *coke, refined petroleum, and other fuels manufacturing*, *tobacco manufacturing*, *food and beverages manufacturing*, *manufacture of wood and wood products (except furniture)*, *manufacture of basic metals*.

Overall, we have five downstream, five upstream, and twelve unlinked two-digit industries. Note that two industries are classified as both upstream and downstream relative to the commodity sector. This is reasonable. *Food and beverages manufacturing* uses crops as an input, and it produces animal feed. *Coke, refined petroleum, and other fuels manufacturing* uses oil and gas as an input and is used as fuel in farming or mining.

Results. We augment equations (4) and (5), that measure the impact of commodity prices on firm employment to identify the cost and demand channels, adding an interaction term between our regional commodity price index and the dummy variables for upstream and downstream industries. Formally:

$$\begin{aligned} \log(\text{Emp})_{ft} = {} & \alpha_0 \cdot \text{Price}_{rt} + \alpha_c \cdot [\text{Price}_{rt} \times \text{Skill Intensity}_i] \\ & + \alpha_1 \cdot [\text{Price}_{rt} \times \text{Upstream}_i] + \alpha_2 \cdot [\text{Price}_{rt} \times \text{Downstream}_i] + \gamma_f + \delta_t + \epsilon_{ft} \,, \end{aligned} \tag{A4}$$

$$\begin{aligned} \log(\text{Emp})_{ft} = {} & \beta_0 \cdot \text{Price}_{rt} + \beta_1 \cdot \text{Exporter}_{ft} + \beta_{w1} \cdot \left[\text{Exporter}_{ft} \times \text{Price}_{rt}\right] + \beta_{w2} \cdot [\text{Tradability}_i \times \text{Price}_{rt}] \\ & + \beta_2 \cdot [\text{Price}_{rt} \times \text{Upstream}_i] + \beta_3 \cdot [\text{Price}_{rt} \times \text{Downstream}_i] + \gamma_f + \delta_t + u_{ft} \,. \end{aligned} \tag{A5}$$

Our results for the cost channel regression (equation (A4)) are shown in column 1 in Table A16. The sample corresponds to the tradable (i.e., manufacturing) sector. These results can be compared to the baseline estimation in column 5 in Table 2. The elasticity of firm employment to commodity prices is -0.17 for unlinked firms, 0.12 for upstream firms and -0.31 for downstream firms. The coefficient on the interaction term between the regional commodity price and industry skill intensity is larger than in the baseline case. Its magnitude is such that the elasticity of firm employment to commodity prices for firms at the 25th and 75th percentiles of skill intensity is -0.19 and -0.16, respectively.

The results for the wealth channel regression (equation (A5)) are shown in column 2 in Table A16, and can be contrasted to the baseline estimation in Table 3. In this case, we find similar coefficients on the upstream and downstream dummy variables in comparison to column 1. The elasticity of firm employment to commodity prices is -0.07 for unlinked firms, 0.13 for upstream firms and -0.17 for downstream firms. The coefficients on the interaction term between the regional commodity price and exporting status and on the interaction term between the regional commodity price and industry tradability are very close to those displayed in the main text (Table 3).

Table A16: Firm-Level Employment and Input-Output Linkages

	Cost Channel	Wealth Channel
	(1)	(2)
Price_{rt}	-0.173***	-0.068***
	(0.031)	(0.022)
Upstream_i x Price_{rt}	0.291***	0.195***
	(0.019)	(0.014)
Downstream_i x Price_{rt}	-0.146***	-0.099***
	(0.022)	(0.014)
Skill Intensity_i x Price_{rt}	0.413**	
	(0.175)	
Exporter_{ft}		0.133***
		(0.004)
Exporter_{ft} x Price_{rt}		-0.060***
		(0.014)
Tradability_i x Price_{rt}		-0.040**
		(0.016)
Observations	8,007,422	8,005,174
R^2	0.873	0.909

NOTE: This table reports the results of the estimation of equations (4) (in column 1) and (5) (in column 2) for the tradable sector. In each case, we add interaction terms between the regional price index and dummy variables for upstream and downstream industries (see text). Each regression includes firm as well as state × time (year–quarter) fixed effects. Column 2 includes the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Note we demean the commodity price index, skill intensity and tradability variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.4 Alternative Commodity Price Index Definitions.

We consider the following four alternative definitions of the regional commodity price index:

Excluding Oil and Gas. The first alternative definition excludes fuels (oil and gas), since this is a regulated sector, and computes the price index based on the 13 remaining commodities. We estimate equations (3), (4) and (5) using this alternative regional commodity price index. The results for the skill premium (equation (3)) are found in column 1 in Table A20. The results for the cost channel (equation (4)) and wealth channels (equation (5)) are shown in column 1 in Tables A17 and A18, respectively. These results are similar to the baseline results in the main text. This is to be expected as employment in the oil and gas industry is small, so leaving it aside from the commodity price index results in minor changes.

Excluding Soybeans, Sugarcane, and Coffee. The second alternative definition excludes commodities in which Brazil has a larger share in world markets. As shown in Table A10 earlier, these are soybeans, sugarcane, and coffee. We compute the regional commodity price index based on the 11 remaining commodities. We estimate equations (3), (4) and (5) using this alternative regional commodity price index. The results for the skill premium (equation (3)) are found in column 2 in Table A20. The results for the cost channel (equation (4)) are shown in column 2 in Table A17. The results for the wealth channel (equation (5)) are shown in column 2 in Table A18. These results are very similar to the baseline results in the main text.

Accounting for shocks to neighboring regions. The second alternative definition takes into account the commodity price shocks to each region's neighboring regions. It is possible that regional employment could depend on commodity prices of other regions to the extent that there is some degree of interregional linkages, including interregional trade or migration. These linkages could lead to geographic spillovers. Following Allcott and Keniston [2018], we assume these spillovers are mostly local, implying that it is shocks to regions within a certain radius that are the most relevant. Under this assumption, the broader commodity price index we construct takes into account the prices faced by nearby regions.

For each region, this alternative regional commodity price index is defined as the mean of the regional commodity price indices of all regions (including itself) within a radius of 100 kilometers.

We compute distances between regions as the distance between their centroids.[11] We estimate equations (3), (4) and (5) using this alternative regional commodity price index. The results for the skill premium (equation (3)) are found in column 4 in Table A20. The results for the cost channel (equation (4)) are shown in column 3 in Table A17. The results for the wealth channel (equation (5)) are shown in column 3 in Table A18. The fact that the coefficients for the cost and wealth channels are similar to those in the baseline case in the main text indicates that geographic spillovers are small in magnitude. These results are also robust to i) assigning lower weight to more distant regions and ii) modifying the 100 km. radius.

Regional Commodity Price: Trend and Cyclical Components. We verify the robustness of our main results to alternative definitions of the regional commodity price index. In particular, we estimate equations (4) and (5) using i) the unfiltered regional price index, and ii) both the trend and cyclical components of the regional price index. The results, shown in Table A19 below, indicate that the trend component (which we use in our empirical analysis in the main text) that drives our findings. The table also indicates that using the unfiltered price index leads to similar results than using the trend. In addition, column 3 in Table A20 reports equivalent results for the skill premium regression (equation (3)).

Table A17: Commodity Prices and Firm-Level Employment: The Cost Channel

	Excl. Oil and Gas	Excl. Soybeans, Sugarcane, and Coffee	Nearby Regions
	Nontradable	Nontradable	Nontradable
	(1)	(2)	(3)
Price_{rt}	0.063***	0.038	0.088***
	(0.020)	(0.024)	(0.029)
Skill Intensity_i x Price_{rt}	0.987***	0.880***	0.981***
	(0.084)	(0.125)	(0.079)
Observations	30,453,437	30,453,437	30,453,437
R^2	0.849	0.849	0.849

NOTE: This table reports the results of the estimation of equation (4) for the nontradable sector. Column 1 uses the regional price index excluding oil and gas. Column 2 uses the regional price index excluding soybeans, sugarcane, and coffee. Column 3 uses the regional price index that accounts for the price indices of neighboring regions. Each regression includes firm as well as state × time (year–quarter) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

[11] The median region has 6 neighboring regions with centroids within this 100 kilometer radius (in addition to itself).

Table A18: Firm-Level Employment and Export Status in the Tradable Sector: The Wealth Channel

	Excl. Oil and Gas	Excl. Soybeans, Sugarcane, and Coffee	Nearby Regions
	(1)	(2)	(3)
Price_{rt}	-0.013	-0.045**	-0.070**
	(0.022)	(0.022)	(0.034)
Exporter_{ft}	0.135***	0.136***	0.135***
	(0.005)	(0.004)	(0.005)
Exporter_{ft} x Price_{rt}	-0.051***	-0.063***	-0.052***
	(0.017)	(0.015)	(0.015)
Tradability_{i} x Price_{rt}	-0.038**	-0.047***	-0.037**
	(0.019)	(0.017)	(0.018)
Observations	8,005,174	8,005,174	8,005,174
R^2	0.909	0.909	0.909

NOTE: This table reports the results of the estimation of equation (5). Column 1 uses the regional price index excluding oil and gas. Column 2 uses the regional price index excluding soybeans, sugarcane, and coffee. Column 3 uses the regional price index that accounts for the price indices of neighboring regions. Each regression includes firm as well as state × time (year–quarter) fixed effects. All columns include the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

Table A19: Firm-Level Employment: Cost and Wealth Channels

	Cost Channel		Wealth Channel	
	Nontradable	Nontradable	Tradable	Tradable
	(1)	(2)	(3)	(4)
Price_{rt}	0.010		-0.005	
	(0.008)		(0.009)	
Price Trend_{rt}		0.013		-0.046**
		(0.021)		(0.022)
Price Cycle_{rt}		0.005		0.010**
		(0.003)		(0.005)
Exporter_{ft}			0.135***	0.135***
			(0.005)	(0.005)
Exporter_{ft} x Price_{rt}			-0.043***	
			(0.012)	
Exporter_{ft} x Price Trend_{rt}				-0.054***
				(0.015)
Exporter_{ft} x Price Cycle_{rt}				-0.005
				(0.010)
Tradability_i x Price_{rt}			-0.019*	
			(0.011)	
Tradability_i x Price Trend_{rt}				-0.041**
				(0.017)
Tradability_i x Price Cycle_{rt}				0.021***
				(0.006)
Skill Intensity_i x Price_{rt}	0.590***			
	(0.073)			
Skill Intensity_i x Price Trend_{rt}		0.846***		
		(0.115)		
Skill Intensity_i x Price Cycle_{rt}		-0.011		
		(0.029)		
Observations	30,453,437	30,453,437	8,005,174	8,005,174
R^2	0.849	0.849	0.909	0.909

NOTE: This table reports the results of the estimation of equation (4) (in columns 1 and 2) and (5) (in columns 3 and 4) using the unfiltered regional price index (in columns 1 and 3) or the trend and cyclical component included at the same time (in columns 2 and 4). Columns 3 and 4 include the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Each regression includes firm as well as state × time (year–quarter) fixed effects. Standard errors are clustered by firm. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

Table A20: Commodity Prices and the Skill Premium

	(1) Excl. Oil and Gas	(2) Excl. Soybeans, Sugarcane, and Coffee	(3) Raw Price Index	(4) Nearby Regions
Price_{rt}	-0.213***	-0.169**	-0.047*	-0.313***
	(0.056)	(0.078)	(0.025)	(0.078)
Observations	8363	8363	8363	8363
R^2	0.695	0.694	0.668	0.695

NOTE: This table reports the results of the estimation of equation (3). All columns correspond to annual earnings. Each regression includes region as well as macroregion × time (year) fixed effects. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.5 Excluding States with the Largest Commodity Export Shares.

We argue in Section 2.3 that our identification of the cost and wealth channels does not rely on the lack of market power of the Brazilian economy (or Brazilian regions) in world commodity markets. We also argue in Appendix A.1.8 that even microregions with the largest share of commodity employment have a small share of national employment in any given commodity.

Nevertheless, in this section we show that our results for the cost and wealth channels are robust to excluding from the sample states with the largest export shares in the main commodities exported by Brazil.

Table A10 showed earlier that Brazil's largest market share is in soybeans, coffee and sugarcane. We drop all the states that have more than a 2% world market share of exports in any of these commodities. Specifically, we drop Minas Gerais (which has a large coffee sector), Sao Paulo (which has a large sugarcane sector), and Mato Grosso, Paraná, and Rio Grande do Sul (which have significant soybean production).[12]

In Table A21 we estimate the regressions for the cost and wealth channels (equations (4) and (5), respectively) using the most demanding set of fixed effects (microregion $\times$ time (year–quarter) fixed effects, as discussed in Appendix Sections A.2.2 and A.2.1). We see that our results are robust. This rules out the possibility that our baseline results are driven by Brazil's market power in world markets in certain commodities, given that the remaining states in the sample have minimal export market shares. After removing these states, the market share in the world market of the remaining states as a whole is also low (under 5% in all cases).

[12]For this purpose, we use a dataset on Brazil's exports by municipality and product obtained from Brazil's MDIC's (Ministry of Industry, Foreign Trade and Services) Foreign Trade Statistics, which we aggregate to the state by product level.

Table A21: Firm-Level Employment: Removing States with Larger Export Shares

	(1) Nontradable	(2) Tradable
Skill Intensity$_i$ x Price$_{rt}$	0.6773***	
	(0.116)	
Exporter$_{ft}$		0.144***
		(0.008)
Exporter$_{ft}$ x Price$_{rt}$		-0.084***
		(0.022)
Tradability$_i$ x Price$_{rt}$		-0.059**
		(0.022)
Observations	13,014,674	2,815,202
R^2	0.849	0.904

Note: This table reports the results of the estimation of equations (4) and (5). Each regression includes firm and region × time (year–quarter) fixed effects. In column 2, we include (but do not display) the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.6 Regional Exposure to Chinese Import Competition.

In this section we verify that our baseline estimates in the main text are not confounded by rising Chinese import competition, which is a relevant shock observed in labor markets in many countries during the sample period.

Cost channel. For our estimates of the cost channel to be confounded by this shock, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate impact of Chinese import competition. This spatial correlation would have to take place within states, because our regressions include state $\times$ time (year–quarter) fixed effects.

2. Chinese import competition would have to lead to a decline in employment in low–skill relative to high–skill industries in the nontradable (i.e., services) sector. The impact of Chinese import competition would also need to be consistent with the observed movement in wages.

Note that the second condition is *not* consistent with what one would expect from rising Chinese import competition, which would reduce the wage of unskilled workers and increase the skill premium, and lead to an increase in employment in low–skill relative to high–skill industries in the nontradable (i.e., services) sector (the opposite of what the second condition states). Despite the implausibility of these conditions, we still consider this hypothesis further.

A robustness test to further rule out that our estimates of the cost channel are confounded by the China shock would augment equation (4) with an interaction term between a measure of regional exposure to the China shock and the measure of industry skill intensity. However, note that our baseline regression already includes firm fixed effects, which already absorb this interaction term.

It is difficult to think of any residual channel through which Chinese import competition could confound our estimates. Nevertheless, we can augment equation (4) with more demanding fixed effects. While we cannot include region $\times$ time (year–quarter) $\times$ 3–digit industry fixed effects (because there would be no variation left to identify the coefficient of interest), we include region $\times$ time (year–quarter) $\times$ 2–digit industry fixed effects. These fixed effects absorb any shock by region, time, and broader 2–digit industry, making any confounding effect of Chinese import competition even more implausible. The results of this regression are shown in column 4 in Table A14, and are consistent with the baseline results in column 1 in Table 2 in the main text.

Wealth channel. For our estimates of the wealth channel to be confounded by rising Chinese import competition, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate impact of Chinese import competition. This spatial correlation would have to take place within states, because our regressions include state $\times$ time (year–quarter) fixed effects.

2. Chinese import competition would have to lead to a decline in employment among exporting firms relative to nonexporting firms in the tradable (i.e., manufacturing) sector. The impact of Chinese import competition would also need to be consistent with the observed movement in wages.

While we do not see a specific mechanism that would meet these conditions, a robustness test to further rule out this hypothesis would augment equation (5) with an interaction term between regional exposure to the China shock and the dummy variable for exporting firms. Note that if exporter status did not change within firms over time, this interaction term would be absorbed by the firm fixed effects already included in the regression. However, the fact that exporter status is time–varying leaves a small possibility for a confounding effect, and allows us to estimate this robustness check.

To this end, we construct measures of regional exposure to the increase in Chinese import competition observed in Brazil during our sample period. We follow Autor et al. [2013] and define a regional measure of import competition as follows:

$$\Delta \text{IP}_r = \sum_i \frac{L_{ir}}{L_i} \cdot \frac{\Delta \text{Imports}_i}{L_r} \,, \tag{A6}$$

where $\Delta\text{Imports}_i$ is the change in Chinese imports of industry i between 2000 and 2013, L_{ir} is employment in region r and industry i in 2000, L_r is employment in region r in 2000, and L_i is employment in industry i in 2000.[13,14] With this measure, we estimate:[15]

$$\log(\text{Emp})_{ft} = \beta_0 \cdot \text{Price}_{rt} + \beta_1 \cdot \text{Exporter}_{ft} + \beta_{w1} \cdot \left[\text{Exporter}_{ft} \times \text{Price}_{rt}\right] + \beta_{w2} \cdot [\text{Tradability}_i \times \text{Price}_{rt}] + \beta_2 \cdot [\Delta\text{IP}_r \times \text{Exporter}_{ft}] + \gamma_f + \delta_{ts} + u_{ft}\,. \quad \text{(A7)}$$

The results for regression (A7) are shown in column 2 in Table A22. They indicate that the baseline estimates in Table 3 are robust to the concern that Chinese import competition could confound our identification of the wealth channel.

[13] To construct this measure, we obtain industry level imports from the UN's Comtrade database. These are originally reported according to the ISIC revision 3 classification, and converted to three-digit level CNAE industries using a cross-walk provided by Brazil's Statistical Institute (IBGE).

[14] Note that studies of the impact of trade shocks on regional outcomes, such as Autor et al. [2013], instrument ΔIP_r with the same weighted average of industry level imports using Chinese exports to a set of "similar" countries. In the case of Brazil, we construct this instrument and find that the correlation across regions with ΔIP_r is 0.9725. Given this extremely high correlation, we report OLS results for equation (A6). We find similar results if we use this instrument instead of ΔIP_r in equations (A6).

[15] Note that adding an interaction term of the industry–level tradability measure and the measure of regional exposure to the China shock is unnecessary because such an interaction term would be absorbed by the firm fixed effects.

A.2.7 Regional Exposure to Trade Liberalization.

In this section we verify that our baseline estimates in the main text are not confounded by Brazil's trade liberalization during the early 1990s.

Cost channel. For our estimates of the cost channel to be confounded by this shock, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate exposure to trade liberalization. This spatial correlation would have to take place within states, because our regressions include state × time (year–quarter) fixed effects.

2. Tariff liberalization would have to lead to a decline in employment in low–skill relative to high–skill industries in the nontradable (i.e., services) sector. The impact of tariff liberalization would also need to be consistent with the observed movement in wages.

Note, however, that Dix-Carneiro and Kovak [2015] find only very small effects of this liberalization episode on the skill premium, which would rule out substantial transmission into the nontradable sector differentially by skill intensity. Despite this, we still consider this hypothesis further.

A robustness test to further rule out that our estimates of the cost channel are confounded by tariff liberalization would augment equation (4) with an interaction term between regional exposure to tariff liberalization and the measure of industry skill intensity. However, note that our baseline regression already includes firm fixed effects, which already absorb this interaction term.

It is difficult to think of any residual channel through which tariff liberalization could confound our estimates. Nevertheless, we can augment equation (4) with more demanding fixed effects. While we cannot include region × time (year–quarter) × 3–digit industry fixed effects (because there would be no variation left to identify the coefficient of interest), we include region × time (year–quarter) × 2–digit industry fixed effects. These fixed effects absorb any shock by region, time, and broader 2–digit industry, making any confounding effect of tariff liberalization even more implausible. The results of this regression are shown in column 4 in Table A14, and are consistent with the baseline results in column 1 in Table 2 in the main text.

Wealth channel. For our estimates of the wealth channel to be confounded by tariff liberalization, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate exposure to tariff liberalization. This spatial correlation would have to take place within states, because our regressions include state $\times$ time (year–quarter) fixed effects.

2. Tariff liberalization would have to lead to a decline in employment among exporting firms relative to nonexporting firms in the tradable (i.e., manufacturing) sector. The impact of tariff liberalization would also need to be consistent with the observed movement in wages.

While we do not see a specific mechanism that would meet these conditions, a robustness test to further rule out this hypothesis would augment equation (5) with an interaction term between regional exposure to tariff liberalization and the dummy variable for exporting firms. Note that if exporter status did not change within firms over time, this interaction term would be absorbed by the firm fixed effects already included in the regression. However, the fact that exporter status is time–varying leaves a small possibility for a confounding effect, and allows us to estimate this robustness check.

To this end, we construct the following measures of regional exposure to Brazil's trade liberalization carried out in the early 1990's:[16]

$$\Delta\tau_r = \sum_i \frac{L_{ir}}{L_r} \cdot \Delta\tau_i \,, \tag{A8}$$

where $\Delta\tau_i$ is the change in tariffs in industry i between 1990 and 1995, L_{ir} is employment in region r and industry i in 1991, and L_r is employment in region r in 1995.[17] With this measure,

[16] For evidence on the impact of Brazil's trade liberalization on labor markets see Dix-Carneiro and Kovak [2015], Dix-Carneiro and Kovak [2017], and Menezes-Filho and Muendler [2011].

[17] To construct this measure, we obtain industry-level tariffs from Kovak [2013] and follow the timing and industry classification used in that paper. We use the 1991 Demographic Census to construct the weights in (A8). Note that as Adão [2015] points out, the definition of microregions by IBGE in the Demographic Census is constant across years between 1991 and 2000, despite the increase in the number of municipalities.

we estimate:[18]

$$\log(\text{Emp})_{ft} = \beta_0 \cdot \text{Price}_{rt} + \beta_1 \cdot \text{Exporter}_{ft} + \beta_{w1} \cdot \left[\text{Exporter}_{ft} \times \text{Price}_{rt}\right] + \beta_{w2} \cdot [\text{Tradability}_i \times \text{Price}_{rt}]$$
$$+ \beta_2 \cdot [\Delta\tau_r \times \text{Exporter}_{ft}] + \gamma_f + \delta_{ts} + u_{ft}\ . \quad \text{(A9)}$$

The results for regression (A7) are shown in column 3 in Table A22. They indicate that the baseline estimates in Table 3 are robust to the potential regional exposure to trade liberalization.

Table A22: Firm-Level Employment and Export Status in the Tradable Sector: The Wealth Channel

	Informality (1)	China Shock (2)	Trade Liberalization (3)
Price_{rt}	-0.044**	-0.045**	-0.044**
	(0.022)	(0.022)	(0.022)
Exporter_{ft}	0.140***	0.136***	0.141***
	(0.004)	(0.005)	(0.004)
Exporter_{ft} x Price_{rt}	-0.049***	-0.055***	-0.049***
	(0.015)	(0.015)	(0.015)
Tradability_i x Price_{rt}	-0.040**	-0.039**	-0.040**
	(0.017)	(0.017)	(0.017)
Informality Share_r x Exporter_{ft}	0.152***		
	(0.042)		
ΔIP_r x Exporter_{ft}		0.005	
		(0.003)	
$\Delta\tau_r$ x Exporter_{ft}			0.009***
			(0.002)
Observations	8,005,174	8,005,174	8,005,174
R^2	0.909	0.909	0.909

Note: This table reports the results of the estimation of equation (5). Column 1 adds an interaction term between regions' informality share and the exporter dummy. Column 2 adds an interaction term between regional exposure to the change in Chinese imports and the exporter dummy. Column 3 adds an interaction term between the regional exposure to the change in tariffs during Brazil's trade liberalization and the exporter dummy. Each regression includes firm as well as state × time (year–quarter) fixed effects. All columns include the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

[18] Note that adding an interaction term of the industry–level tradability measure and the measure of regional exposure to tariff liberalization is unnecessary because such an interaction term would be absorbed by the firm fixed effects.

A.2.8 Informality.

A potential concern with the labor market data used in our analysis is that it is restricted to the formal sector. In Brazil, workers must register their employment contracts in their *carteira de trabalho* - a passport-type notebook. The literature widely considers workers who do not register their contract in their *carteira de trabalho* as informal (Paes De Barros and Corseuil [2004]). According to this definition, the share of informal employees within the commodity, tradable and nontradable sector is 35.8% in 2000 based on Brazil's Demographic Census.[19]

In this section we verify that our baseline estimates in the main text are not confounded by varying degrees of informality across regions.

Cost channel. For our estimates of the cost channel to be confounded by this shock, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate degree of informality. This spatial correlation would have to take place within states, because our regressions include state × time (year–quarter) fixed effects.

2. Regions with a higher share of informal labor would have to have lower employment in low–skill relative to high–skill industries in the nontradable (i.e., services) sector during the sample period. The effect of informality would also need to be consistent with the observed movement in wages.

There is no specific mechanism in the literature suggesting that the second condition is plausible. Despite this, we still consider this hypothesis further.

A robustness test to further rule out that our estimates of the cost channel are confounded by informality would augment equation (4) with an interaction term between regional informality shares and the measure of industry skill intensity. However, note that our baseline regression includes firm fixed effects, which already absorb this interaction term.

It is difficult to think of any residual channel through which informality could confound our estimates. Nevertheless, we can augment equation (4) with more demanding fixed effects. While

[19]This number computes the share of informal employees among all employees, excluding employers and self-employed individuals. It is based on males and females aged 20-60.

we cannot include region × time (year–quarter) × 3–digit industry fixed effects (because there would be no variation left to identify the coefficient of interest), we include region × time (year–quarter) × 2–digit industry fixed effects. These fixed effects absorb any shock by region, time, and broader 2–digit industry, making any confounding effect of informality even more implausible. The results of this regression are shown in column 4 in Table A14, and are consistent with the baseline results in column 1 in Table 2 in the main text.

Wealth channel. For our estimates of the wealth channel to be confounded by informality, the following two conditions would have to hold *simultaneously*:

1. A spatial correlation such that regions facing larger increases in the regional commodity price index also face a disproportionate degree of informality. This spatial correlation would have to take place within states, because our regressions include state × time (year–quarter) fixed effects.

2. Regions with a higher share of informal labor would have to have lower employment among exporting firms relative to nonexporting firms in the tradable (i.e., manufacturing) sector. The effect of informality would also need to be consistent with the observed movement in wages.

While we do not see a specific mechanism that would meet these conditions, a potential robustness test to further rule out this hypothesis would be based on an augmented version of equation (5) with an interaction term between regional informality shares and the dummy variable for exporting firms. However, if exporter status did not change within firms over time, this interaction term would be absorbed by the firm fixed effects already included in the regression. Nevertheless, the fact that exporter status is time–varying leaves a small possibility for a confounding effect, and allows us to estimate this robustness check.

To this end, we use the 2000 Demographic Census to compute regional shares of informal employment. With these measures, we estimate:[20]

$$\begin{aligned}\log(\text{Emp})_{ft} = {} & \beta_0 \cdot \text{Price}_{rt} + \beta_1 \cdot \text{Exporter}_{ft} + \beta_{w1} \cdot \left[\text{Exporter}_{ft} \times \text{Price}_{rt}\right] + \beta_{w2} \cdot \left[\text{Tradability}_i \times \text{Price}_{rt}\right] \\ & + \beta_2 \cdot \left[\text{Informality Share}_r \times \text{Exporter}_{ft}\right] + \gamma_f + \delta_{ts} + u_{ft}\,. \quad \text{(A10)}\end{aligned}$$

[20]Note that adding an interaction term of the industry–level tradability measure and the regional informality share is unnecessary because such an interaction term would be absorbed by the firm fixed effects.

The results for regression (A10) are shown in column 1 in Table A22. They indicate that the baseline estimates in Table 3 are robust to informality.

A.2.9 Exporters, Importers and the Exchange Rate.

We verify the robustness of our results to the following alternative specifications of equation (5):

1. Baseline regression plus the interaction between the exchange rate and the exporter dummy;
2. Baseline regression plus an importer dummy in addition to the exporter dummy;
3. Baseline regression plus the interaction between the exchange rate and the exporter and importer dummies.

The results, displayed in Table A23 below, confirm the robustness of our main findings.

Table A23: Firm-Level Employment and Export Status in the Tradable Sector: The Wealth Channel

	(1)	(2)	(3)
Price_{rt}	-0.043**	-0.045**	-0.043**
	(0.022)	(0.022)	(0.022)
Exporter_{ft}	0.135***	0.124***	0.124***
	(0.004)	(0.004)	(0.004)
Exporter_{ft} x Price_{rt}	-0.065***	-0.132***	-0.133***
	(0.015)	(0.013)	(0.013)
Tradability_i x Price_{rt}	-0.039**	-0.052***	-0.052***
	(0.017)	(0.017)	(0.017)
Exporter_{ft} x Exchange Rate_t	-0.017**		0.000
	(0.007)		(0.007)
Importer_{ft}		0.099***	0.099***
		(0.006)	(0.006)
Importer_{ft} x Price_{rt}		0.200***	0.192***
		(0.018)	(0.018)
Importer_{ft} x Exchange Rate_t			-0.017***
			(0.006)
Observations	8,005,174	8,005,174	8,005,174
R^2	0.909	0.909	0.909

NOTE: This table reports the results of the estimation of equation (5) for the tradable sector. In addition to the baseline specification in Table 3 in the main text, column 1 includes the interaction between the exchange rate and the exporter dummy; column 2 includes an importer dummy, and column 3 includes the importer dummy and the interaction between the exchange rate and both the exporter and importer dummies. Each regression includes firm as well as state × time (year–quarter) fixed effects. Standard errors are clustered by firm. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.10 Standard Errors

Our regional price index defined in equation (2) is a weighted average of commodity prices, with weights given by initial regional employment shares in each commodity industry. Adão et al. [2019] develop a method to compute standard errors in cross-regional regressions with these type of regressors. In this section, we apply this method to our baseline results in Section 2.3. Specifically, we apply the method detailed in remark 5 in Adão et al. [2019] extended to a panel setting as explained in section V.B in their paper.

Note that our firm-level employment regressions differ from the examples in Adão et al. [2019] in that the unit of observation is a firm-period rather than a region-period. Nevertheless, Adão et al. [2019]'s method extends naturally to this situation. Note also that the regional commodity price index used throughout the paper is the HP trend of the logarithm of the weighted average of individual commodity prices, defined in equation (2) and copied below (i.e., it is a transformation of a shift-share variable).

$$p_{rt} = \frac{\sum\limits_{i \epsilon C} p_{it} \times e_{ir}}{\sum\limits_{i \epsilon C} e_{ir}}. \tag{A11}$$

Since Adão et al. [2019]'s method to compute standard errors does not apply to transformations of shift-share variables, we define the following regional commodity price index as a weighted average of the log of individual commodity prices:

$$p_{rt} = \frac{\sum\limits_{i \epsilon C} log(p_{it}) \times e_{ir}}{\sum\limits_{i \epsilon C} e_{ir}}. \tag{A12}$$

The correlation with the price index used in the main text is high (0.92).

Table A24 shows our results. As we discussed in the main text, the standard errors on the coefficients of interest (i.e., on the interaction terms) computed following Adão et al. [2019]'s procedure are lower than the standard errors in our baseline results. Note that Adão et al. [2019]'s correction does not necessarily imply larger standard errors.

Table A24: Firm-Level Employment: Cost and Wealth Channels

	Cost Channel	Cost Channel	Wealth Channel
	Tradable	Nontradable	Tradable
	(1)	(2)	(3)
Price_{rt}	-0.044	0.016**	-0.003
	(0.207)	(0.008)	(0.013)
$\text{Skill Intensity}_{i}$ x Price_{rt}	0.605***	0.646***	
	(0.127)	(0.011)	
Exporter_{ft}			0.138***
			(0.0002)
Exporter_{ft} x Price_{rt}			-0.043***
			(0.001)
Tradability_{i} x Price_{rt}			-0.021*
			(0.012)
Observations	8,007,422	30,453,437	8,005,174

NOTE: This table reports the results of the estimation of equations (4) (in columns 1 and 2) and (5) (in column 3). Each regression includes firm as well as state × time (year–quarter) fixed effects. Column 3 includes the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers. Note we demean the commodity price index, skill intensity and tradability variables. Standard errors are computed following Adão et al. [2019] (see text). ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

A.2.11 Identification of the Wealth Channel based on Differences in Income Elasticities within the Nontradable Sector and Robustness of Results to Controlling for Income Elasticities.

Identification of the Wealth Channel based on Differences in Income Elasticities. An alternative approach to identifying the wealth channel can exploit variation differences in income elasticities across nontradable industries. If a commodity price increase leads to an increase in wealth and, consequently, an increase in the local demand for nontradables, this should lead to a relative expansion in industries with a higher income elasticity. We estimate the following equation in which we interact the regional commodity price index with a measure of industry-level income elasticities:

$$\log(\text{Emp})_{ft} = \beta_0 \cdot \text{Price}_{rt} + \beta_w \cdot [\text{Price}_{rt} \times \text{Income Elasticity}_i] + \gamma_f + \delta_t + \epsilon_{ft}\,. \quad \text{(A13)}$$

We obtain income elasticities from Borusyak and Jaravel [2018]. These are constructed based on the U.S. Consumer Expenditure Survey and reported according to BEA I-O codes. We use a concordance to transform them first to the ISIC classification and then to the Brazilian CNAE classification. In this way, we are able to obtain measures of income elasticities that vary by two-digit industry.

Note that while not shown in the equation, we control for the interaction of the price index and industry skill intensity. The results are shown in Table A25. They indicate that among nontradable industries with higher income elasticities the positive response of firm employment to an increase in the regional commodity price index is larger, and the coefficient on the interaction term is statistically significant. The magnitude is such that the total elasticity of firm employment to the regional commodity price index is -0.02 for firms in industries at the 25th percentile of income elasticity and 0 for firms in industries at the 75th percentile of income elasticity.

Robustness of Results to Controlling for Income Elasticities. Table A26 shows the results of estimation equations (4) and (5) for the tradable sector controlling for the interaction between the regional commodity price index and the income elasticity of each firm's industry.

Table A25: Firm-Level Employment and Income Elasticities in the Nontradable Sector: Alternative Identification of the Wealth Channel

	Nontradable
	(1)
Price_{rt}	-0.007
	(0.030)
Skill Intensity_i x Price_{rt}	0.559***
	(0.089)
Income Elasticity_i x Price_{rt}	0.055**
	(0.021)
Observations	22,859,404
R^2	0.842

Note: This table reports the results of the estimation of equation (A13). The regression includes firm and state × time (year–quarter) fixed effects. Note we estimate equation (A13) demeaning all variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

Table A26: Commodity Prices and Firm-Level Employment: Controlling for Income Elasticities

	Cost Channel	Wealth Channel
	(1)	(2)
Price_{rt}	-0.123***	-0.135***
	(0.030)	(0.039)
Skill Intensity_i x Price_{rt}	0.604***	
	(0.182)	
Income Elasticity_i x Price_{rt}	0.177**	0.076**
	(0.023)	(0.035)
Exporter_{ft}		0.121***
		(0.004)
Exporter_{ft} x Price_{rt}		-0.127***
		(0.012)
Tradability_i x Price_{rt}		-0.036**
		(0.015)
Observations	8,002,953	6,894,808
R^2	0.873	0.899

Note: This table reports the results of the estimation of equations (4) (in column 1) and (5) (in column 2) for the tradable sector. The regression includes firm and state × time (year–quarter) fixed effects. Column 2 includes the interaction between the regional commodity price index and the following firm–size bin dummies (as well as the uninteracted dummies): 5 to 50, 50 to 100, 100 to 500, 500 to 1000, and 1000 or more workers.. Note we demean all variables. Standard errors are clustered by region. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

B Quantitative Appendix

In this appendix we document the robustness of our quantitative results to changing the value of key parameters, a different initial condition for the ratio of net foreign assets to GDP, and the inclusion of a bond-holding cost. We also include additional results on the evolution of productivity cutoffs and wages. In addition, we develop two alternative versions of our model. First, we analyze a multiregion version with interregional trade and migration. Second, we present a version with a representative firm. Our quantitative findings are robust to these changes.

B.1 Multiregion Model with Interregional Trade and Migration

Our baseline model in Section 3 can be extended to accommodate interregional trade and migration. The economy consists of two regions $l = \{A, B\}$. Each region has a commodity, nontradable (services), and tradable (manufacturing) sectors. The industrial organization in each sector is identical to that in the baseline model except for the addition of interregional trade in the commodity and tradable sectors. In the commodity sector, a representative firm produces a region-specific commodity good that is traded across regions and also exported abroad. Firms in the tradable sector can sell their varieties to their own region, they can export to the other region subject to a fixed cost of interregional exporting, and they can also export internationally subject to a larger fixed cost of international exporting. As a consequence of these fixed export costs, the most productive firms sell their varieties in both regions as well as internationally, less productive firms supply only to the two regions in this country, whereas the least productive firms sell only to consumers in their own region. Firms in all sectors use both skilled and unskilled labor.

There is a household consisting of a continuum of workers and a household head. First, the household head collects rents from the natural resource ($\bar{R}^l$) and firms in the economy. She can save and borrow freely from the rest of the world through an external bond B at an exogenous interest rate r^*. The household head solves the aggregate consumption/saving decision of the household and chooses skill-specific transfers to the workers.[21] Second, individual workers receive transfers from the household head and labor income and spend all these resources to consume goods produced by the three sectors of the economy as well as an imported good. A fixed fraction κ of household workers are skilled and the rest are unskilled. The workers are heterogeneous in their time-invariant preferences toward living in either region. Individual workers choose where to work and how to allocate their disposable income upon observing prices, wages, and transfers.

The model is written in real terms. We index regions by $l \in \{A, B\}$, sectors by $k \in \{C, N, T\}$ (for commodity, nontradable, and tradable), skill types by $d \in \{U, S\}$ (for unskilled and skilled), and firms by f.

B.1.1 Household Head and Workers

To focus our attention on the interaction of commodity fluctuations and labor markets, we consider a simple model of a household head's consumption-saving decision, in a similar way to Kehoe et al.

[21]Note that if transfers were both region-specific and skill-specific there would be no migration.

[2019] and Kehoe et al. [2020].

Workers. A type-d worker living in region l at time t has a utility:

$$U\left(C_t^{dl}\right) = \frac{\left(C_t^{dl}\right)^{1-\nu}}{1-\nu} + \xi_d \cdot \epsilon_j^l\,, \tag{A14}$$

where ϵ_j^l is a time-invariant location preference term that varies across workers (j) and is drawn from a mean-zero type-I extreme value distribution.[22] For notational simplicity, we omit the worker subscript j whenever possible.[23] C_t^{dl} is the final consumption bundle that is a nested-CES aggregate of an imported good (m_t^{dl}), a tradable bundle (t_t^{dl}), a nontradable bundle (n_t^{dl}), and region-specific commodity goods (c_t^{dlA}, c_t^{dlB}):

$$C_t^{dl} = \left\{\left[\left[\left(m_t^{dl}\right)^{\theta_1} + \alpha_T\left(t_t^{dl}\right)^{\theta_1}\right]^{\frac{\theta_2}{\theta_1}} + \alpha_N\left(n_t^{dl}\right)^{\theta_2}\right]^{\frac{\theta_4}{\theta_2}} + \alpha_C\left[\left(c_t^{dlA}\right)^{\theta_3} + \left(c^{dlB}\right)^{\theta_3}\right]^{\frac{\theta_4}{\theta_3}}\right\}^{\frac{1}{\theta_4}}. \tag{A15}$$

The tradable bundle t_t^{dl} and nontradable bundle n_t^{dl} are both CES aggregators of individual varieties according to:

$$t_t^{dl} = \left[\int_{\zeta\in\mathfrak{Z}_t^l} t_t^{dl}(\zeta)^\rho d\zeta\right]^{\frac{1}{\rho}} \qquad \text{and} \qquad n_t^{dl} = \left[\int_{\varphi\in\mathfrak{P}_t^l} n_t^{dl}(\varphi)^\rho d\varphi\right]^{\frac{1}{\rho}},$$

where ζ and φ are indices for individual varieties and $\mathfrak{Z}_t^l$ and $\mathfrak{P}_t^l$ denote sets of individual varieties sold in region l at time t.

In a given location, all workers of a given type pool their total labor income, which they then redistribute among themselves, so that there is complete risk-sharing within each region for each skill type. Given the prevailing wage w_t^{dl}, all workers regardless of their employment status earn an income $w_t^{dl} \cdot \frac{h_t^{dl}}{H_t^{dl}}$. In this expression, h_t^{dl} and H_t^{dl} denote the total measure of employed type-d workers in l at time t and the total measure of type-d workers residing in l at t, respectively; and the ratio h_t^{dl}/H_t^{dl} represents the employment rate. In addition, all workers receive a lump-sum transfer τ_t^d (that can be positive or negative) from the household head, which is taken as exogenous by individual workers. This transfer is the result of the household head's intertemporal

[22] This is a tractable way of modeling migration. An alternative is assuming a migration cost.

[23] Omitting the worker subscript j is not problematic given that in equilibrium, all workers of a given skill d in a given location l have the same consumption.

consumption-saving decision.

In each period, workers make two decisions given their location preference, disposable income, and prices. First, they choose where to locate themselves. Second, they choose how to allocate their disposable income. Formally, given their disposable income in a given location, workers choose m_t^l, $t_t^l(\zeta)_{\zeta\in\mathfrak{Z}_t^l}$, $n_t^l(\varphi)_{\varphi\in\mathfrak{P}_t^l}$, c_t^{lA}, and c_t^{lB} to maximize their utility (in equation (A14)) subject to their budget constraint:

$$m_t^{dl} + P_{Nt}^l n_t^{dl} + P_{Tt}^l t_t^{dl} + P_{Ct}^A c_t^{dlA} + P_{Ct}^B c_t^{dlB} = w_t^{dl} \cdot \frac{h_t^{dl}}{H_t^{dl}} + \tau_t^d .$$

Workers make a discrete decision regarding where to locate themselves in the current period based on the their disposable income $w_t^{dl} \cdot \frac{h_t^{dl}}{H_t^{dl}} + \tau_t^d$ and prices P_t^l in each region $l = \{A, B\}$, where P_t^l is the price index of the final consumption bundle in equation (A15) and is defined in the Appendix (equation (A72)).

The Household Head's Problem. The household head collects firm profits and returns from the natural resource and then chooses how much to save and the amount of transfers to maximize the lifetime discounted utility of all workers of the household. Let $\bar{U}\left(E_t^{dl}(\tau_t^d), \vec{P}_t^l\right)$ denote a household worker's indirect utility given expenditure E_t^{dl} and a set of prices $\vec{P}_t^l$. Formally, the household head takes as given the sequence $\{\vec{P}_t^l, w_t^{dl}, H_t^{dl}, h_t^{dl}\}_{\forall d,l,t}$ and chooses $\{\tau_t^d, B_{t+1}\}_{\forall d,t}$ to maximize the sum of utility of unskilled and skilled workers across both regions:

$$\max_{\{\tau_t^d, B_{t+1}\}} \sum_t \beta^t \left(H_t^{uA}\bar{U}_t^{uA}(\tau_t^u) + H_t^{uB}\bar{U}_t^{uB}(\tau_t^u) + H_t^{sA}\bar{U}_t^{sA}(\tau_t^s) + H_t^{sB}\bar{U}_t^{sB}(\tau_t^s)\right),$$

subject to the sequence of budget constraints:

$$B_{t+1} + \left(H_t^{uA} + H_t^{uB}\right)\tau_t^u + \left(H_t^{sA} + H_t^{sB}\right)\tau_t^s \leq \Pi_t + P_{R,t}\bar{R}_t + (1+r)\,B_t \quad \forall t.$$

B.1.2 Production

Labor input. Firm f in each sector $k \in \{C, N, T\}$ uses a composite labor input that combines skilled and unskilled labor according to the following CES function:

$$l_f^k\big(l_{f,t}^{u,k}, l_{f,t}^{s,k}\big) \equiv \left[(\phi^k)^{\frac{1}{\gamma}}(l_{f,t}^{u,k})^{\frac{\gamma-1}{\gamma}} + (1-\phi^k)^{\frac{1}{\gamma}}(l_{f,t}^{s,k})^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{A16}$$

where $l^{s,k}_{f,t}$ and $l^{u,k}_{f,t}$ are the skilled and unskilled labor inputs, respectively. We assume that the relative use of these two types of labor varies across sectors (ϕ^k), while the elasticity of substitution between skill types is constant across them.

Commodity Sector. In each region, a representative firm produces a region-specific commodity that can be sold in both regions of this country and also exported internationally. To produce the commodity good, the representative firm combines the composite labor input L^l_{Ct} and a resource input R_t according to the following production function:

$$Y^l_{Ct} = \left(L^l_{Ct}\right)^{\eta} \cdot \left(R^l_t\right)^{1-\eta} .$$

The prices of each commodity good, P^l_{Ct}, are determined exogenously in the international market. After the demand from both regions for each commodity is met, the remaining output is exported internationally.

Nontradable Sector. The nontradable sector in each region is identical to the description in the baseline model in the main text.

Tradable Sector. The production technology of the tradable sector is identical to that of the nontradable sector. In each region, there is a continuum of firms heterogeneous in productivity z each producing a differentiated variety ζ using the following production function:

$$q^l_t(z) = z \cdot \left(l^l_t(z) - f^l_d\right) ,$$

where f^l_d is a fixed per-period production cost in terms of the composite labor input. Akin to the nontradable sector, each firm's productivity type z is permanent and is drawn from a log-normal distribution with mean μ_T and standard deviation Σ_T upon entry.

Unlike the nontradable sector, firms in the tradable sector located in region l can sell their varieties in the other region by paying a fixed per-period interregional export cost f^l_c. Furthermore, they can also export internationally subject to a (larger) per-period fixed cost f^l_x. Both fixed costs are expressed in terms of the composite labor input. The foreign demand for exports is:

$$q^l_x(z) = \Gamma \left[p^l_t(z)\right]^{-\sigma} ,$$

where Γ is exogenous and fixed throughout the commodity super-cycle. In contrast, the size of each domestic region's demand for tradable goods responds endogenously to changes in prices and wealth over the cycle. This feature is key to generating the wealth channel.

In each period all continuing firms face an exogenous exit risk that occurs with probability δ_T that is i.i.d. across firms and time. Meanwhile, potential entrants can enter the market subject to a fixed entry cost:

$$f_{Tet}^{l} = f_{Te}^{l} + \xi_{Te} \left[\exp\left(\frac{\mathcal{M}_{Tet}^{l} - \overline{\mathcal{M}}_{Te}^{l}}{\overline{\mathcal{M}}_{Te}^{l}} \right) - 1 \right] .$$

B.1.3 Equilibrium

Location Choices. Given the distributional assumptions on workers' idiosyncratic location preferences, the fraction of type-d workers living in region l at time t is given by:

$$\sigma_t^{d,l} = \frac{\exp\left(U\left(\frac{E_t^{d,l}}{P_t^l}\right)\right)^{1/\xi_d}}{\exp\left(U\left(\frac{E_t^{d,l}}{P_t^l}\right)\right)^{1/\xi_d} + \exp\left(U\left(\frac{E_t^{d,\neg l}}{P_t^{\neg l}}\right)\right)^{1/\xi_d}} ,$$

where $E_t^{d,l} \equiv w_t^{dl} \cdot \frac{h_t^{dl}}{H_t^{dl}} + \tau_t^d$ is a worker's disposable income and P_t^l is the ideal price index of the final consumption bundle. Note that migration flows are determined by regional differences in wages, prices, and employment levels. All else equal, an increase in wages leads to population inflows, whereas an increase in price levels or unemployment rates leads to population outflows. This is consistent with dynamic economic geography models such as Caliendo et al. [2019].

Entry and Exit in the Nontradable Sector. Firms are subject to an exogenous exit probability δ_N in every period. In addition, firms exit endogenously when the discounted present value of profits is negative. Letting optimal profits of a nontradable firm i be denoted by $\pi_{f,t}^l$, the value function of a firm with productivity z is:

$$W_{f,t}^l(z) = \max\left\{0, \pi_{f,t}^l(z) + \beta(1-\delta_N)W_{f,t+1}^l(z)\right\} .$$

The domestic productivity cutoff $\bar{z}_t^l$ is implicitly defined by the productivity level that solves $W_{f,t}^l(\bar{z}_t^l) = 0$.

In each period, potential entrants may pay the fixed entry cost to draw their permanent productivity levels z. If the realized draw is higher than the domestic cutoff, the firm will enter the market and produce. Potential entrants will pay to get their productivity draws until the present discounted value of entry is equal to the fixed entry cost:

$$\hat{w}^l_{Nt} \cdot f^l_{Net} = \int_{\bar{z}^l_t}^{\infty} W^l_t(z) g(z) dz \,.$$

Entry, Exit, and Exporting in the Tradable Sector. Entry and exit decisions in the tradable sector are identical to those in the nontradable sector. However, in the tradable sector, firms make the additional decisions of whether or not to sell to the other region in the economy and to the foreign market.

Let $\pi^l_{m,t}$ denote the static profits associated with each sales mode $m \in \{d, c, x\}$ (selling in the own region, exporting to the other region, and exporting internationally, respectively). The value functions corresponding to each of these modes are:

$$\begin{aligned}
W^l_{d,t}(z) &= \max\left\{0, \pi^l_{d,t}(z) + \beta(1-\delta_N) W^l_{t+1}(z)\right\} \,, \\
W^l_{c,t}(z) &= \max\left\{0, \pi^l_{d,t}(z) + \pi^l_{c,t}(z) + \beta(1-\delta_N) W^l_{t+1}(z)\right\} \text{ , and} \\
W^l_{x,t}(z) &= \max\left\{0, \pi^l_{d,t}(z) + \pi^l_{c,t}(z) + \pi^l_{x,t}(z) + \beta(1-\delta_N) W^l_{t+1}(z)\right\} \,.
\end{aligned}$$

The continuation value is given by: $W_{t+1}(z) = \max\{W^l_{d,t}(z), W^l_{c,t}(z), W^l_{x,t}(z)\}$. The domestic ($\bar{z}^l_{d,t}$), interregional export ($\bar{z}^l_{c,t}$), and international export cutoffs ($\bar{z}^l_{x,t}$) are implicitly defined by $W^l_{d,t}(\bar{z}^l_{d,t}) = 0$, $\pi^l_{c,t}(\bar{z}^l_{c,t}) = 0$, and $\pi^l_{x,t}(\bar{z}^l_{x,t}) = 0$. Finally, the free entry condition is:

$$\hat{w}^l_{Tt} \cdot f^l_{Tet} = \int_{\bar{z}^l_t}^{\infty} W^l_t(z) g(z) dz \,.$$

B.1.4 Calibration

In our quantitative analysis, we analyze two regions that are symmetric in the steady state but face different commodity price sequences. We assign to these two regions the prices faced by the states of Sao Paulo and Minas Gerais, based on the following criteria. These states are the largest in Brazil and are representative of the country as a whole in terms of their economic structure.[24] In addition, they experience very different commodity prices, with Minas Gerais among the top

[24]The share of employment in Sao Paulo and Minas Gerais combined is 42% of the national employment in 2001.

10% and Sao Paulo in the bottom 10% in terms of the magnitude of the commodity boom between the trough in 2002 and the peak in 2011. Finally, these two states share a long border between them, which leads to a larger amount of migration than between more distant states. We calibrate the model to target the observed migration and trade between the two states.

The externally calibrated parameters are the same as those shown in Table 4 in the main text. A second set of parameters is internally calibrated to match macroeconomic ratios and sectoral and firm-level outcomes computed from our data. The calibration is done at an annual frequency and uses data for the year 2001.[25] Table A27 reports these internally calibrated parameters. We discuss here only the parameters that are not part of the baseline single–region model in the main text. The fixed cost of interregional sales in the tradable sector (f_c) is calibrated to match the interstate trade to GDP ratio.[26] The location preference parameter (ξ_d) is calibrated to mimic the net migration rate between Minas Gerais and Sao Paulo during the commodity boom.[27]

Simulation. In the following exercises, we assume that the economy starts in a steady state in period 0. In period 1, a commodity price super-cycle is revealed to the agents in the economy. The size of the cycle is different for the two regions in the economy, with region A being subject to a larger boom in commodity prices. As Figure A5 shows, the price of the commodity good produced in region A increases steadily for ten years (period marked by the darker gray area in each graph) and reaches a cumulative increase close to 90%. Region B experiences a smaller boom-bust cycle, with the peak cumulative increase being around 50%. These trough-to-peak amplitudes are obtained from the increase in commodity prices observed in the State of Minas Gerais (corresponding to region A) and Sao Paulo (corresponding to region B) in Brazil between 2002 and 2011, as measured with employment-weighted prices at the state level. In both regions, commodity prices decrease steadily after the peak of the boom, reverting to their initial levels after ten years. The price dynamic during the bust is extrapolated from the data in a symmetric fashion.

[25] We choose 2001 because it is the year right before the start of the boom. The model is calibrated to the exact same sample used in the empirical analysis.

[26] Because the commodity price series used in the quantitative exercise correspond to that of Minas Gerais and Sao Paulo, we use the interstate trade to GDP ratio between these two states.

[27] The calibration of the location preference parameter is described in detail in Section B.9.

Table A27: Internally-Calibrated Parameters

Parameter	Description	Moment Targeted	Moment (Data)	Moment (Model)	Param. Value
P_C	Commodity price	C share in GDP	0.14	0.14	5.37
α_N	Weight on N good in utility	N share in GDP	0.55	0.59	14.76
α_C	Weight on C good in utility	Share of C in exports	0.32	0.31	0.11
f_d	Production fixed cost in T	Share of T emp. in 20% smallest firms	0.02	0.02	0.21
f_c	Fixed cost of interregional sales in T	Interstate trade to GDP ratio	0.12	0.12	0.39
f_x	Fixed cost of international exports in T	Fraction of exporting firms in T	0.09	0.08	6.99
Σ_T	St. dev. of productivity distribution in T	Share of T emp. in 10% largest firms	0.68	0.64	0.82
Γ	Foreign demand	Export to GDP ratio	0.15	0.16	196.62
$\bar{R}$	Resource endowment	C share in employment	0.08	0.09	18.15
f_N	Production fixed cost in N	Share of N emp. in 20% smallest firms	0.04	0.04	0.14
μ_N	Mean of productivity distribution in N	Relative mass of firms: M_T/M_N	0.27	0.27	0.08
Σ_N	St. dev. of productivity distribution in N	Share of N emp. in 10% largest firms	0.66	0.54	1.08
κ	Aggregate share of unskilled labor	Skill premium (w^s/w^u)	3.16	3.16	0.83
ϕ^C	Skill intensity in C	Share of unskilled labor in C $(L^{u,C}/L^C)$	0.92	0.92	0.69
ϕ^N	Skill intensity in N	Share of unskilled labor in N $(L^{u,N}/L^N)$	0.79	0.79	0.43
ϕ^T	Skill intensity in T	Share of unskilled labor in T $(L^{u,T}/L^T)$	0.88	0.88	0.59
ξ_e	Entry congestion elasticity	Fraction of entry cost: $\max\{\frac{\text{cong. term}}{f_e}\}$	0.25	0.22	1
ξ_d	Location preference	Minas Gerais share of national employment at peak of boom	0.51	0.51	10

Note: This table shows the values of internally-calibrated parameters. The abbreviations C, T and N stand for the commodity, tradable and nontradable sectors.

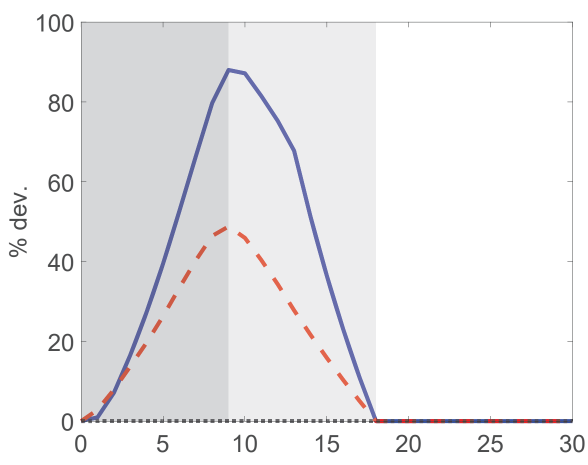


Figure A5: Commodity Prices in the Multiregion Model

Note: This figure shows the path of the prices of the commodity goods produced in region A (solid blue line) and region B (dashed red line) used in the quantitative analysis.

B.1.5 Model Validation

First, we show that the model can replicate the evolution of the skill premium. We estimate the skill premium regression in equation (3) in Section 2.3 using simulated data from the model. Recall that in the model there are two regions, corresponding to Brazilian states. Consequently, we contrast this result with the same regression estimated with the actual data at the state level.[28,29] The results are displayed in columns 1 and 2 in Table A28. This comparison indicates that the model matches closely the skill premium dynamics triggered by the commodity price super-cycle.

Table A28: Model Validation: Skill Premium and Regional Employment

	(1)	(2)	(3)	(4)
	Skill Premium		Regional Employment	
	Model	Data	Model	Data
Price_{rt}	-0.106***	-0.221***		
	(0.005)	(0.087)		
$\text{Price}_{rt} \cdot T_s$			-0.086***	-0.199***
			(0.033)	(0.008)
Observations	24	267	48	594

NOTE: The first two columns report the results of the estimation of equation (3). Each regression includes state and year fixed effects. The last two columns report the results of the estimation of equation (A17). Each regression includes state × year and sector fixed effects. Columns 1 and 3 use simulated data. Columns 2 and 4 use actual data. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

The intersectoral reallocation of labor between the tradable and nontradable sectors lies at the core of the transmission of commodity price super-cycles in the model. Therefore, this is another important dimension along which to test the calibrated model. To this end, we estimate the following equation of sectoral employment shares (Emp. Share_{rst}) on an interaction between the price and a tradable sector dummy (T_S), and region × time and sector fixed effects:[30]

$$\text{Emp. Share}_{rst} = \beta_1 \cdot \text{Price}_{rt} \cdot T_s + \nu_{rt} + \gamma_s + \epsilon_{rst}\,. \tag{A17}$$

[28] As shown in Table 1 in Section 2.3 we found similar results when observations correspond to microregions.

[29] The simulated price series fed into the model (shown in Figure A5) are based on the bust to boom commodity price increase in each state from 2002 to 2013, with 2002 corresponding to the initial steady state in the model. In this subsection we contrast data and model using in both cases the "transition years" 2003-2013, although we find similar results with different timing assumptions.

[30] We estimate this equation jointly for the tradable and nontradable sectors because we are concerned in our quantitative results (later in this section) with the reallocation of employment between these sectors.

The coefficient β_1 measures the differential employment response in the tradable sector relative to the nontradable sector. As before, to match the model closely, we use data at an annual frequency with each observation corresponding to a state, although we find similar patterns using data at the microregion level. We compare the estimated parameters obtained using the simulated data with those obtained based on the actual data. The results are reported in columns 3 and 4 in Table A28. We observe a close match between model and data in the reallocation of employment across sectors.

Finally, we compare the model-generated firm-level employment responses to the commodity price super-cycle to those estimated from the actual data to distinguish between the impact of prices on exporting and nonexporting firms in the tradable sector. Specifically, we estimate the following equation:

$$\log(\text{Emp})_{ft} = \beta_1 \cdot \text{Exporter}_{ft} + \beta_2 \cdot \text{Exporter}_{ft} \cdot \text{Price}_{rt} + \gamma_f + \delta_{rt} + \epsilon_{ft}\,. \tag{A18}$$

This equation is analogous to equation (5) estimated in the empirical section, but we include region $\times$ time fixed effects which absorb the uninteracted regional price index.[31] Once again, we use actual data with prices defined at the state level at an annual frequency to be consistent with the model calibration. The results are displayed in Table A29, and again confirm a close parallel between the behavior of the model and the empirical results.

Table A29: Model Validation: Firm-Level Employment

	(1)	(2)
	Tradable	
	Model	Data
Exporter$_{ft}$ x Price$_{rt}$	-0.122***	-0.094***
	(0.005)	(0.024)
Observations	1,397,018	1,538,219

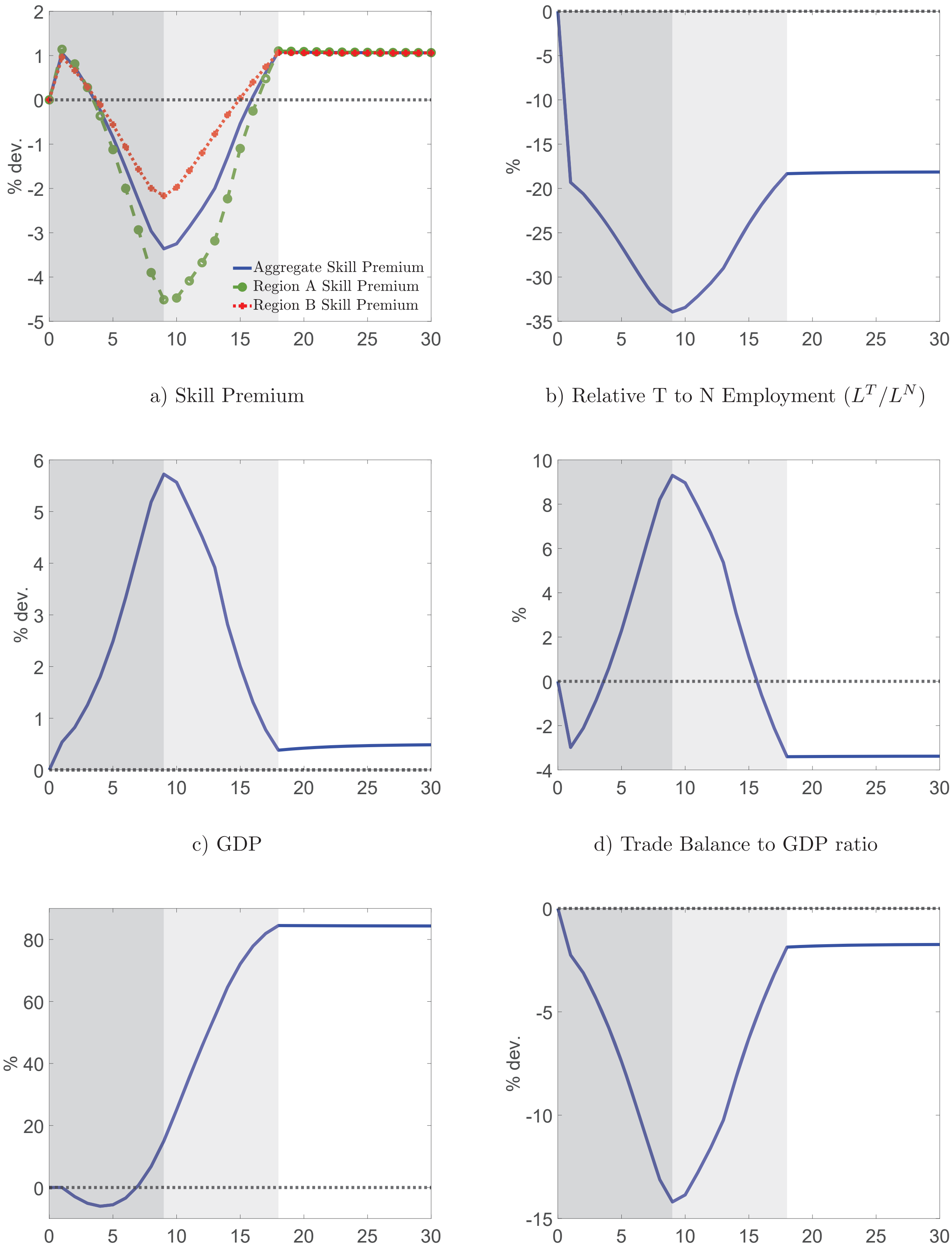
NOTE: Columns 1 and 2 in this table reports the results of the estimation of equation (A18) using the simulated and actual data respectively. ***, **, and * denote statistical significance at a 1, 5 and 10 percent confidence level, respectively.

[31] As in equation (5) we also include interaction terms between firm–size bin dummies and the price index.

B.1.6 Transmission Mechanisms and Aggregate Impact

We can use the calibrated model to assess the transmission mechanisms and aggregate impact, comparing the response of this multiregion model to the baseline model in the main text. Figure A6 plots the response of the economy to the price cycles of the commodities produced by regions A and B shown in Figure A5. The path of the skill premium (see Figure A6a) maps closely the response of the baseline model (displayed in Figure 4b). This leads to a similar reallocation across sectors, as seen by comparing the ratio of tradable to nontradable employment in the multiregion model (in Figure A6b) to the baseline model (in Figure 5a). In addition, the macroeconomic impact tracks the response of the baseline model closely, as shown in the plots for GDP, the trade balance, net foreign assets to GDP and the real exchange rate in panels A6c through A6f (which are equivalent to Figure 6 for the baseline model).

Finally, it is worth noting that as part of the adjustment process there is a displacement of population during the boom toward region A, which has the largest increase in the commodity price (see Figure A7). Sections B.1.7 and B.1.8 show that these results are robust to using different values for the location preference parameter and the fixed cost of interregional trade.



a) Skill Premium

b) Relative T to N Employment (L^T/L^N)

c) GDP

d) Trade Balance to GDP ratio

e) Net Foreign Assets to GDP ratio

f) Real Exchange Rate

Figure A6: Response of Macroeconomic Outcomes to a Commodity Price Super–Cycle in the Multiregion Model

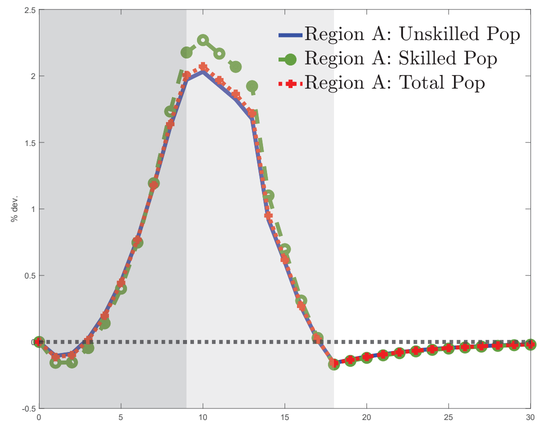


Figure A7: Response of Migration to a Commodity Price Super–Cycle in the Multiregion Model

B.1.7 Multiregion Model Robustness: Location Preferences

Another fundamental parameter in the model is the location preference ξ, which we calibrated using microdata. Here we document the response of the model a commodity price cycle in an economy with a stronger or weaker location preference. We also allow heterogeneous location preferences between skilled and unskilled workers. Specifically, the baseline value for this parameter was $\xi = 10$. We compare this to an economy with a lower location preference $\xi_{LOW} = 5$ and to an extreme case with no migration due to an infinite location preference parameter ($\xi_{HIGH} = \infty$). In the economy with heterogeneous location preferences we set this equal to $\xi_{skilled} = 4$ and $\xi_{unskilled} = 11$.

Figure A8 illustrates the response of the skill premium in regions A and B during a commodity price cycle, under each value of the location preference parameter. The response of each of these economies with different degrees of interregional mobility is fairly similar.

Figure A9a illustrates the dynamics of migration, showing the total population in region A. Evidently, under the infinite location preference parameter, it remains constant. Comparing the baseline economy ($\xi = 10$) to the economy with a low location preference parameter ($\xi_{LOW} = 5$), in the latter the share of population in region A increases substantially more during the boom. Figures A9b and A9c indicate that these flows are driven by both skilled and unskilled workers.

We also find that most aggregate outcomes do not vary significantly as the location preference parameter changes (see Figure A10). Figure A10f in particular shows that intersectoral labor reallocation as a result of the commodity cycle, captured by the ratio of employment in the tradable relative to the nontradable sector, does not depend meaningfully on the location preference parameter. Note finally that allowing for differential location preferences between skilled and unskilled workers does not appear to have much of a macroeconomic impact.

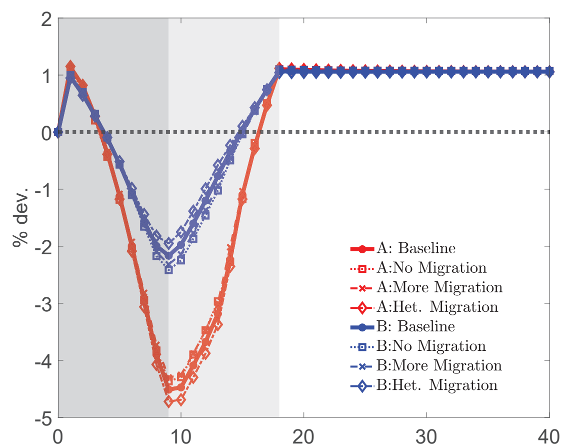
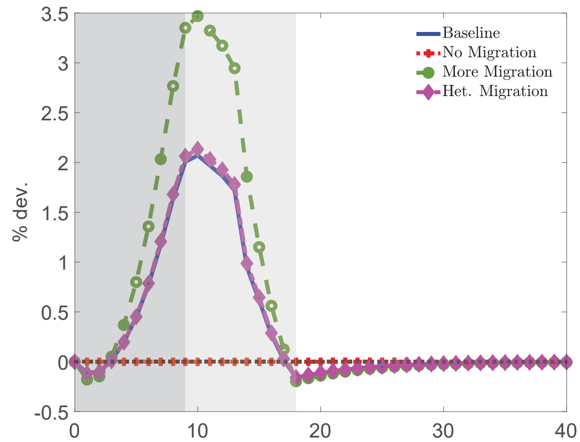
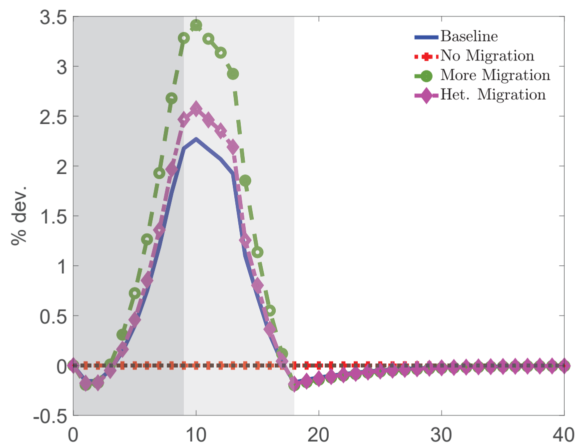


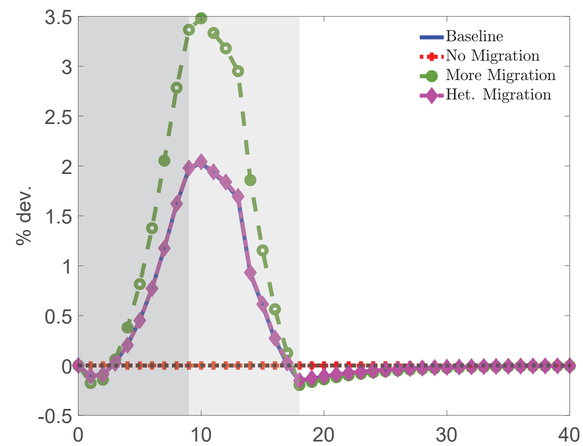
Figure A8: Response of the Skill Premium to a Commodity Price Super–Cycle in the Multiregion Model under Different Location Preferences



a) Total Population in Region A

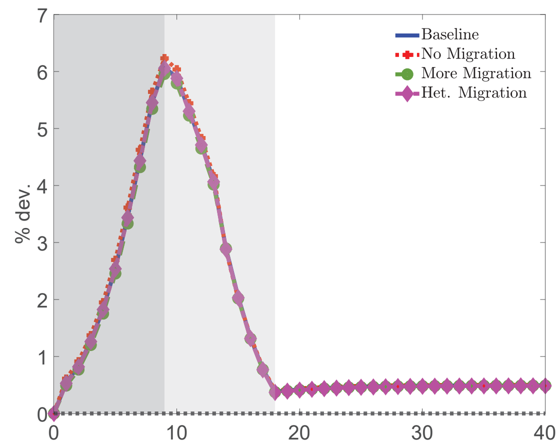


b) Skilled Population in Region A

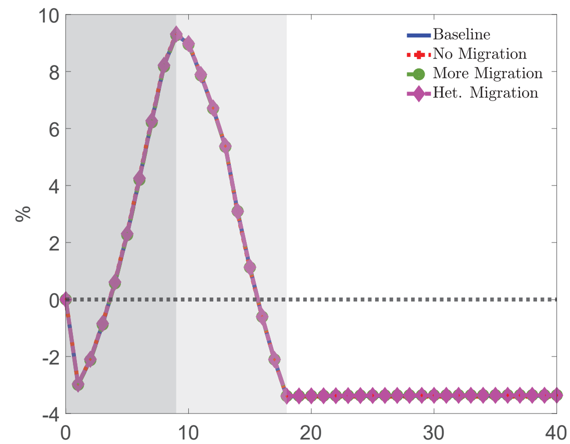


c) Unskilled Population in Region A

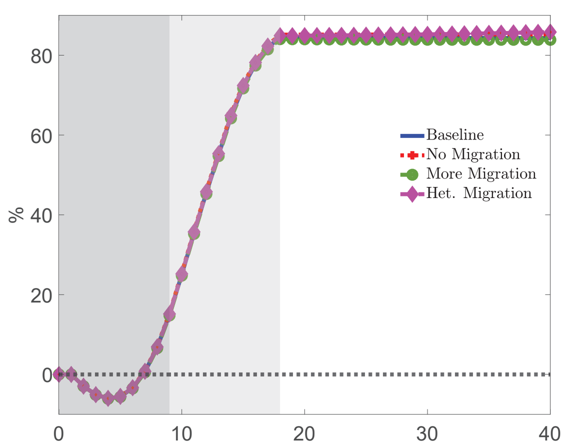
Figure A9: Response of Population by Skill Type to a Commodity Price Super–Cycle in the Multiregion Model under Different Location Preferences



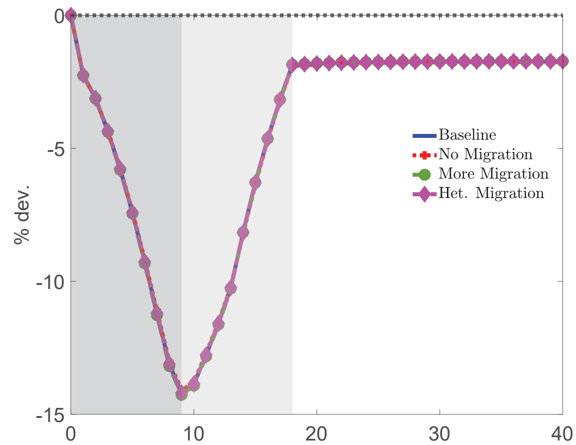
a) GDP



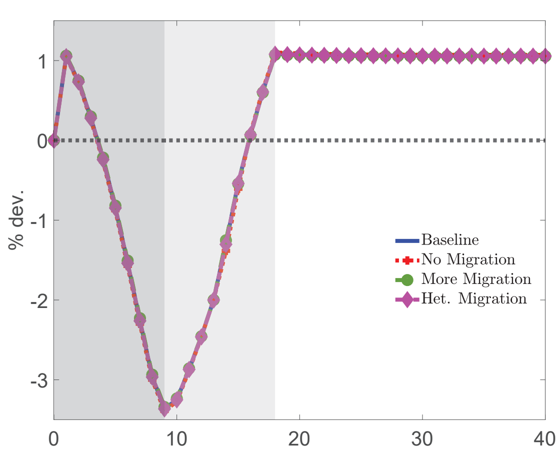
b) Trade Balance to GDP ratio



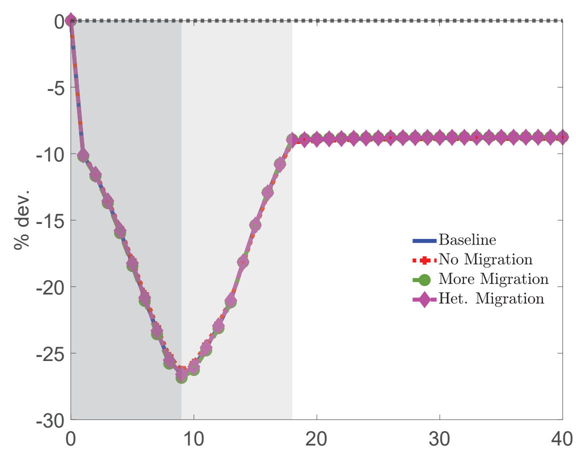
c) Net Foreign Assets to GDP ratio



d) Real Exchange Rate



e) Skill Premium



f) Relative T to N Employment (L^T/L^N)

Figure A10: Response of Macroeconomic Outcomes to a Commodity Price Super–Cycle in the Multiregion Model under Different Location Preferences

B.1.8 Multiregion Model Robustness: The Fixed Cost of Interregional Exporting

In this section we document the sensitivity of our results to varying the fixed cost of interregional exporting (f_c). We compare the baseline economy with two other parametrizations with a 25% higher and 25% lower values for this fixed cost. Recall that the interregional export fixed cost impacts aggregate trade flows through a selection effect; a higher fixed cost limits the set of firms that export to the other region. Figure A11 illustrates the total volume of interregional trade in Brazil (adding exports from region A to B and exports from B to A). The first message that emerges from this figure is that these large changes in the fixed cost of interregional exports result in small changes in trade flows. Intuitively, changes in interregional trade flows are smaller in magnitude in the economy with the larger fixed cost.

Next, Figure A12 indicates that the macroeconomic effects from varying the interregional export fixed cost are very small. Finally, panel f) in the same figure depicts the intersectoral labor reallocation as a result of the commodity cycle, plotting employment in the tradable relative to the nontradable sector. As with the other outcomes described earlier, the three economies behave very similarly during the boom and bust.

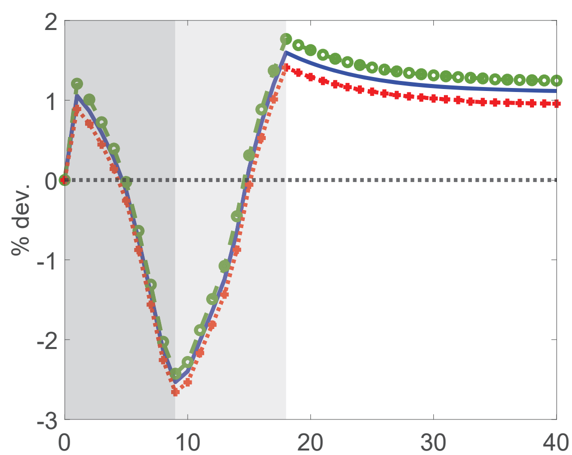
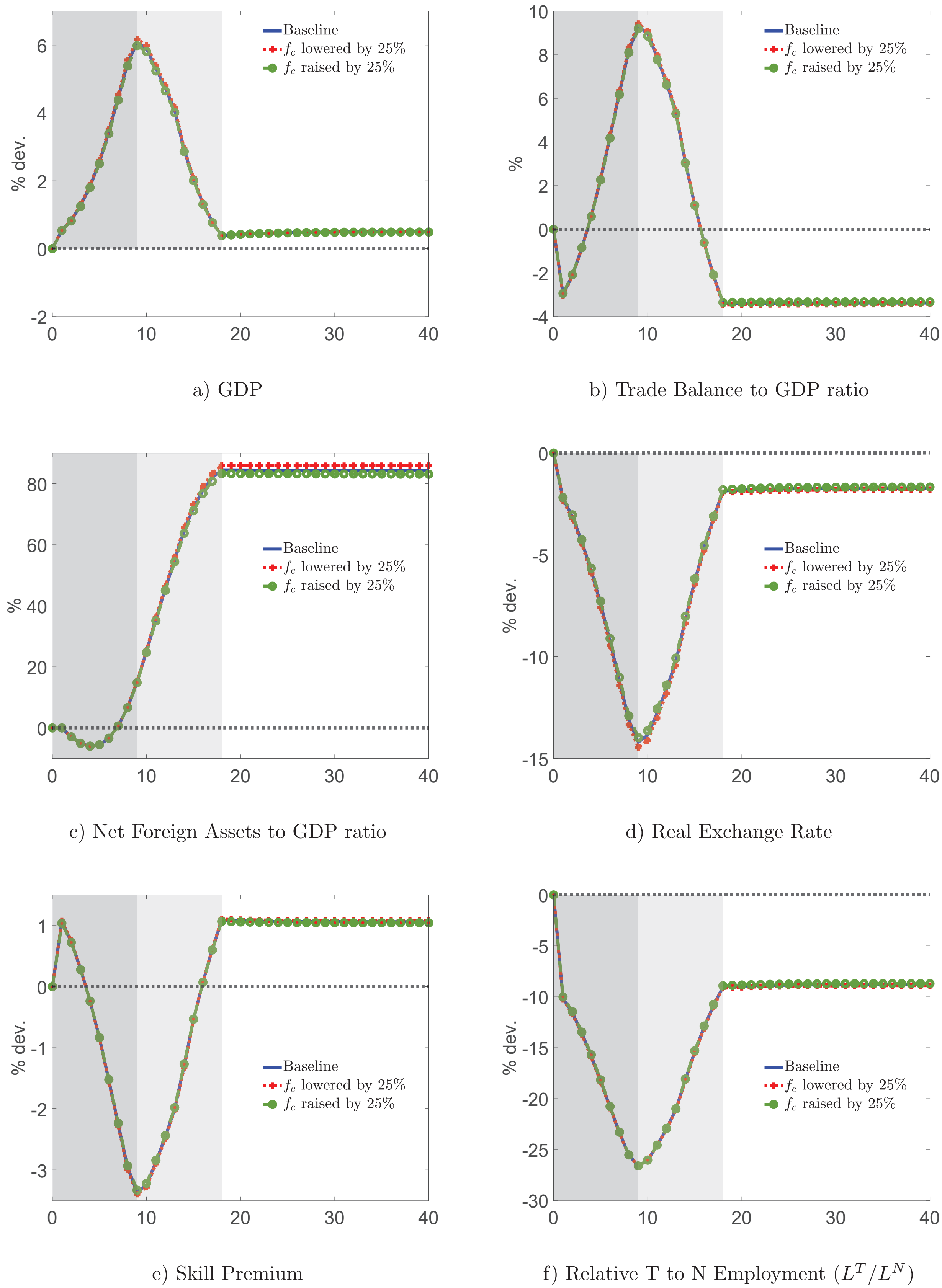


Figure A11: Response of the Interregional Trade Volume to a Commodity Price Super–Cycle in the Multiregion Model under Different Fixed Costs of Interregional Exporting



a) GDP

b) Trade Balance to GDP ratio

c) Net Foreign Assets to GDP ratio

d) Real Exchange Rate

e) Skill Premium

f) Relative T to N Employment (L^T/L^N)

Figure A12: Response of Macroeconomic Outcomes to a Commodity Price Super–Cycle in the Multiregion Model under Different Fixed Costs of Interregional Exporting

B.1.9 Robustness: Welfare Comparison

Finally, we assess the robustness of our results by comparing the long–run level of the net foreign assets to GDP ratio and of consumption–equivalent welfare in the baseline multiregion model against the economies with different location preferences (resulting in more or less migration), the economy with heterogeneous location preferences for skilled and unskilled workers, and the economies with different fixed costs of interregional trade. We see in Table A30 that the results are quite close across all these scenarios.

Table A30: Welfare Comparisons: Multiregion Model

	CEQ Welfare (%)	Long Run B/Y
Baseline	1.86	0.84
More Migration	1.82	0.84
No Migration	1.91	0.85
Het. Migration	1.82	0.83
High f_c	1.83	0.83
Low f_c	1.89	0.86

NOTE: This table reports consumption–equivalent welfare (column 1) and the long–run value of the net foreign assets to GDP ratio (column 2) to the commodity price super-cycle shown in Figure A5. The rows correspond to the baseline multiregion model (first row), different values of the location preference paramenter (resulting in more or less migration) (second and third row), different values of the location preference parameters for skilled and unskilled workers (fourth row), and a higher or lower value of the fixed cost of interregional sales (fifth and sixth rows).

B.2 Representative Firm Model

To highlight the generality of the baseline model, we present an alternative version in which all three sectors are perfectly competitive and have representative firms. The model structure is identical to the baseline model with heterogeneous firms, except that the nontradable and tradable sectors are each populated by a representative firm.

We first describe the key equations that differ from the baseline model. We then discuss the calibration and quantitative results under these assumptions.

B.2.1 Model Outline

Nontradable Sector. A representative firm produces the nontradable good with a linear production technology:

$$Y_t^N = A_N \cdot \left(L_t^N\right) . \tag{A19}$$

The unit cost of the composite labor input is given by:

$$\hat{w}_t^N = \left[\phi_N \left(w_t^u\right)^{1-\gamma} + \left(1-\phi_N\right)\left(w_t^s\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} . \tag{A20}$$

Given perfect competition, the price of the nontradable good is pinned down by the zero profit condition:

$$P_t^N = \frac{\hat{w}_t^N}{A_N} . \tag{A21}$$

Tradable Sector. A representative firm produces the tradable good with a linear production technology:

$$Y_t^T = A_T \cdot \left(L_t^T\right) . \tag{A22}$$

The tradable good is sold both domestically and exported. Export demand is price elastic with the following schedule:

$$T_t^F = \Gamma \cdot \left(P_t^T\right)^{-\sigma} . \tag{A23}$$

The representative firm cannot price discriminate across the domestic and export market, but rather sets one price only. The unit cost of the composite labor input is given by:

$$\hat{w}_t^T = \left[\phi_T \left(w_t^u\right)^{1-\gamma} + \left(1-\phi_T\right)\left(w_t^s\right)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} . \tag{A24}$$

The zero profit condition in the domestic market pins down the price of the tradable good:

$$P_t^T = \frac{\hat{w}_t^T}{A_T}\,. \tag{A25}$$

B.2.2 Calibration

We calibrate the representative firm model to match the Brazilian data. The externally calibrated parameters do not change relative to the baseline model. We normalize the productivity of the tradable sector to 1, and calibrate A_N to match the employment ratio in the tradable sector relative to the nontradable sector, L_T/L_N. The rest of the internally–calibrated parameters are calibrated using the same strategy as in the baseline model.

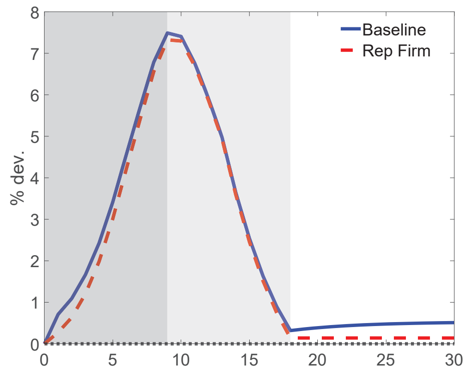
Table A31: Internally-Calibrated Parameters

Parameter	Description	Moment Targeted	Moment (Data)	Moment (Model)	Param. Value
P_C	Commodity price	C share in GDP	0.14	0.15	41.47
α_N	Weight on N good in utility	N share in GDP	0.55	0.55	6.94
α_C	Weight on C good in utility	Share of C in exports	0.32	0.32	2.87
Γ	Foreign demand	Export to GDP ratio	0.15	0.15	5000
$\bar{R}$	Resource endowment	C share in employment	0.08	0.08	0.32
A_N	Nontradable productivity	L_T/L_N	0.48	0.49	0.79
κ	Aggregate share of unskilled labor	Skill premium (w^s/w^u)	3.16	3.16	0.83
ϕ^C	Skill intensity in C	Share of unskilled labor in C ($L^{u,C}/L^C$)	0.92	0.92	0.69
ϕ^N	Skill intensity in N	Share of unskilled labor in N ($L^{u,N}/L^N$)	0.79	0.79	0.43
ϕ^T	Skill intensity in T	Share of unskilled labor in T ($L^{u,T}/L^T$)	0.88	0.88	0.59

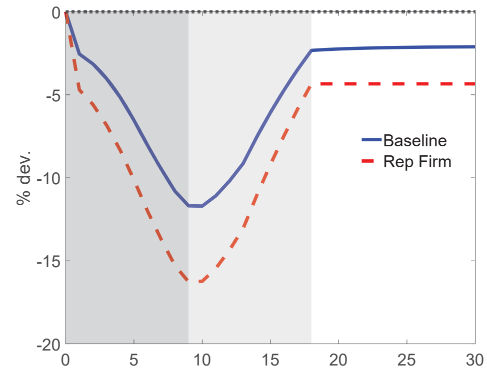
NOTE: This table shows the values of internally-calibrated parameters. The abbreviations C, T and N stand for the commodity, tradable and nontradable sectors.

B.2.3 Aggregate Outcomes: Baseline Model vs. Representative Firm Model

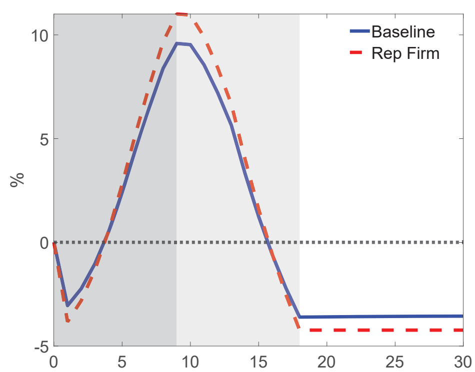
Figure A13 shows that the response of various macroeconomic outcomes to the commodity cycle is similar in the baseline and the representative firm models. Panel f) indicates that the ratio of employment in the tradable sector relative to employment in the nontradble sector falls further in the baseline model with heterogeneous firms. Part of the reason is that under heterogeneous firms, the increase in the export productivity cutoff leads to a fall in the mass of exporting firms. Consequently, less labor is used to cover the fixed exporting cost. Of course, this effect is absent in the model with representative firms. In addition, there is a fall in the mass of firms in the tradable sector in the heterogeneous firms model, which also leads to a relative decline of employment in the tradable sector.



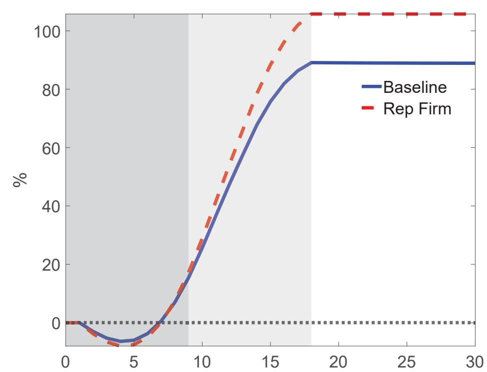
a) GDP



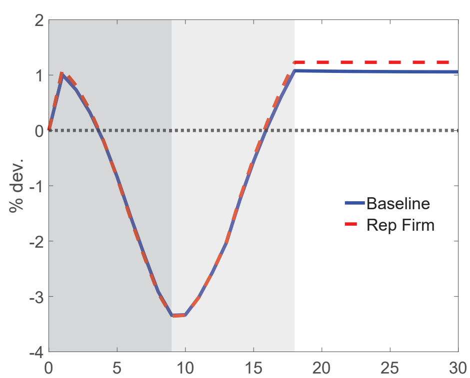
b) Real Exchange Rate



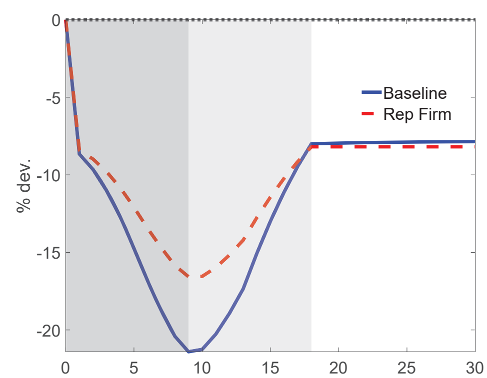
c) Trade Balance to GDP ratio



d) Net Foreign Assets to GDP ratio



e) Skill Premium



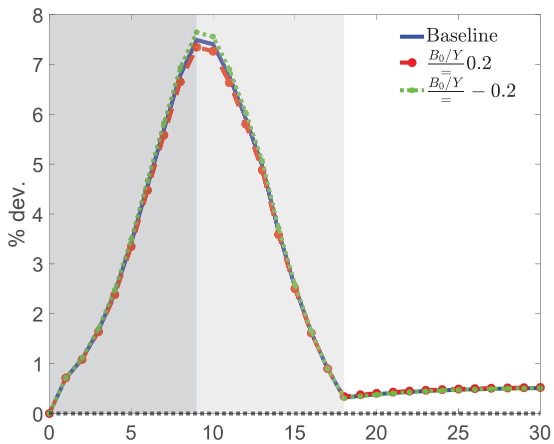
f) Relative T to N Employment (L^T/L^N)

Figure A13: Response of Macroeconomic Outcomes to a Commodity Price Super-Cycle in the Representative Firm Model

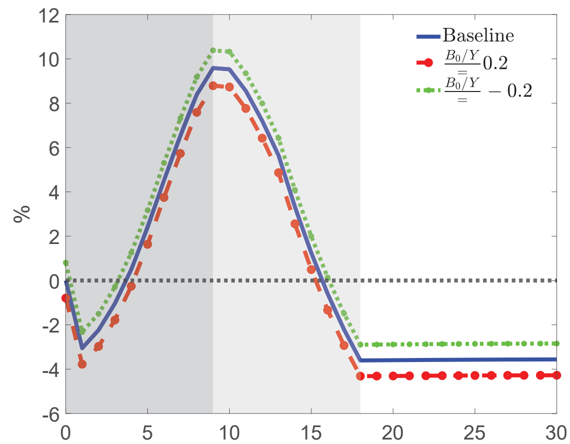
NOTE: This figure shows the response of consumption-deflated GDP (top left), the real exchange rate (top right), the trade balance to GDP ratio (center left), the net foreign assets to GDP ratio (center right), the skill premium (bottom left) and the ratio of employment in the tradable relative to the nontradable sector (bottom right) to the commodity price super-cycle shown in Figure 3. The blue solid line corresponds to the baseline economy described in the main text. The red dashed line corresponds to the economy with a representative firm described in this appendix.

B.3 Initial Condition for Net Foreign Assets to GDP

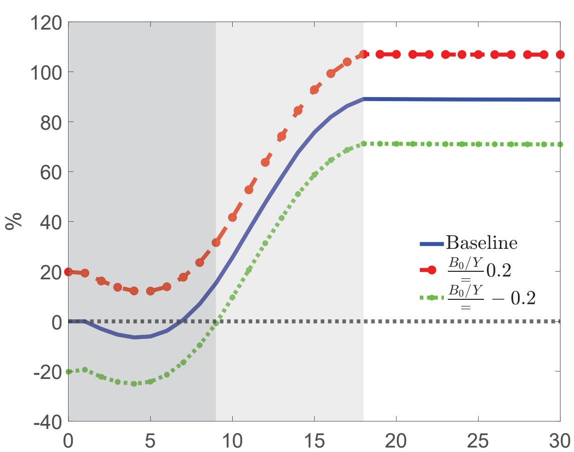
In our baseline analysis we assume the initial household debt to be zero. In this section, we show that changes in this initial condition have practically no impact on the evolution of the skill premium, intersectoral labor reallocation, and various other outcomes. We simulate the baseline economy alongside two alternative economies with +20% and -20% initial net foreign assets to GDP. Figure A14 illustrates the path of macroeconomic outcomes, showing no differences between the three economies except, of course, in the plots of net foreign assets to GDP, which follow parallel paths, and in plots of the trade balance to GDP ratio. In the case of the trade balance to GDP ratio, note that an economy starting with higher net foreign assets to GDP accumulates higher holdings after the commodity cycle as well, and is able to sustain a larger trade deficit in the new steady state. Figure A14f focuses on the intersectoral labor reallocation as a result of the commodity cycle. It plots the relative employment in the tradable relative to the nontradable sector, showing the three economies behave similarly during the boom and bust.



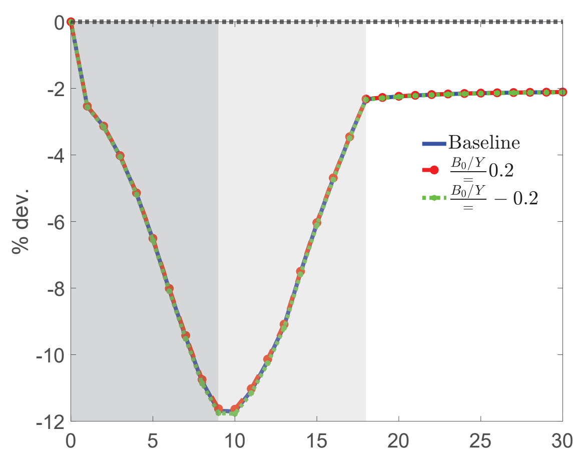
a) GDP



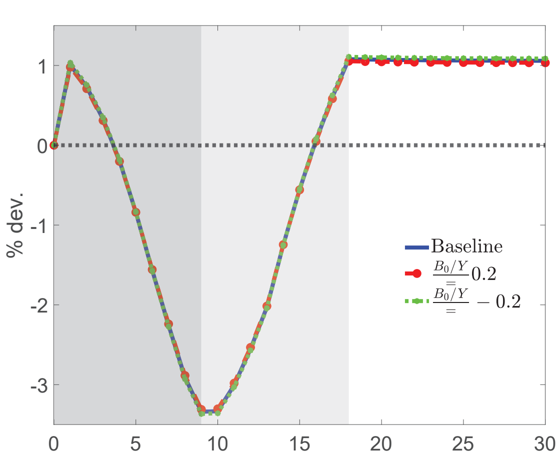
b) Trade Balance to GDP ratio



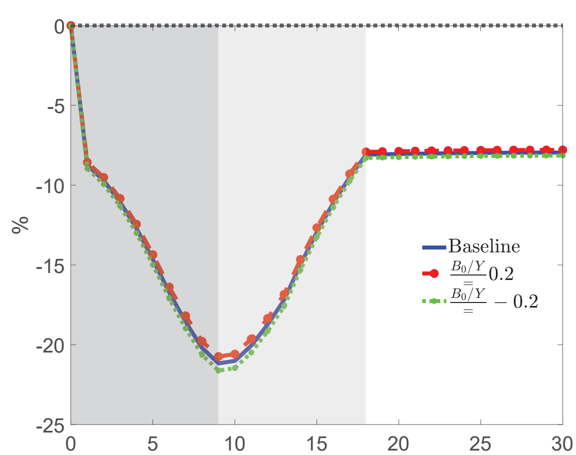
c) Net Foreign Assets to GDP ratio



d) Real Exchange Rate



e) Skill Premium



f) Relative T to N Employment (L^T/L^N)

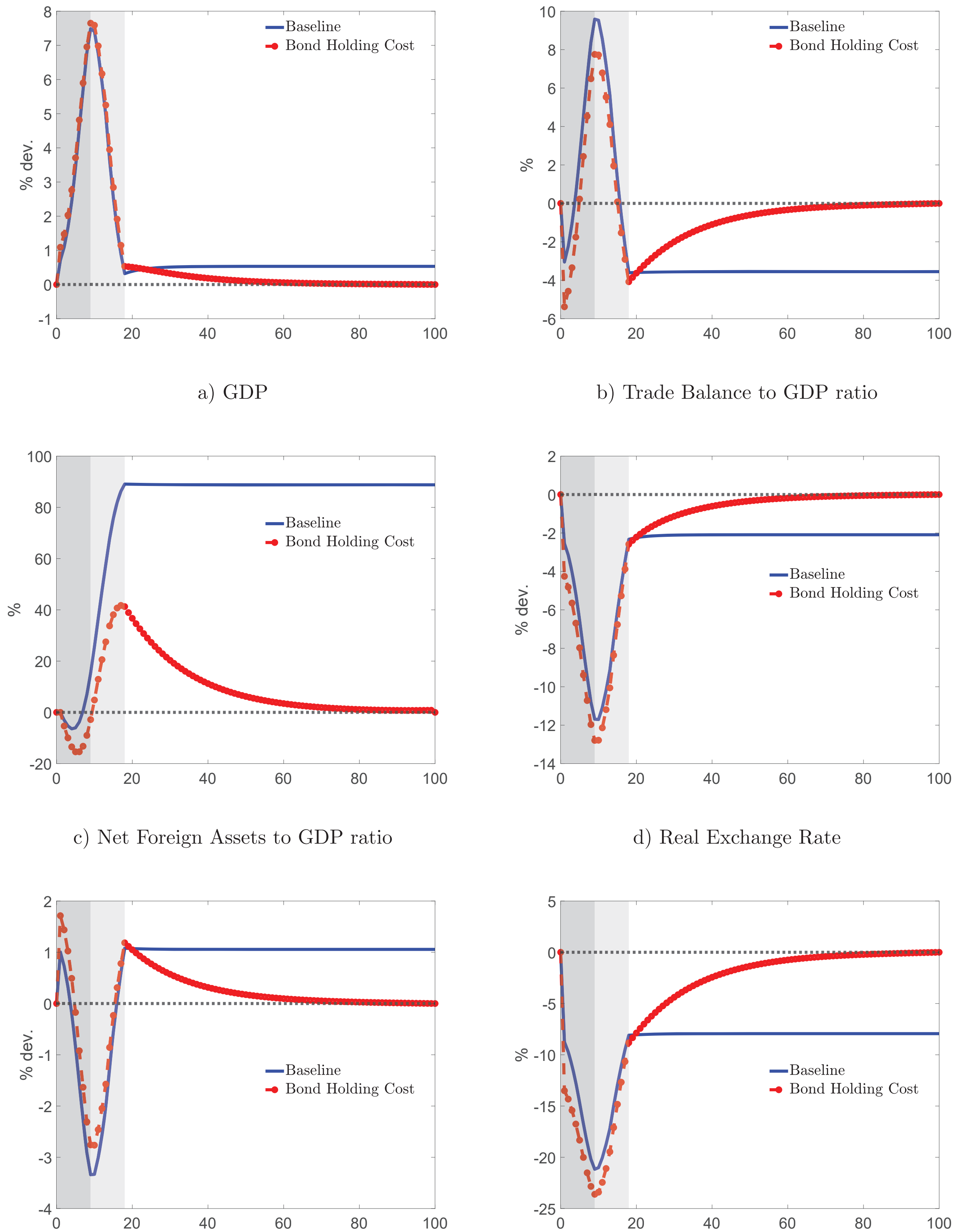
Figure A14: Response of Macroeconomic Outcomes to a Commodity Price Super-Cycle under Different Initial Conditions for Net Foreign Assets to GDP

B.4 Including a Bond-Holding Cost

In this section, we show our results are robust to adding a bond-holding cost. A bond-holding cost forces the economy to eventually converge to the original steady state. We thus show that our short and medium-run results are not driven by the permanent long-run divergence from the initial steady state in the baseline case. Specifically, the bond holding cost is assumed to be quadratic in the amount of bond held ($\frac{\psi_B}{2}\left(B_t\right)^2$) and it is added to the household's budget constraint. The long-run steady state has $B = 0$, just like the initial condition. Note that the bondholding cost implies that there is no longer perfect consumption smoothing as saving is now costly. The household's consumption will thus be larger during the boom.

Figure A15 compares the evolution of macroeconomic outcomes in the baseline economy and the case with the bondholding cost. The main message from these plots is that while the two economies differ in the long-run values to which they converge, their behavior is very similar in the short and medium-run (during the boom and bust). Regarding the long-run steady state after the cycle, as expected, the economy with a bond-holding cost accumulates less net foreign assets.

Figure A15f, in particular, illustrates the intersectoral labor reallocation as a result of the commodity cycle. It plots the relative employment in the tradable relative to the nontradable sector. As with the other outcomes described earlier, the two economies behave similarly during the boom and bust.



a) GDP

b) Trade Balance to GDP ratio

c) Net Foreign Assets to GDP ratio

d) Real Exchange Rate

e) Skill Premium

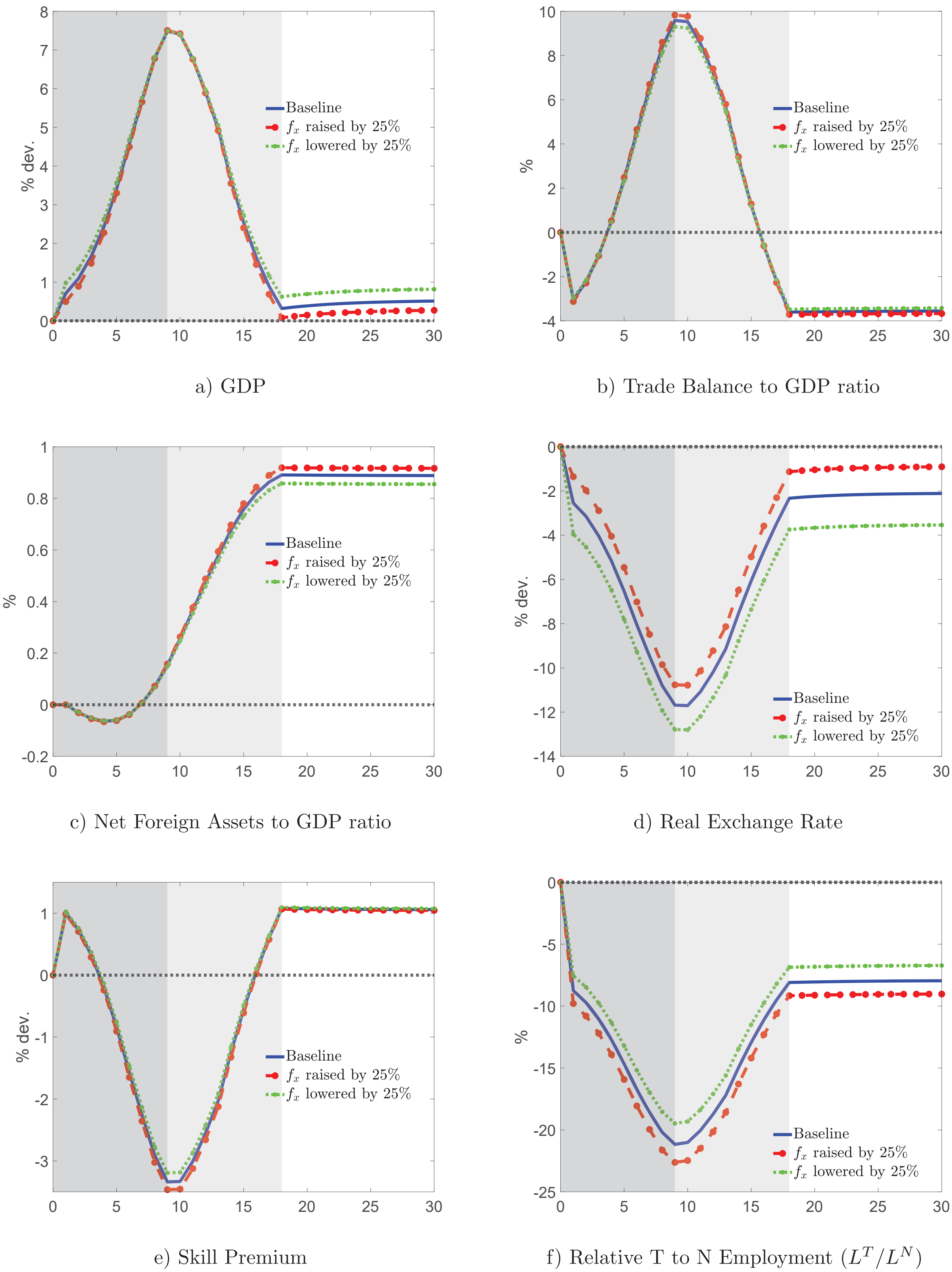
f) Relative T to N Employment (L^T/L^N)

Figure A15: Response of Macroeconomic Outcomes to a Commodity Price Super-Cycle when Including a Bond-Holding Cost

B.5 The Fixed Cost of International Exporting

An important parameter in our model is the fixed cost of exporting (f_x). We compare the baseline economy with two other parametrizations with a 25% higher and 25% lower value for this fixed cost. Recall that the international export fixed cost impacts aggregate trade flows through a selection effect; a higher fixed cost limits the set of firms that export abroad.

Figure A16 indicates that the macroeconomic effects from varying the international export fixed cost are negligible. Specifically, Figure A16f shows the intersectoral labor reallocation as a result of the commodity cycle, plotting the relative employment in the tradable relative to the nontradable sector. As with the other outcomes, the three economies (baseline, 25% higher f_x, and 25% lower f_x) behave similarly during the boom and bust.



a) GDP

b) Trade Balance to GDP ratio

c) Net Foreign Assets to GDP ratio

d) Real Exchange Rate

e) Skill Premium

f) Relative T to N Employment (L^T/L^N)

Figure A16: Response of Macroeconomic Outcomes to a Commodity Price Super-Cycle under Different Fixed Costs of International Exporting

B.6 Interest Rate

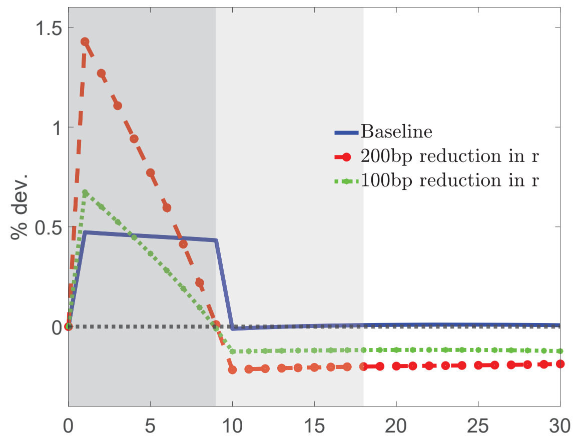
The literature has established that commodity booms are often accompanied by reductions in interest rates as a policy response [Shousha, 2016, Fernández et al., 2017]. We have argued (see Section 2.4) that this does not invalidate our empirical evidence in favor of the cost and wealth channels. Nevertheless, in this appendix we contrast the response of the economy to a commodity cycle versus a temporary reduction in the real interest rate. We find that the response of the economy is different in these two scenarios, especially regarding labor market outcomes such as the skill premium. We view a reduction in the interest rate as a complementary mechanism, but we argue that given the evolution of the skill premium observed in Brazil during the 2000s, commodity prices account for the first–order effect on the labor market.

Figure A17 plots the evolution of a series of outcomes to a commodity price cycle or a temporary reduction in the real interest rate. The blue solid line corresponds to a one–time increase in the commodity price starting in period one, lasting nine periods, and then reverting to the original level. The dashed green and red lines correspond to 100 and 200 basis points reductions in the real interest rate also starting in period one and lasting nine periods.[32]

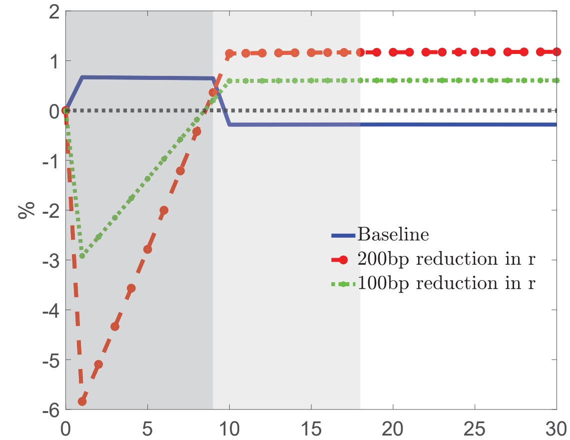
With the interest rate shock, the economy temporarily increases foreign borrowing leading to a temporary increase in GDP and a temporary fall in the trade balance. The consequent temporary increase in domestic spending leads to increased demand for both tradable and nontradable goods. Because tradable goods can be imported, domestic production temporarily shifts toward the nontradable sector. Given that this sector is skilled-intensive, the skill premium increases. This stands in contrast to the evolution of the skill premium during the commodity cycle.

Note also that during a commodity boom the economy saves, and the trade balance improves, unlike the case of an interest rate reduction.

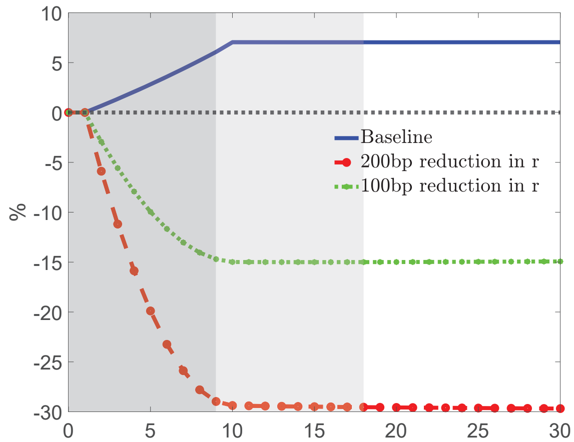
[32] To make the commodity cycle comparable quantitatively to the interest rate shock, we choose the increase in the commodity price to be such that the present value of future output is the same as that with the 200 basis point interest rate reduction.



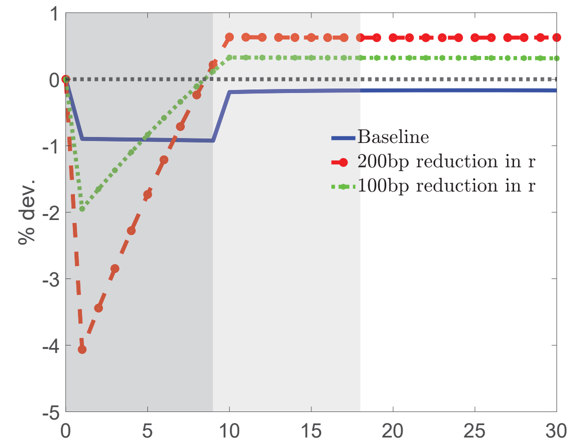
a) GDP



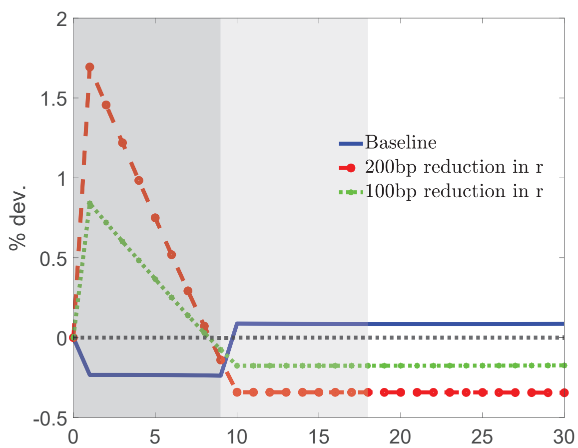
b) Trade Balance to GDP ratio



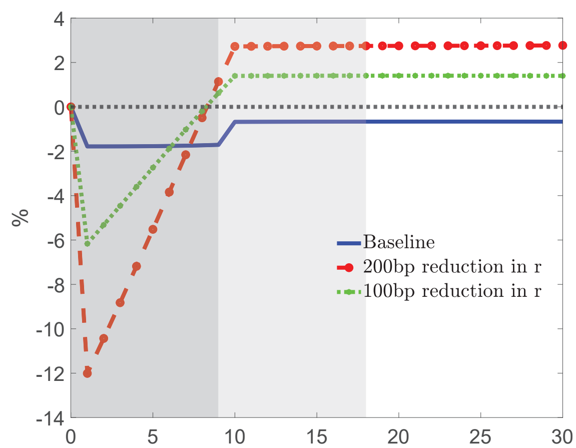
c) Net Foreign Assets to GDP ratio



d) Real Exchange Rate



e) Skill Premium



f) Relative T to N Employment (L^T/L^N)

Figure A17: Macroeconomic Outcomes under an Interest Rate Cut

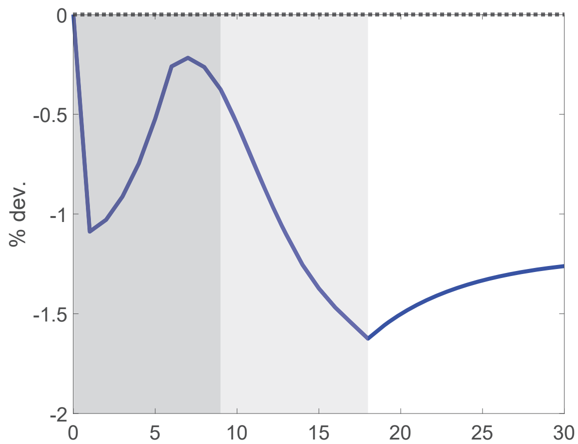
B.7 Additional Outcomes: Productivity Cutoffs and Average Productivity

Our model generates rich entry and exit dynamics as a result of the commodity cycle. In this section, we describe the evolution of the entry and exit productivity cutoffs that summarize the response of the extensive margins. We then describe the evolution of average productivity that results from these changes in entry and exit.

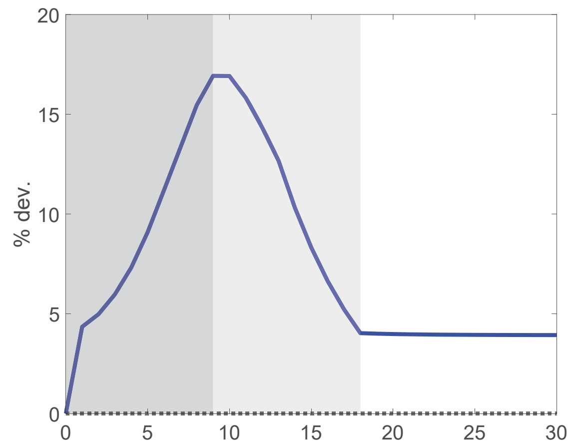
In the tradable sector (see Figure A18) there are two productivity cutoffs: for selling domestically and for exporting. The domestic cutoff decreases on impact (as a result of consumption smoothing) and later increases during the boom due to the increase in wages. The export cutoff increases during the boom due to the increase in wages. In the nontradable sector (also in Figure A18) there is a single cutoff, for selling domestically. The initial decline in this cutoff is due to the increase in nontradable consumption. The fact that wages increase during the boom, however, also implies higher costs leading to an increase in the cutoff. During the bust, the productivity cutoff falls.

As a result of the entry or exit of firms throughout the cycle, the model also features productivity dynamics as shown in Figure A19. Average productivity follows the same pattern of the productivity cutoffs. As domestic cutoffs rise or fall, low productivity firms exit or enter, and average productivity increases. In the same way, as the export cutoff rises or falls in the tradable sector, marginal firms quit or start exporting.

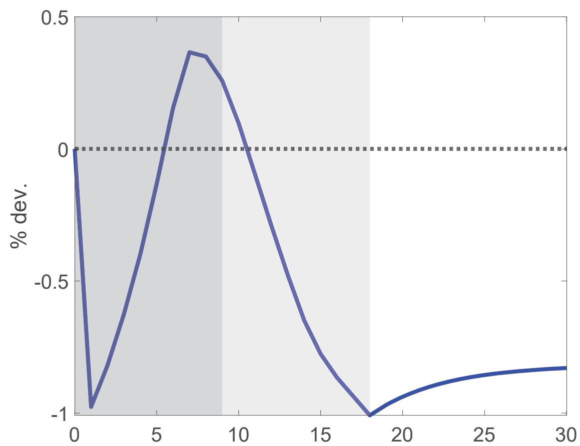
Note that, in contrast, in the representative firm model discussed in Appendix B.2 there are no productivity dynamics as there is no entry and exit.



a) Tradable Sector: Entry Productivity Cutoff

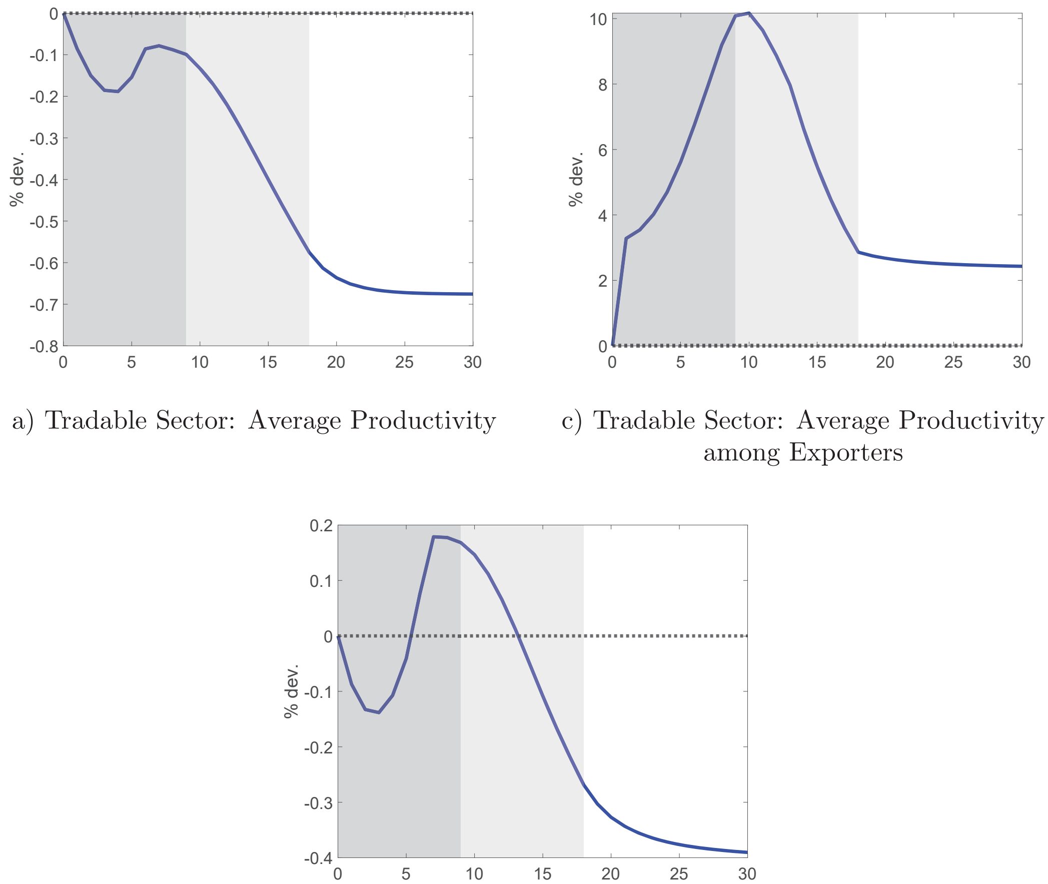


b) Tradable Sector: Export Productivity Cutoff



c) Nontradable Sector: Entry Productivity Cutoff

Figure A18: Response of Productivity Cutoffs to a Commodity Price Super-Cycle



a) Tradable Sector: Average Productivity

c) Tradable Sector: Average Productivity among Exporters

b) Nontradable Sector: Average Productivity

Figure A19: Response of Average Productivity to a Commodity Price Super-Cycle

B.8 Additional Outcomes: Intersectoral Reallocation

Figure A20 illustrates the path of the share of total employment, output, and the mass of entrants in the tradable and nontradable sectors. The increase in employment and output in the nontradable sector relative to the tradable sector shown in the main text is driven by a smaller decrease in these outcomes in the former than in the latter sector. There is a large fall in the mass of entrants in the tradable sector, while in the nontradable sector entry has a non-monotonic behavior during the boom and decreases about five times less than the mass of entrants in the tradable sector.

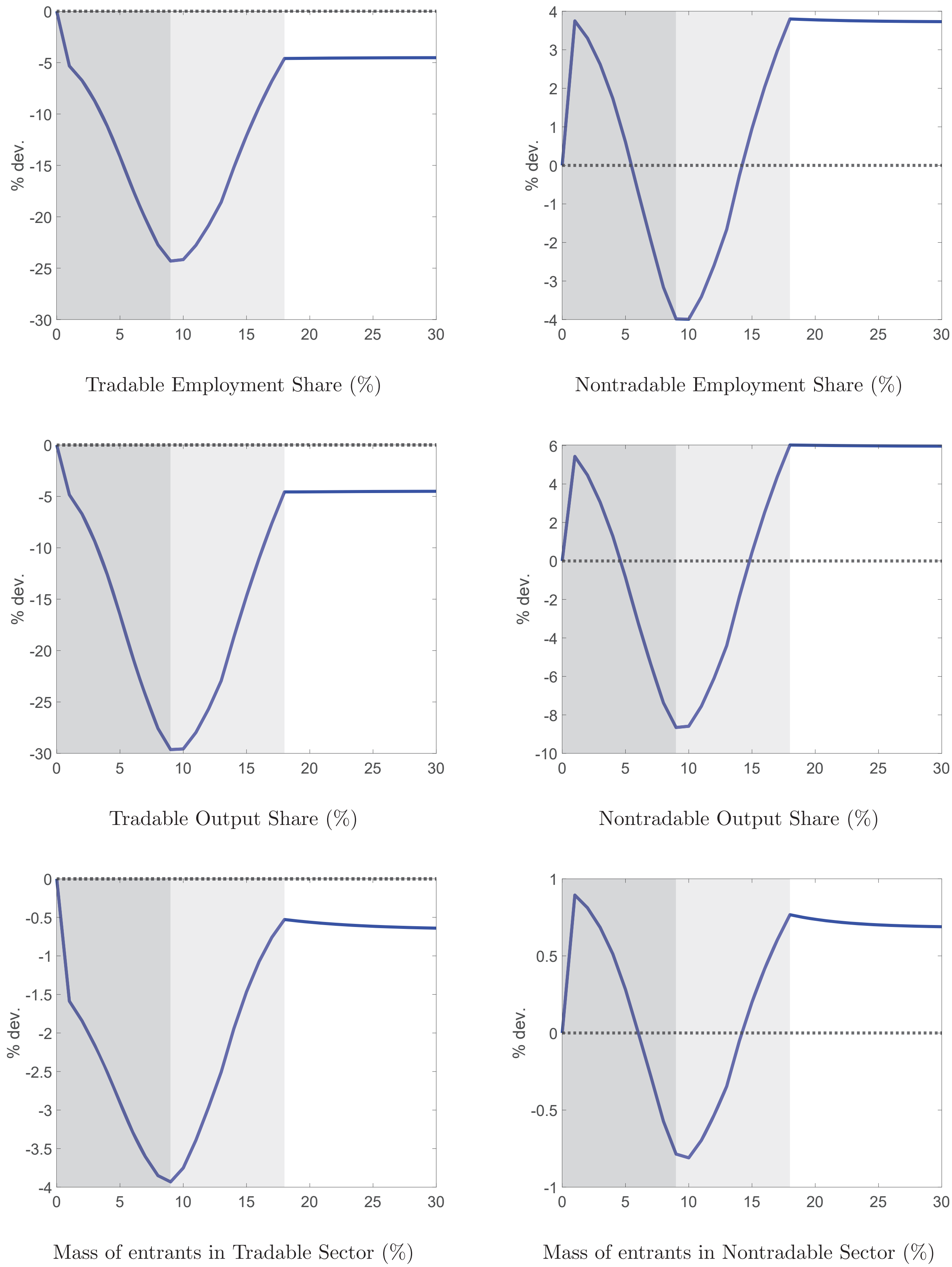


Figure A20: Response of Intersectoral Reallocation to a Commodity Price Super-Cycle

B.9 Construction of Moments Targeted in the Calibration

Our calibration uses moments for the two largest states in Brazil: Minas Gerais and Sao Paulo. We use data for 2001, which is the start of the boom. Note that in our calibration, GDP includes the same commodity, tradable, and nontradable sectors used in the paper, and excludes goverment and quasi-public sectors.

Exogenous exit probabilities. Given that we calibrate the model in the steady state, in which entry and exit rates are both equal to the exogenous exit probabilities, we average entry and exit rates in each sector. These entry and exit rates are computed from RAIS over the entire sample period.

Sectoral shares in GDP. We use Brazil's regional accounts in 2001 obtained from IBGE, which report GDP by sector and state.

Sectoral employment shares. Employment shares are computed for 2001 from RAIS. In the denominator, total employment includes the same commodity, tradable, and nontradable sectors used in the paper, and excludes goverment and quasi-public sectors.

Ratio of Unskilled to Skilled Employment by Sector These moments are computed from RAIS.

Exports to GDP ratio. Exports are obtained from Brazil's (Ministry of Industry, Foreign Trade and Services) Foreign Trade Statistics. GDP comes from Brazil's national accounts, obtained from IBGE.

Share of commodities in total exports. This ratio is constructed from product-level exports obtained from Brazil's MDIC (Ministry of Industry, Foreign Trade and Services) Foreign Trade Statistics.

Fraction of exporting firms in the tradable sector. This moment is computed from RAIS and the SECEX data on exporting firms, using the same firm-level panel as described in Section 2.1.

Skill premium. The skill premium in each state is computed from RAIS defined exactly as in Section 2.3.

Migration. Using a regression of state-level employment on the commodity price index, we find that a one log point increase in the regional commodity price index leads to an increase of 0.32 log points in total regional employment. Between 2002q2 and 2011q4, Sao Paulo had a 39 log point increase in the commodity price index (which implies a 12.5 log point increase in employment) while Minas Gerais had a 53 log point increase in the commodity price index (which implies a 17 log point increase in employment). Holding the total population in the model economy fixed, and assuming both regions start with a population equal to 50 in the initial steady state, these results imply that Minas Gerais (region A in the model) has a population of 51 at the peak of the boom while Sao Paulo (region B in the model) has a population of 49. An equivalent exercise is used for unskilled and for skilled employment.

Interregional trade. Data on interstate trade flows for 1999 is reported by Vasconcelos [2001] and recorded as a result of Brazil's state tax on the movement of goods and services (Imposto sobre Circulacao de Mercadorias e Servicos - ICMS). We use these data, and data on GDP from Brazil's regional accounts, to compute an interstate trade to GDP ratio.

C Model Appendix: Conceptual Framework in Section 2.2

In this Appendix we provide the details of the model outlined in Section 2.2 and proofs to propositions 1 through 3. As in the main text, we supress region subscripts for clarity. The first part of this derivation follows Dix-Carneiro and Kovak [2015].

Let a_{Si}, a_{Ui} and a_{Ti} be the unit factor requirements for skilled labor, unskilled labor and the specific factor in each industry i. Let Y_i denote output in industry i in each region. The terms L_i, L_{Ui} and L_{Si} denote total, unskilled and skilled labor in each industry and region, while L, L_U and L_S denote total, unskilled and skilled labor in each region. Let T denote the quantity of the specific factor in each region. Let P_i denote the output price of industry i in each region. Finally, let w_U, w_S, and R_i denote the unskilled wage, the skilled wage, and the return to the specific factor in each region.

We define employment shares $\lambda_{Ui} = \frac{L_{Ui}}{L_i}$ and $\lambda_{Si} = \frac{L_{Si}}{L_i}$. We also define cost shares $\theta_{Ui} = \frac{a_{Ui}w_U}{P_i}$, $\theta_{Si} = \frac{a_{Si}w_S}{P_i}$, and $\theta_{Ti} = \frac{a_{Ti}R_i}{P_i}$.

Factor market clearing conditions are:

$$a_{Ti}Y_i = T_i \qquad \forall i\,, \tag{A26}$$

$$\sum_i a_{Ui}Y_i = L_U\,, \tag{A27}$$

and

$$\sum_i a_{Si}Y_i = L_S\,. \tag{A28}$$

We use hats to represent proportional changes in each variable. The factor market clearing conditions then imply:

$$\sum_i \lambda_{Ui}(\hat{a}_{Ui} - \hat{a}_{Ti}) = 0\,, \tag{A29}$$

and

$$\sum_i \lambda_{Si}(\hat{a}_{Si} - \hat{a}_{Ti}) = 0\,. \tag{A30}$$

Cost minimization and unit elasticities of substitution imply:

$$\hat{a}_{Ui} - \hat{a}_{Ti} = \hat{R}_i - \hat{w}_U \tag{A31}$$

and

$$\hat{a}_{Si} - \hat{a}_{Ti} = \hat{R}_i - \hat{w}_S \tag{A32}$$

Replacing these expressions in (A29) and (A30) we obtain:

$$\sum_i \lambda_{Ui}(\hat{R}_i - \hat{w}_U) = 0\,, \tag{A33}$$

and

$$\sum_i \lambda_{Si}(\hat{R}_i - \hat{w}_S) = 0\,. \tag{A34}$$

The zero profit condition in each industry, that is $a_{Ui}w_U + a_{Si}w_S + a_{Ti}R_i = P_i$, implies:

$$\theta_{Ui}\hat{w}_U + \theta_{Si}\hat{w}_S + \theta_T\hat{R}_i = \hat{P}_i \tag{A35}$$

The set of factor market clearing and zero profit conditions can be solved to obtain the following expressions for the proportional change in unskilled and skilled wages:

$$\hat{w}_U = \frac{\sum_i \lambda_{Ui}\frac{1}{\theta_T}\hat{P}_i + \left(\sum_i \lambda_{Ui}\frac{1}{\theta_T}\hat{P}_i\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Si}}{\theta_T}\right) - \left(\sum_i \lambda_{Ui}\frac{\theta_{Si}}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{1}{\theta_T}\hat{P}_i\right)}{1 + \sum_i \lambda_{Ui}\frac{\theta_{Ui}}{\theta_T} + \sum_i \lambda_{Si}\frac{\theta_{Si}}{\theta_T} + \left(\sum_i \lambda_{Ui}\frac{\theta_{Ui}}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Si}}{\theta_T}\right) - \left(\sum_i \lambda_{Ui}\frac{\theta_{Si}}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Ui}}{\theta_T}\right)} \tag{A36}$$

and

$$\hat{w}_S = \frac{\sum_i \lambda_{Si}\frac{1}{\theta_T}\hat{P}_i + \left(\sum_i \lambda_{Ui}\frac{\theta_{Ui}}{\theta_T}\hat{P}_i\right)\left(\sum_i \lambda_{Si}\frac{1}{\theta_T}\right) - \left(\sum_i \lambda_{Ui}\frac{1}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Ui}}{\theta_T}\hat{P}_i\right)}{1 + \sum_i \lambda_{Ui}\frac{\theta_{Ui}}{\theta_T} + \sum_i \lambda_{Si}\frac{\theta_{Si}}{\theta_T} + \left(\sum_i \lambda_{Ui}\frac{\theta_{Ui}}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Si}}{\theta_T}\right) - \left(\sum_i \lambda_{Ui}\frac{\theta_{Si}}{\theta_T}\right)\left(\sum_i \lambda_{Si}\frac{\theta_{Ui}}{\theta_T}\right)}\,. \tag{A37}$$

These expressions are the same as in Dix-Carneiro and Kovak [2015].[33] From this point onward we go beyond their analysis to derive our propositions.

We simplify (A36) and (A37) using, first, the fact that the assumption of constant cost shares across industries within the commodity sector imply constant skilled to unskilled employment ratios:[34]

$$\frac{\lambda_{Ui}}{\lambda_{Si}} = \frac{L_{Ui}}{L_{Si}} \cdot \frac{L_S}{L_U} = \frac{a_{Ui}}{a_{Si}} \cdot \frac{L_S}{L_U} = \frac{\theta_{Ui}}{\theta_{Si}} \cdot \frac{L_S}{L_U} = k_1^C \qquad \forall i \in C\,. \tag{A38}$$

[33]See the Appendix in Dix-Carneiro and Kovak [2015] for further details.

[34]The assumption of constant cost shares across commodity industries was discussed in the main text following the evidence in Figure 1.

The same procedure yields $\frac{\lambda_{Ui}}{\lambda_{Si}} = k_1^T$, $\frac{\lambda_{Ui}}{\lambda_{Si}} = k_1^{Nh}$, and $\frac{\lambda_{Ui}}{\lambda_{Si}} = k_1^{N\ell}$ in the tradable industry and each of the two nontradable industries, respectively.

Second, we use the fact that we can write the employment share of each industry (λ_i) as a constant times the share of skilled employment (λ_{Si}).

$$\lambda_i = \frac{L_i}{L} = \frac{\lambda_{Ui} L_U + \lambda_{Si} L_S}{L} = \frac{\lambda_{Si}\left(k_1 L_U + L_S\right)}{L} = k_2^C \cdot \lambda_{Si} \qquad \forall i \in C\,. \tag{A39}$$

Similarly, $\lambda_i = k_2^T \cdot \lambda_{Si}$, $\lambda_i = k_2^{Nh} \cdot \lambda_{Si}$, and $\lambda_i = k_2^{N\ell} \cdot \lambda_{Si}$ in the tradable industry and each of the nontradable industries, respectively.

Using these identities, we can write the proportional changes in unskilled and skilled wages as follows:

$$\hat{w}_U = \kappa_C^U \left(\sum_{i \in C} \lambda_i \hat{P}_i\right) + \kappa_T^U \lambda_T \hat{P}_T + \kappa_{N\ell}^U \lambda_{N\ell} \hat{P}_{N\ell} + \kappa_{Nh}^U \lambda_{Nh} \hat{P}_{Nh} = \sum_i \kappa_i^U \lambda_i \hat{P}_i\,, \tag{A40}$$

and

$$\hat{w}_S = \kappa_C^S \left(\sum_{i \in C} \lambda_i \hat{P}_i\right) + \kappa_T^S \lambda_T \hat{P}_T + \kappa_{N\ell}^S \lambda_{N\ell} \hat{P}_{N\ell} + \kappa_{Nh}^S \lambda_{Nh} \hat{P}_{Nh} = \sum_i \kappa_i^S \lambda_i \hat{P}_i\,. \tag{A41}$$

We can also write the change in the skill premium as:

$$\hat{w}_S - \hat{w}_U = \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right) + \kappa_T \lambda_T \hat{P}_T + \kappa_{N\ell} \lambda_{N\ell} \hat{P}_{N\ell} + \kappa_{Nh} \lambda_{Nh} \hat{P}_{Nh} = \sum_i \kappa_i \lambda_i \hat{P}_i\,. \tag{A42}$$

We show below that $\hat{P}_T$, $\hat{P}_{N\ell}$ and $\hat{P}_{Nh}$ can all be written as weighted averages of the proportional changes in commodity prices.

■ **Proposition 1:** In consequence, as stated in proposition 1, we approximate the change in the skill premium as:

$$\hat{w}_S - \hat{w}_U \approx \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right)\,, \tag{A43}$$

where $\kappa_C < 0$ given that by assumption the commodity sector is unskilled–intensive relative to the rest of the economy.[35]

[35]Specifically, $\kappa_C = \frac{1 - k_1^C}{k_2^C\left(\theta_T + \sum_i \theta_{Si}(\lambda_{Si} - \lambda_{Ui})\right)}$.

■ Next, we can derive proportional changes in employment in an industry i. First, note that:

$$\hat{L}_i = \hat{L}_{Ui} \cdot \gamma_{Ui} + \hat{L}_{Si} \cdot \gamma_{Si}\,, \tag{A44}$$

where $\gamma_{Ui} = \frac{L_{Ui}}{L_i}$ and $\gamma_{Si} = \frac{L_{Si}}{L_i}$. From the definition of elasticities of substitution, and imposing unit elasticities, we have $\hat{L}_{Ui} = \hat{R}_i - \hat{w}_U$ and $\hat{L}_{Si} = \hat{R}_i - \hat{w}_S$. From the zero profit condition, we can write $\hat{R}_i = \frac{\hat{P}_i}{\theta_T} - \frac{\theta_U}{\theta_T}\hat{w}_U - \frac{\theta_S}{\theta_T}\hat{w}_S$. Combining these expressions we get:

$$\hat{L}_{Ui} = \hat{R}_i - \hat{w}_U = \frac{\hat{P}_i}{\theta_T} - \left(1 + \frac{\theta_U}{\theta_T}\right)\hat{w}_U - \frac{\theta_S}{\theta_T}\hat{w}_S\,, \tag{A45}$$

and

$$\hat{L}_{Si} = \hat{R}_i - \hat{w}_S = \frac{\hat{P}_i}{\theta_T} - \frac{\theta_U}{\theta_T}\hat{w}_U - \left(1 + \frac{\theta_S}{\theta_T}\right)\hat{w}_S\,. \tag{A46}$$

Replacing these in (A44) we get the following expression for proportional changes in employment as a function of changes in price and skilled and unskilled wages:

$$\hat{L}_i = \frac{\hat{P}_i}{\theta_T} - \left(\gamma_{Ui} + \frac{\theta_U}{\theta_T}\right)\hat{w}_U - \left(\gamma_{Si} + \frac{\theta_S}{\theta_T}\right)\hat{w}_S\,. \tag{A47}$$

We come back to this expression after writing the proportional changes in price ($\hat{P}_i$) as a function of proportional changes in income ($\hat{m}$) and wages.

■ We assume consumers have Cobb–Douglas preferences over all goods sold domestically. Consumers own all factors. The demand for any good implies:

$$\hat{Y}_i = \hat{m} - \hat{P}_i \qquad \forall\, i \notin T\,, \tag{A48}$$

where m represents domestic income. For the tradable good ($i \in T$), demand implies $\hat{Y}_i = \hat{m}^* - \hat{P}_i$, where m^* is foreign income.

Proportional changes in domestic income can be written as follows using the envelope theorem on regional industry revenue:

$$\hat{m} = \sum_i \varphi_i \hat{P}_i\,, \tag{A49}$$

where $\varphi_i = \frac{P_i Y_i}{\sum_i P_i Y_i}$ is the share of regional production in each industry.

■ We can derive an expression for proportional changes in output as a function of changes in price and wages as follows. Differentiating the production function, $Y_i = F^i(L_{Ui}, L_{Si}, T_i)$, yields $dY_i = F^i_U dL_{Ui} + F^i_S dL_{Si} + F^i_T dT_i = F^i_U dL_{Ui} + F^i_S dL_{Si}$. This implies:

$$\hat{Y}_i = \frac{F^i_U L_{Ui}}{F^i}\hat{L}_{Ui} + \frac{F^i_S L_{Si}}{F^i}\hat{L}_{Si}\,, \tag{A50}$$

which by definition of the cost shares becomes:

$$\hat{Y}_i = \theta_{Ui}\hat{L}_{Ui} + \theta_{Si}\hat{L}_{Si}\,. \tag{A51}$$

Using (A45) and (A46) we obtain:

$$\hat{Y}_i = \hat{P}_i\left(\frac{1-\theta_T}{\theta_T}\right) - \frac{\theta_{Ui}}{\theta_T}\hat{w}_U - \frac{\theta_{Si}}{\theta_T}\hat{w}_S\,. \tag{A52}$$

■ We use (A48) and (A52) to write proportional changes in prices as:

$$\hat{P}_i = \theta_T\hat{m} + \theta_{Ui}\hat{w}_U + \theta_{Si}\hat{w}_S\,. \tag{A53}$$

To derive the expressions for the cost and wealth channels in propositions 2 and 3, we can replace (A53) in (A47) to obtain proportional changes in employment as a function of proportional changes in income and wages:

$$\hat{L}_i = \hat{m} - \left(\gamma_{Ui} + \frac{2\theta_{Ui}}{\theta_T}\right)\hat{w}_U - \left(\gamma_{Si} + \frac{2\theta_{Si}}{\theta_T}\right)\hat{w}_S\,. \tag{A54}$$

■ **Proposition 2: Cost Channel.** We use (A54) to write the difference in the proportional change in employment between the high– and low–skill nontradable industries as a function of the relative skill intensity of these two industries times the change in the skill premium:

$$\hat{L}_{Nh} - \hat{L}_{N\ell} = \left(\eta_U^{Nh} - \eta_U^{N\ell}\right)\left(\hat{w}_S - \hat{w}_U\right), \tag{A55}$$

where $\eta_U^{Nh} = \gamma_{U,Nh} + \frac{2\theta_{U,Nh}}{\theta_T}$ and $\eta_U^{N\ell} = \gamma_{U,N\ell} + \frac{2\theta_{U,N\ell}}{\theta_T}$, such that $\eta_U^{Nh} < \eta_U^{N\ell}$ given the lower skill–intensity of the low–skill nontradable industry.[36] Given the expression for changes in the skill

[36]To derive (A55) we use the facts that $\gamma_{Ui} + \gamma_{Si} = 1$ and $\theta_{Ui} + \theta_{Si} + \theta_T = 1$.

premium in equation (A43), we obtain proposition 2:

$$\hat{L}_{Nh} - \hat{L}_{N\ell} \approx \left(\eta_U^{Nh} - \eta_U^{N\ell}\right) \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right) . \tag{A56}$$

■ **Proposition 3: Wealth Channel.** We use (A54) to write the difference in the proportional change in employment between the low–skill nontradable industries and the tradable industry. By assumption, these two industries have the same skill intensities, but differ in that they depend on foreign and domestic demand, respectively. Given that foreign expenditure is constant by assumption, we can write the difference in changes in employment between these two industries as a function of the change in domestic expenditure:[37]

$$\hat{L}_{N\ell} - \hat{L}_T = \hat{m} \, . \tag{A57}$$

We can write changes in income as a weighted average of changes in prices ($\hat{m} = \sum_i \varphi_i \hat{P}_i$). Consequently, we can write:

$$\hat{L}_{N\ell} - \hat{L}_T \approx \kappa_C \left(\sum_{i \in C} \lambda_i \hat{P}_i\right) , \tag{A58}$$

which is proposition 3.

■ Finally, we show that the endogenous prices of the tradable and nontradable industries can be written as a weighted average of the exogenous prices of commodity goods.

Given that by assumption foreign income is constant ($\hat{m} = 0$), equation (A53) for the tradable industry ($i \in T$) implies:

$$\hat{P}_i = \theta_{Ui} \hat{w}_U + \theta_{Si} \hat{w}_S \, . \tag{A59}$$

In addition, from (A49) we can write:

$$\hat{Y}^{Nh} = \left(\sum_{i \neq I-2} \varphi_i \hat{P}_i\right) - (1 - \varphi_{Nh}) \hat{P}_{Nh} \, , \tag{A60}$$

and

$$\hat{Y}^{N\ell} = \left(\sum_{i \neq I-1} \varphi_i \hat{P}_i\right) - (1 - \varphi_{N\ell}) \hat{P}_{N\ell} \, , \tag{A61}$$

[37]Note that income is equal to expenditure.

where industry $i = I - 2$ corresponds to the high-skill nontradable industry and $i = I - 1$ corresponds to the low–skill nontradable industry.

We use (A52) for the high–skill and low–skill nontradable industries to get rid of proportional changes in output $\hat{Y}^{Nh}$ and $\hat{Y}^{N\ell}$ in (A60) and (A61). The resulting two equations together with (A59) and the expressions for wages in (A40) and (A41) form a linear system for the prices of the two nontradable industries as well as the tradable industry. The solution is given by:

$$\hat{P}_{Nh} = \sum_{i \in C} \zeta_i^{Nh} \hat{P}_i \,, \tag{A62}$$

$$\hat{P}_{N\ell} = \sum_{i \in C} \zeta_i^{N\ell} \hat{P}_i \,, \tag{A63}$$

and

$$\hat{P}_{T} = \sum_{i \in C} \zeta_i^{T} \hat{P}_i \,. \tag{A64}$$

D Model Appendix

D.1 System of Dynamic Equations

This appendix describes the full system of dynamic equations and the definition of equilibrium.

D.1.1 Household

$$\lambda_t = \beta(1+r)\lambda_{t+1}\,, \tag{A65}$$

$$\lambda_t = \frac{(C_t)^{-\nu}}{P_t}\,. \tag{A66}$$

Consumption Bundle:

$$A_t = \left((M_t)^{\theta_1} + \alpha_T\,(T_t)^{\theta_1}\right)^{\frac{1}{\theta_1}}\;, \tag{A67}$$

$$E_t = \left((A_t)^{\theta_2} + \alpha_N\,(N_t)^{\theta_2}\right)^{\frac{1}{\theta_2}}\;, \tag{A68}$$

$$C_t = \left((E_t)^{\theta_3} + \alpha_C\,\left(C_t^d\right)^{\theta_3}\right)^{\frac{1}{\theta_3}}\;. \tag{A69}$$

Prices:

$$P_{A,t} = \left[1 + \left(\frac{\alpha_T}{(P_{T,t})^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{\theta_1-1}{\theta_1}}\;, \tag{A70}$$

$$P_{E,t} = P_{A,t}\left[1 + \left(\frac{\alpha_N\,(P_{A,t})^{\theta_2}}{(P_{N,t})^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{\theta_2-1}{\theta_2}}\;, \tag{A71}$$

$$P_t = P_{E,t}\left[1 + \left(\frac{\alpha_C\,(P_{E,t})^{\theta_3}}{(P_{C,t})^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{\theta_3-1}{\theta_3}}\;. \tag{A72}$$

Demands:

$$E_t = A_t \left[1 + \left(\frac{\alpha_N \left(P_{A,t}\right)^{\theta_2}}{\left(P_{N,t}\right)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{1}{\theta_2}}, \tag{A73}$$

$$C_t = E_t \left[1 + \left(\frac{\alpha_C \left(P_{E,t}\right)^{\theta_3}}{\left(P_{C,t}\right)^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{1}{\theta_3}}, \tag{A74}$$

$$A_t = M_t \left[1 + \left(\frac{\alpha_T}{\left(P_{T,t}\right)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{1}{\theta_1}}, \tag{A75}$$

$$T_t = \left(\frac{\alpha_T}{P_{T,t}}\right)^{\frac{1}{1-\theta_1}} \cdot M_t\,, \tag{A76}$$

$$N_t = \left(\frac{\alpha_N P_{A,t}}{P_{N,t}}\right)^{\frac{1}{1-\theta_2}} \cdot A_t\,, \tag{A77}$$

$$C_t^d = \left(\frac{\alpha_C P_{E,t}}{P_{C,t}}\right)^{\frac{1}{1-\theta_3}} \cdot E_t\,. \tag{A78}$$

D.1.2 Commodity Sector

Optimal Decisions:

$$\hat{w}_{C,t} = \left[\phi_C (w_t^u)^{1-\gamma} + (1-\phi_C)(w_t^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \tag{A79}$$

$$L_{C,t} = \left(\frac{\eta \cdot P_{C,t}}{\hat{w}_{C,t}}\right)^{\frac{1}{1-\eta}} \cdot R_t\,, \tag{A80}$$

$$L_{C,t}^u = \phi_C \cdot \left(\frac{\hat{w}_{C,t}}{w_t^u}\right) \cdot L_{C,t}\,, \tag{A81}$$

$$L_{C,t}^s = (1-\phi_C) \cdot \left(\frac{\hat{w}_{C,t}}{w_t^s}\right) \cdot L_{C,t}\,, \tag{A82}$$

$$P_{R,t} = (1-\eta) \cdot P_{C,t} \cdot \left(\frac{L_{C,t}}{R_t}\right)^{\eta}. \tag{A83}$$

Aggregate:

$$Y_{C,t} = \left(L_{C,t}\right)^{\eta} \left(R_t\right)^{1-\eta}. \tag{A84}$$

D.1.3 Nontradable Sector

Optimal decisions:

$$\hat{w}_{N,t} = \left[\phi_N (w_t^u)^{1-\gamma} + (1-\phi_N)(w_t^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} , \tag{A85}$$

$$p_{N,t}(z_N) = \frac{\hat{w}_{N,t}}{\rho z_N} , \tag{A86}$$

$$q_{N,t}(z_N) = n_t \cdot \left(\frac{p_{N,t}(z_N)}{P_{N,t}}\right)^{-\sigma} , \tag{A87}$$

$$l_{N,t}^u(z_N) = \phi_N \cdot \left(\frac{\hat{w}_{N,t}}{w_t^u}\right)^{\gamma} \cdot \left(\frac{q_{N,t}}{z_N} + f_N\right) , \tag{A88}$$

$$l_{N,t}^s(z_N) = (1-\phi_N) \cdot \left(\frac{\hat{w}_{N,t}}{w_t^s}\right)^{\gamma} \cdot \left(\frac{q_{N,t}}{z_N} + f_N\right) . \tag{A89}$$

Profits:

$$\pi_{N,t} = \frac{p_{N,t}(z_N) \cdot q_{N,t}(z_N)}{\sigma} - \hat{w}_{N,t} \cdot f_N . \tag{A90}$$

Value Function:

$$W_{N,t}(z_N) = \max\left\{0, \pi_{N,t}(z_N) + (1-\delta_N)\beta \max\left\{0, W_{N,t+1}(z_N)\right\}\right\} . \tag{A91}$$

Cutoff:

$$0 = W_{N,t}\left(\underline{z}_{N,t}\right) . \tag{A92}$$

Free entry condition:

$$\int_{\underline{z}_{N,t}}^{\infty} W_{N,t}(z)\, g_N(z_N)\, dz_N = \hat{w}_{N,t} \cdot \left\{f_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\mathcal{M}_{N,e,t+1} - \overline{\mathcal{M}}_{N,e}}{\overline{\mathcal{M}}_{N,e}}\right) - 1\right]\right\} . \tag{A93}$$

Laws of Motion: Distribution and Mass of producers:

$$\mathcal{M}_{t+1}^{N}\mu_{t+1}^{N}(z_N) = (1-\delta_N)\cdot\mathcal{M}_{N,t}\cdot\mu_t^N(z_N)\cdot\mathbb{I}_{\left\{z_N \geq \underline{z}_{N,t+1}\right\}} + \mathcal{M}_{N,e,t+1}\cdot g_N(z_N)\cdot\mathbb{I}_{\left\{z_N \geq \underline{z}_{N,t+1}\right\}}\,, \tag{A94}$$

$$\mathcal{M}_{t+1}^{N} = (1-\delta_N)\cdot\mathcal{M}_t^N\int_{\underline{z}_{N,t+1}}^{\infty}\mu_t^N(z_N)dz_N + \mathcal{M}_{N,e,t+1}\int_{\underline{z}_{N,t+1}}^{\infty} g(z_N)dz_N\,. \tag{A95}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L_{N,p,t}^{u} = \mathcal{M}_t^N\int_{\underline{z}_{N,t}^{u}}^{\infty} l_{N,t}^{u}\left(z_N\right)\mu_t^N(z_N)dz_N\,,$$
$$L_{N,p,t}^{s} = \mathcal{M}_t^N\int_{\underline{z}_{N,t}^{s}}^{\infty} l_{N,t}^{s}\left(z_N\right)\mu_t^N(z_N)dz_N\,.$$

- Total skilled and unskilled labor for the fixed entry cost

$$L_{N,e,t}^{u} = \phi_N\cdot\left(\frac{\hat{w}_{N,t}}{w_t^u}\right)^{\gamma}\cdot\left\{f_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\mathcal{M}_{N,e,t}-\overline{\mathcal{M}}_{N,e}}{\overline{\mathcal{M}}_{N,e}}\right)-1\right]\right\}\,,$$
$$L_{N,e,t}^{s} = (1-\phi_N)\cdot\left(\frac{\hat{w}_{N,t}}{w_t^s}\right)^{\gamma}\cdot\left\{f_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\mathcal{M}_{N,e,t}-\overline{\mathcal{M}}_{N,e}}{\overline{\mathcal{M}}_{N,e}}\right)-1\right]\right\}\,.$$

- Total skilled and unskilled labor demand

$$L_{N,t}^{u} = L_{N,p,t}^{u} + L_{N,e,t}^{u}\,, \tag{A96}$$
$$L_{N,t}^{s} = L_{N,p,t}^{s} + L_{N,e,t}^{s}\,. \tag{A97}$$

- Total output

$$Y_{N,t} = \mathcal{M}_t^N\left[\int_{\underline{z}_{N,t}}^{\infty}\left(q_{N,t}\left(z_N\right)\right)^{\rho}\cdot d\mu_t^N(z_N)\right]^{\frac{1}{\rho}}\,. \tag{A98}$$

- Ideal price index

$$P_{N,t} = \left[\int_{\underline{z}_{N,t}}^{\infty} \left(p_{N,t}\left(z_N\right)\right)^{1-\sigma} d\mu_t^N(z_N) \right]^{\frac{1}{1-\sigma}} . \tag{A99}$$

D.1.4 Tradable Sector

Optimal decisions:

$$\hat{w}_{T,t} = \left[\phi_T (w_t^u)^{1-\gamma} + (1-\phi_T)(w_t^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} , \tag{A100}$$

$$p_{T,t}\left(z_T\right) = \frac{\hat{w}_{T,t}}{\rho \cdot z_T} , \tag{A101}$$

$$q_{T,t}(z_T) = \begin{cases} q_{d,t} = T_t \left[\frac{p_{T,t}(z_T)}{P_{T,t}}\right]^{-\sigma} , & \underline{z}_{d,t} < z_T < \underline{z}_{x,t} \\ q_{d,t} + q_{x,t} = T_t \left[\frac{p_{T,t}(z_T)}{P_{T,t}}\right]^{-\sigma} + \Gamma \left[p_{T,t}(z_T)\right]^{-\sigma} , & \underline{z}_{x,t} < z_T \end{cases} \tag{A102}$$

$$l_{T,t}^u(z_T) = \begin{cases} l_d^u = \phi_T \left(\frac{\hat{w}_{T,t}}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q_{d,t}(z_T)}{z_T} + f_d\right] , & \overline{z}_d < z_T < \overline{z}_x \\ l_d^u + l_x^u = \phi_T \left(\frac{\hat{w}_T}{w^d}\right)^{\gamma} \cdot \left[\frac{q_{d,t}(z_T) + q_{x,t}(z_T)}{z_T} + f_d + f_x\right] , & \underline{z}_x < z_T \end{cases} \tag{A103}$$

$$l_{T,t}^s(z_T) = \begin{cases} l_d^s = (1-\phi_T) \left(\frac{\hat{w}_{T,t}}{w_t^s}\right)^{\gamma} \cdot \left[\frac{q_{d,t}(z_T)}{z_T} + f_d\right] , & \underline{z}_d < z_T < \underline{z}_x \\ l_d^s + l_x^s = (1-\phi_T) \left(\frac{\hat{w}_{T,t}}{w_t^s}\right)^{\gamma} \cdot \left[\frac{q_{d,t}(z_T) + q_{x,t}(z_T)}{z_T} + f_d + f_x\right] . & \underline{z}_x < z_T \end{cases} \tag{A104}$$

Profits:

$$\pi_{T,t}(z_T) = \begin{cases} \pi_{d,t} = \frac{p_{T,t}(z_T) q_{d,t}(z_T)}{\sigma} - \hat{w}_{T,t} f_d, & \underline{z}_{d,t} < z_T < \underline{z}_{x,t} \\ \pi_{d,t} + \pi_{x,t} = \frac{p_{T,t}(z_T)\left[q_{d,t}(z_T) + q_{x,t}(z_T)\right]}{\sigma} - \hat{w}_{T,t}(f_d + f_x). & \underline{z}_{x,t} < z_T \end{cases} \tag{A105}$$

Value functions:

$$W_{T,t}(z_T) = \max\left\{W_{d,t}(z_T), W_{x,t}(z_T)\right\} \ , \tag{A106}$$

$$W_{d,t}(z_T) = \max\left\{0, \pi_{d,t}(z_T) + \beta(1-\delta_T)W_{T,t+1}(z_T)\right\} \ , \tag{A107}$$

$$W_{x,t}(z_T) = \max\left\{0, \pi_{d,t}(z_T) + \pi_{x,t}(z_T) + \beta(1-\delta_T)W_{T,t+1}(z_T)\right\} \ . \tag{A108}$$

Cutoffs:

$$W_{d,t}(\underline{z}_{d,t}) = 0\,, \tag{A109}$$

$$\pi_{x,t}(\underline{z}_{x,t}) = 0\,. \tag{A110}$$

Free entry condition:

$$\int_{\bar{z}_{Tt}}^{\infty} W_{T,t}\left(z_T\right) g_T\left(z_T\right) dz_N = \hat{w}_{T,t} \cdot \left\{ f_{Te} + \xi_{Te} \left[\exp\left(\frac{\mathcal{M}_{T,e,t} - \overline{\mathcal{M}}_{T,e}}{\overline{\mathcal{M}}_{T,e}} \right) - 1 \right] \right\} . \tag{A111}$$

Laws of Motion: Distribution and Mass of producers:

$$\mathcal{M}_{T,t+1}\mu_{T,t+1}(z_T) = (1-\delta_T)\cdot\mathcal{M}_{T,t}\cdot\mu_t^T(z_T)\cdot\mathbb{I}_{\left\{z_T\geq \underline{z}_{d,t+1}\right\}} + \mathcal{M}_{T,e,t+1}\cdot g_T(z_T)\cdot\mathbb{I}_{\left\{z_T\geq \underline{z}_{d,t+1}\right\}}\,, \tag{A112}$$

$$\mathcal{M}_{T,t+1} = (1-\delta_T)\mathcal{M}_{T,t}\int_{\underline{z}_{d,t+1}}^{\infty}\mu_{t+1}(z_T)dz_T + \mathcal{M}_{T,e,t+1}\int_{\underline{z}_{d,t+1}}^{\infty} g_T(z_T)dz_T\,. \tag{A113}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^u_{T,p,t} = \mathcal{M}_{T,t}\int_{\underline{z}_{T,t}}^{\infty} l^u_{T,t}\left(z_T\right)\mu_{T,t}(z_T)dz_T\,,$$

$$L^s_{T,p,t} = \mathcal{M}_{T,t}\int_{\underline{z}_{T,t}}^{\infty} l^s_{T,t}\left(z_T\right)\mu_{T,t}(z_T)dz_T\,.$$

- Total skilled and unskilled labor for the fixed entry cost

$$L^{u}_{T,e,t} = \phi^{u}_{T} \cdot \left(\frac{\hat{w}_{T,t}}{w^{u}_{t}}\right)^{\gamma} \cdot \left\{ f_{Te} + \xi_{Ne} \left[\exp\left(\frac{\mathcal{M}_{T,e,t} - \overline{\mathcal{M}}_{T,e}}{\overline{\mathcal{M}}_{T,e}} \right) - 1 \right] \right\},$$
$$L^{s}_{T,e,t} = \phi^{d}_{T} \cdot \left(\frac{\hat{w}_{T,t}}{w^{s}_{t}}\right)^{\gamma} \cdot \left\{ f_{Te} + \xi_{Ne} \left[\exp\left(\frac{\mathcal{M}_{T,e,t} - \overline{\mathcal{M}}_{T,e}}{\overline{\mathcal{M}}_{T,e}} \right) - 1 \right] \right\}.$$

- Total skilled and unskilled labor demand

$$L^{u}_{T,t} = L^{u}_{T,p,t} + L^{u}_{T,e,t}, \tag{A114}$$

$$L^{s}_{T,t} = L^{s}_{T,p,t} + L^{s}_{T,e,t}. \tag{A115}$$

- Total tradable goods output sold domestically

$$Y_{T,t} = \mathcal{M}_{T,t} \left(\int_{\underline{z}_{d,t}}^{\infty} \left[q_{d,t}(z_T) \right]^{\rho} \mu_{T,t}(z_T) dz_T \right)^{\frac{1}{\rho}}. \tag{A116}$$

- Value of tradable good output sold in the foreign market

$$X_{T,t} = \mathcal{M}_{T,t} \int_{\underline{z}_{xt}}^{\infty} p_{T,t}(z_T) q_{xt}(z_T) \mu_{T,t}(z_T) dz_T. \tag{A117}$$

D.1.5 Aggregation and Market Clearing

Market Clearing:

$$Y_{N,t} = N_t, \tag{A118}$$

$$Y_{T,t} = T_t, \tag{A119}$$

$$\overline{R}_t = R_t. \tag{A120}$$

Labor Market Clearing:

$$L^{s}_{T,t} + L^{s}_{N,t} + L^{s}_{C,t} = H^{s}, \tag{A121}$$

$$L^{u}_{T,t} + L^{u}_{N,t} + L^{u}_{C,t} = H^{u}. \tag{A122}$$

(A123)

Balance of Payments:

$$X_t = P_{C,t}\left(Y_{C,t} - C_t^d\right) + X_{T,t}\,, \tag{A124}$$

$$TB_t = X_t - M_t\,, \tag{A125}$$

$$B_{t+1} = (1+r^*)\,B_t + TB_t\,. \tag{A126}$$

D.1.6 Transition Equilibrium Definition

Given an exogenous sequence of commodity prices $\{P_{C,t}\}_{t=0}^T$, initial conditions for the net foreign asset (B_0) and sectoral firm distributions $(\mathcal{M}_{j,0}, \mu_{j,0}(z^j))_{j\in\{N,T\}}$, a competitive equilibrium consists of sequences of:

(i) firm value functions $\{(W_t^j(z^j))_{j\in\{N,T\}}\}_{t=0}^T$,

(ii) masses of producers and entrants $\{(M_{j,t}, M_{j,e,t})_{j\in\{N,T\}}\}_{t=0}^T$,

(iii) cutoffs for domestic operation and international exports $\{(\underline{z}_t^j)_{j\in\{N,T\}}, \underline{z}_{x,t}^T\}_{t=0}^T$,

(iv) firm distributions $\{\mu_{j,t}(z^j))_{j\in\{N,T\}}\}_{t=0}^T$,

(v) firm decision rules $\{\left(p_{j,t}(z^j), q_{j,t}^u(z^j), l_{j,t}^u(z^j), l_{j,t}^s(z^j)\right)_{j\in\{N,T\}}, L_t^{C,u}, L_t^{C,s}, R_t\}_{t=0}^T$,

(vi) total firm outputs $\{Y_{T,t},\, Y_{N,t},\, Y_{C,t}\}_{t=0}^T$,

(vii) consumption decisions $\{T_t, N_t, C_t^d, M_t\}_{t=0}^T$,

(viii) wages and prices $\{w_t^u, w_t^s, P_t^N, P_t^T, P_t^R\}_{t=0}^T$,

(ix) asset holdings $\{B_t\}_{t=0}^T$,

such that for all $t = 1, ..., T$:

1. Given prices in (viii), the value functions (i), cutoff rules (iii), and decision rules (v) solve the firms' problems in each sector and location according to (A101), (A102),(A103),(A104), (A86), (A87),(A88),(A89), (A82),(A81), and (A83).

2. Given prices in (viii) and value functions (i), the masses of entrants in each sector and region satisfy the free entry conditions (A93) and (A111).

3. Given prices in (viii), the sequences of firm distributions (iv) and firm masses (ii) are consistent with the firms' decisions. In particular, they follow the laws of motion from (A94), (A112), (A95), and (A113).

4. Given wages and prices in (viii), the consumption decisions in (vii) solve the household's static optimization problem from (A73)-(A78).

5. Domestic goods market clear for the nontradable and tradable sectors ((A118),(A119)), given domestic demands ((A76),(A77)) and supplies ((A116),(A98)). In addition, the market for the natural resource clears ((A83),(A120)).

6. The sequences of wages clear the labor markets for skilled and unskilled labor ((A192), (A193)).

7. The sequence of asset holding in (ix) solves the household's dynamic optimization problem and is consistent with the balance of payments condition in the economy (A126). In addition, in period $t = T$, the economy has settled in the new steady state with a finite and stable net foreign asset position.

D.1.7 Transition Algorithm

Assumptions:

- The economy is in stationary equilibrium at $t = 0$, associated with known $P_{C,0}$.
- The economy is in stationary equilibrium at $t = \infty$, associated with known $P_{C,\infty}$.
- Full sequence $\{P_{C,t}\}_{t=1}^{\infty}$ is exogenously given. Transition is complete after T periods.

Algorithm:

1. Fix T. Compute the initial steady state.

2. **Outer Loop.** Guess the marginal utility λ in the new steady state. Given λ we in fact obtain the full sequence $\{\lambda_t = \lambda\}_{t=1}^{T}$ from (A65) (permanent income).

3. For each level of λ, recover the implied new steady state.

4. **Inner Loop.** Guess sequences $\{w_t^s, w_t^u, P_{T,t}, P_{N,t}\}_{t=1}^{T}$.

5. **Backward Iteration Loop**. Use time-T value functions (at the new steady state) and the guessed sequences to find several decision rules. For each $t = T, ..., 1$.

    - Recover prices of all good bundles from (A71), (A70), and (A72).
    - Recover consumer demands from (A73)-(A78).
    - Evaluate the value functions (A106) and (A91), to get the productivity cutoffs for production, and international exports ($\underline{z}_{N,t}$,$\underline{z}_{d,t}$,$\underline{z}_{x,t}$) using (A92),(A109), and(A110).
    - Given value functions and cutoffs, recover the masses of entrants from the free entry conditions (A111) and (A93).

6. **Forward Iteration Loop**. Use the initial masses and distributions, the guesses, and the cutoff rules, to iterate the sectoral distributions forward. For each $t = 1, ..., T$.

    - Get the mass $\mathcal{M}_{N,t}$ and distribution $\mu_{N,t}(z_N)$ in the N sector using (A95) and (A94).
    - Get the mass $\mathcal{M}_{T,t}$ and distribution $\mu_{T,t}(z_T)$ in the T sector using (A113) and (A112).

7. **Update Guesses**

    - Get the implied sequence $\{P_{T,t}\}_{t=1}^{T}$ from domestic tradable market clearing conditions (A119).
    - Get the implied sequence $\{P_{N,t}\}_{t=1}^{T}$ from domestic tradable market clearing conditions (A118).
    - Get labor aggregates from (A81), (A82), (A96), (A97), (A114), and (A115).
    - Get the implied sequences $\{w_t^u, w_t^s\}_{t=1}^{T}$ jointly from both labor market clearings (A121) and (A122).
    - Update guesses for wages and prices using a weighted average of the initial guess and the model implied values.
    - Go back to step 4 and repeat until convergence.

8. **Update Guess for λ.**

    - Compute total domestic demand and supply for commodity goods from (A78) and (A84).

- Compute total exports, imports, and trade balance from (A124) and (A125).
- Compute the implied net foreign assets by iterating the balance of payment equation (A126) forward.
- Check the transversality condition for bond holdings and update the guess for marginal utility λ using a bisection rule:
  - If the economy accumulates too many assets, decrease the guess for λ.
  - If the economy accumulates too much debt, increase the guess for λ.
- Go back to step 2 and repeat until convergence.

D.2 Steady State System

D.2.1 Household

$$1 = \beta(1 + r)\,. \tag{A127}$$

Consumption Bundle:

$$A = \Big((M)^{\theta_1} + \alpha_T \,(T)^{\theta_1}\Big)^{\frac{1}{\theta_1}}\,, \tag{A128}$$

$$E = \Big((A)^{\theta_2} + \alpha_N \,(N)^{\theta_2}\Big)^{\frac{1}{\theta_2}}\,, \tag{A129}$$

$$C = \Big((E)^{\theta_3} + \alpha_C \,\big(C^d\big)^{\theta_3}\Big)^{\frac{1}{\theta_3}}\,. \tag{A130}$$

Prices:

$$P_A = \left[1 + \left(\frac{\alpha_T}{(P_T)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{\theta_1-1}{\theta_1}}\,, \tag{A131}$$

$$P_E = P_A\left[1 + \left(\frac{\alpha_N\,(P_A)^{\theta_2}}{(P_N)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{\theta_2-1}{\theta_2}}\,, \tag{A132}$$

$$P_t = P_E\left[1 + \left(\frac{\alpha_C\,(P_E)^{\theta_3}}{(P_C)^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{\theta_3-1}{\theta_3}}\,. \tag{A133}$$

Demands:

$$E = A\left[1 + \left(\frac{\alpha_N \left(P_A\right)^{\theta_2}}{\left(P_N\right)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{1}{\theta_2}}, \tag{A134}$$

$$C = E\left[1 + \left(\frac{\alpha_C \left(P_E\right)^{\theta_3}}{\left(P_C\right)^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{1}{\theta_3}}, \tag{A135}$$

$$A = M\left[1 + \left(\frac{\alpha_T}{\left(P_T\right)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{1}{\theta_1}}, \tag{A136}$$

$$T = \left(\frac{\alpha_T}{P_T}\right)^{\frac{1}{1-\theta_1}} \cdot M_t\,, \tag{A137}$$

$$N = \left(\frac{\alpha_N P_A}{P_N}\right)^{\frac{1}{1-\theta_2}} \cdot A_t\,, \tag{A138}$$

$$C^d = \left(\frac{\alpha_C P_E}{P_C}\right)^{\frac{1}{1-\theta_3}} \cdot E_t\,. \tag{A139}$$

D.2.2 Commodity Sector

Optimal Decisions:

$$\hat{w}_C = \left[\phi_C (w^u)^{1-\gamma} + (1-\phi_C)(w^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}}\,, \tag{A140}$$

$$L_C = \left(\frac{\eta \cdot P_C}{\hat{w}_C}\right)^{\frac{1}{1-\eta}} \cdot R_t\,, \tag{A141}$$

$$L_C^u = \phi_C \cdot \left(\frac{\hat{w}_C}{w^u}\right) \cdot L_C\,, \tag{A142}$$

$$L_C^s = (1-\phi_C) \cdot \left(\frac{\hat{w}_C}{w^s}\right) \cdot L_C\,, \tag{A143}$$

$$P_R = (1-\eta) \cdot P_C \cdot \left(\frac{L_C}{R}\right)^{\eta}\,. \tag{A144}$$

$$\tag{A145}$$

Aggregate:

$$Y_C = (L_C)^{\eta} (R)^{1-\eta} \ . \tag{A146}$$

D.2.3 Nontradable Sector

Optimal decisions:

$$\hat{w}_N = \left[\phi_N (w^u)^{1-\gamma} + (1-\phi_N)(w^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \ , \tag{A147}$$

$$p_N(z_N) = \frac{\hat{w}_N}{\rho z_N} \ , \tag{A148}$$

$$q_N(z_N) = N \cdot \left(\frac{p_N(z_N)}{P_N}\right)^{-\sigma} \ , \tag{A149}$$

$$l_N^u(z_N) = \phi_N \cdot \left(\frac{\hat{w}_N}{w^{u,l}}\right)^{\gamma} \cdot \left(\frac{q_N}{z_N} + f_N\right) \ , \tag{A150}$$

$$l_N^s(z_N) = (1-\phi_N) \cdot \left(\frac{\hat{w}_N}{w^s}\right)^{\gamma} \cdot \left(\frac{q_N}{z_N} + f_N\right) \ . \tag{A151}$$

$$\tag{A152}$$

Profits:

$$\pi_N = \frac{p_N(z_N) \cdot q_N(z_N)}{\sigma} - \hat{w}_N \cdot f_N \ .$$

Value Function:

$$W_N(z_N) = \max\left\{0, \frac{\pi_N(z_N)}{1-\beta(1-\delta_N)}\right\} \ . \tag{A153}$$

Cutoff:

$$0 = W_{N,t}(\underline{z}_N) \ . \tag{A154}$$

Free entry condition:

$$\int_{\underline{z}_N}^{\infty} W_N(z)\, g_N(z_N)\, dz_N = \hat{w}_N \cdot (f_{Ne}) \; . \tag{A155}$$

Productivity Distributions and Firm Masses:

$$\mu_N(z_N) = \begin{cases} \frac{g_N(z_N)}{1-G_N(\underline{z}_N)} & z_N \geq \underline{z}_N \\ 0 & \text{otherwise} \end{cases} \tag{A156}$$

$$\delta_N \cdot \mathcal{M}_N = [1 - G_N(\underline{z}_N)]\, \mathcal{M}_{N,e} \, . \tag{A157}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^u_{N,p} = \mathcal{M}^N \int_{\underline{z}_N}^{\infty} l^u_N(z_N)\, \mu_N(z_N) dz_N \, , \tag{A158}$$

$$L^s_{N,p} = \mathcal{M}^N \int_{\underline{z}_N}^{\infty} l^s_N(z_N)\, \mu_N(z_N) dz_N \, . \tag{A159}$$

- Total skilled and unskilled labor for the fixed entry cost

$$L^u_{N,e} = \phi_N \cdot \left(\frac{\hat{w}_N}{w^u} \right)^{\gamma} \cdot (f_{Ne}) \; , \tag{A160}$$

$$L^s_{N,e} = (1 - \phi_N) \cdot \left(\frac{\hat{w}_N}{w^s} \right)^{\gamma} \cdot (f_{Ne}) \; . \tag{A161}$$

- Total skilled and unskilled labor demand

$$L^u_N = L^u_{N,p} + L^u_{N,e} \, , \tag{A162}$$

$$L^s_N = L^s_{N,p} + L^s_{N,e} \, . \tag{A163}$$

- Total output

$$Y_N = \mathcal{M}^N \left[\int_{\underline{z}_N}^{\infty} \left(q_N\left(z_N\right)\right)^{\rho} \cdot d\mu_N(z_N) \right]^{\frac{1}{\rho}} . \tag{A164}$$

- Ideal Price Index

$$P_N = \left[\int_{\underline{z}_N}^{\infty} \left(p_N\left(z_N\right)\right)^{1-\sigma} d\mu_N(z_N) \right]^{\frac{1}{1-\sigma}} . \tag{A165}$$

D.2.4 Tradable Sector

Optimal decisions:

$$\hat{w}_T = \left[\phi_T (w^u)^{1-\gamma} + (1-\phi_T)(w^s)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} , \tag{A166}$$

$$p_T\left(z_T\right) = \frac{\hat{w}_T}{\rho \cdot z_T} , \tag{A167}$$

$$q_T(z_T) = \begin{cases} q_d = T_t \left[\frac{p_T(z_T)}{P_T}\right]^{-\sigma} , & \underline{z}_d < z_T < \underline{z}_x \\ q_d + q_x = T \left[\frac{p_T(z_T)}{P_T}\right]^{-\sigma} + \Gamma \left[p_T(z_T)\right]^{-\sigma} , & \underline{z}_x < z_T \end{cases} \tag{A168}$$

$$l_T^u(z_T) = \begin{cases} l_d^u = \phi_T \left(\frac{\hat{w}_T}{w^u}\right)^{\gamma} \cdot \left[\frac{q_d(z_T)}{z_T} + f_d\right] , & \underline{z}_d < z_T < \underline{z}_x \\ l_d^u + l_x^{u,l} = \phi_T \left(\frac{\hat{w}_T}{w^u}\right)^{\gamma} \cdot \left[\frac{q_d(z_T)+q_x(z_T)}{z_T} + f_d + f_x\right] , & \underline{z}_x < z_T \end{cases} \tag{A169}$$

$$l_T^s(z_T) = \begin{cases} l_d^s = (1-\phi_T) \left(\frac{\hat{w}_{T,t}}{w_t^s}\right)^{\gamma} \cdot \left[\frac{q_d(z_T)}{z_T} + f_d\right] , & \underline{z}_d < z_T < \underline{z}_c \\ l_d^s + l_x^s = (1-\phi_T) \left(\frac{\hat{w}_T}{w^s}\right)^{\gamma} \cdot \left[\frac{q_d(z_T)+q_x(z_T)}{z_T} + f_d + f_x\right] , & \underline{z}_x < z_T \end{cases} \tag{A170}$$

Profits:

$$\pi_T(z_T) = \begin{cases} \pi_d = \frac{p_T(z_T)q_{d,t}(z_T)}{\sigma} - \hat{w}_T f_d, & \underline{z}_d < z_T < \underline{z}_x \\ \pi_d + \pi_x = \frac{p_T(z_T)[q_d(z_T)+q_x(z_T)]}{\sigma} - \hat{w}_T(f_d + f_x), & \underline{z}_x < z_T \end{cases} \tag{A171}$$

Value functions:

$$W_T(z_T) = \max\left\{W_d(z_T), W_c(z_T), W_x(z_T)\right\}\,, \tag{A172}$$

$$W_d(z_T) = \max\left\{0, \frac{\pi_d(z_T)}{1-\beta(1-\delta_T)}\right\}\,, \tag{A173}$$

$$W_x(z_T) = \max\left\{0, \frac{\pi_d(z_T)+\pi_x(z_T)}{1-\beta(1-\delta_T)}\right\}\,. \tag{A174}$$

$$\tag{A175}$$

Cutoffs:

$$W_d(\underline{z}_d) = 0\,, \tag{A176}$$

$$\pi_x(\underline{z}_x) = 0\,. \tag{A177}$$

Free entry condition:

$$\int_{\bar{z}_T}^{\infty} W_T\left(z_T\right) g_T\left(z_T\right) dz_N = \hat{w}_T \cdot f_{Te}\,. \tag{A178}$$

Productivity Distributions and Firm Masses:

$$\mu_T(z_T) = \begin{cases} \frac{g_T(z_T)}{1-G_N(\overline{z}_d)} & z_T \geq \underline{z}_d \\ 0 & \text{otherwise} \end{cases} \tag{A179}$$

$$\delta_T \cdot \mathcal{M}_T = \left[1 - G(\overline{z}_d)\right]\mathcal{M}_{T,e} \tag{A180}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^u_{T,p} = \mathcal{M}^T_t \int_{\underline{z}_T}^{\infty} l^u_T\,(z_T)\,\mu_T(z_T)dz_T\,, \tag{A181}$$

$$L^s_{T,p} = \mathcal{M}^T_t \int_{\underline{z}_T}^{\infty} l^s_T\,(z_T)\,\mu_T(z_T)dz_T\,. \tag{A182}$$

- Total skilled and unskilled labor for the fixed entry cost

$$L^u_{T,e} = \phi^u_T \cdot \left(\frac{\hat{w}_T}{w^u}\right)^{\gamma} \cdot (f_{Te})\ , \tag{A183}$$

$$L^s_{T,e} = \phi^d_T \cdot \left(\frac{\hat{w}_T}{w^s}\right)^{\gamma} \cdot (f_{Te})\ . \tag{A184}$$

- Total skilled and unskilled labor demand

$$L^u_T = L^u_{T,p} + L^u_{T,e}\,, \tag{A185}$$

$$L^s_T = L^s_{T,p} + L^s_{T,e}\,. \tag{A186}$$

- Total tradable goods output sold domestically

$$Y_T = \left[\mathcal{M}\left(\int_{\underline{z}_d}^{\infty} [q_d(z_T)]^{\rho}\,\mu_T(z_T)dz_T\right)\right]^{\frac{1}{\rho}}\,. \tag{A187}$$

- Value of tradable good outputs sold in the foreign market

$$X = \mathcal{M}_T \int_{\underline{z}_x}^{\infty} p_T(z_T)q_x(z_T)\mu_T(z_T)dz_T\,. \tag{A188}$$

D.3 Aggregation and Market Clearing

Market Clearing:

$$Y_N = N\,, \tag{A189}$$

$$Y_T = T\,. \tag{A190}$$

$$\overline{R} = R \tag{A191}$$

Labor Market Clearing:

$$L_T^s + L_N^s + L_C^s = H^s \,, \tag{A192}$$

$$L_T^u + L_N^u + L_C^u = H^u \,. \tag{A193}$$

$$\tag{A194}$$

Balance of Payments:

$$X = P_C \left(Y_C - C^d\right) + X_T \,, \tag{A195}$$

$$TB = X - M \,, \tag{A196}$$

$$B = -\frac{TB}{r^*} \,. \tag{A197}$$

D.3.1 Steady State Algorithm

Assumption:

- Entry cost is identical in the tradable and nontradable sectors.

Algorithm:

1. Guess unskilled wage (w^u), import demand (M), and nontradable price (P_N). Given the skill premium, the guess for unskilled wages implies a guess for skilled wages.

2. Recover all good bundle prices from (A131)-(A133) and demands from (A134)-(A139).

3. Evaluate the firm value functions in the tradable and nontradable sectors using (A172) and (A153). Then, solve for the cutoffs for operation and international exporting from (A154), (A176), and (A177).

4. Using the firm value functions, recover the fixed entry cost implied by the free entry conditions (A155) and (A178).

5. Given operational cutoffs, define the steady state productivity distributions using (A156) and (A179). Then, compute the total firm masses using the market clearing conditions (A164), (A189), (A187), and (A190). Given firm masses, recover the mass of entrants from (A157) and (A180).

6. Recover total labor demands from the tradable, nontradable, and commodity sectors using (A142), (A143), (A162), (A163), (A185), and (A186),

7. Compute the steady state net foreign asset position from (A197).

8. Update guesses until markets for skilled and unskilled labor clear, the free entry condition holds in the nontradable sector, and the net foreign asset position matches the target $\overline{B}$.

E Model Appendix: Multiregion Model

E.1 System of Dynamic Equations

This appendix describes the full system of dynamic equations and the definition of equilibrium.

E.1.1 Household Head

$$\lambda_t = \beta(1+r)\lambda_{t+1}\,. \tag{A198}$$

$$\lambda_t = \frac{H_t^{u,A} \cdot \left(\overline{U}_t^{u,A}\right)'(\tau_t^u) + H_t^{u,B} \cdot \left(\overline{U}_t^{u,B}\right)'(\tau_t^u)}{\left(H_t^{u,A} + H_t^{u,B}\right)}\,, \tag{A199}$$

$$\lambda_t = \frac{H_t^{s,A} \cdot \left(\overline{U}_t^{s,A}\right)'(\tau_t^s) + H_t^{s,A} \cdot \left(\overline{U}_t^{s,B}\right)'(\tau_t^s)}{\left(H_t^{s,A} + H_t^{s,B}\right)}\,. \tag{A200}$$

Prices:

$$P_{\Omega,t}^l = P_{M,t}^l \left[1 + \left(\frac{\alpha_T \left(P_{M,t}^l\right)^{\theta_1}}{\left(P_{T,t}^l\right)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{\theta_1-1}{\theta_1}}\,, \tag{A201}$$

$$P_{G,t}^l = P_{\Omega,t}^l \left[1 + \left(\frac{\alpha_N \left(P_{X,t}^l\right)^{\theta_2}}{\left(P_{N,t}^l\right)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{\theta_2-1}{\theta_2}}\,, \tag{A202}$$

$$P_{A,t}^l = P_{C,t}^A \left[1 + \left(\frac{P_{C,t}^A}{P_{C,t}^B}\right)^{\frac{\theta_1}{1-\theta_1}}\right]^{\frac{\theta_1-1}{\theta_1}}\,, \tag{A203}$$

$$P_t^l = P_{G,t}^l \left[1 + \left(\frac{\alpha_A \left(P_{G,t}^l\right)^{\theta_3}}{\left(P_{A,t}^l\right)^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{\theta_3-1}{\theta_3}}\,. \tag{A204}$$

Expenditure and Consumption:

$$E_t^{d,l} = w_t^{d,l} \cdot \frac{h^{u,l}}{H^{d,l}} + \tau_t^d \,, \tag{A205}$$

$$c_t^{d,l} = \frac{E_t^{d,l}}{P_t^l} \,. \tag{A206}$$

Demands:

$$g_t^{d,l} = c_t^{d,l} \left[1 + \left(\frac{\alpha_A \left(P_{G,t}^l\right)^{\theta_4}}{\left(P_{A,t}^l\right)^{\theta_4}} \right)^{\frac{1}{1-\theta_4}} \right]^{\frac{-1}{\theta_4}} \,, \tag{A207}$$

$$\omega_t^{d,l} = g_t^{d,l} \left[1 + \left(\frac{\alpha_N \left(P_{X_t}^l\right)^{\theta_2}}{\left(P_{N,t}^l\right)^{\theta_2}} \right)^{\frac{1}{1-\theta_2}} \right]^{\frac{-1}{\theta_2}} \,, \tag{A208}$$

$$m_t^{d,l} = \omega_t^{d,l} \left[1 + \left(\frac{\alpha_T \left(P_{M,t}^l\right)}{\left(P_{T,t}^l\right)^{\theta_1}} \right)^{\frac{1}{1-\theta_1}} \right]^{\frac{-1}{\theta_1}} \,, \tag{A209}$$

$$a_t^{d,l} = \left(\frac{\alpha_A \cdot P_{G,t}^l}{P_{A,t}^l} \right)^{\frac{1}{1-\theta_4}} \cdot g_t^{d,l} \,, \tag{A210}$$

$$t_t^{d,l} = \left(\frac{\alpha_T \cdot P_{M,t}^l}{P_T^l} \right)^{\frac{1}{1-\theta_1}} \cdot m_t^{d,l} \,, \tag{A211}$$

$$n_t^{d,l} = \left(\frac{\alpha_N \cdot P_{X,t}^l}{P_{N,t}^l} \right)^{\frac{1}{1-\theta_2}} \cdot \omega_t^{d,l} \,, \tag{A212}$$

$$c_{C,t}^{d,l,A} = a_t^{d,l} \left[1 + \left(\frac{P_{C,t}^A}{P_{C,t}^B} \right)^{\frac{\theta_3}{1-\theta_3}} \right]^{\frac{-1}{\theta_3}} \,, \tag{A213}$$

$$c_{C,t}^{d,l,B} = c_{C,t}^{d,l,A} \left(\frac{P_{C,t}^A}{P_{C,t}^B} \right)^{\frac{1}{1-\theta_1}} \,. \tag{A214}$$

Migration:

$$\frac{H_t^{d,l}}{\overline{H}^d} \equiv \sigma_t^{d,l} = \frac{\exp\left(\overline{U}\left(\frac{E_t^{d,l}}{P_t^l}\right)\right)^{1/\xi_d}}{\exp\left(\overline{U}\left(\frac{E_t^{d,l}}{P_t^l}\right)\right)^{1/\xi_d} + \exp\left(\overline{U}\left(\frac{E_t^{d,\neg l}}{P_t^{\neg l}}\right)\right)^{1/\xi_d}} \,. \tag{A215}$$

E.1.2 Commodity Sector

Optimal Decisions:

$$\hat{w}^{l}_{C,t} = \left[\phi_C (w^{u,l}_t)^{1-\gamma} + (1-\phi_C)(w^{s,l}_t)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \,. \tag{A216}$$

$$L^{l}_{C,t} = \left(\frac{\eta \cdot P^{l}_{C,t}}{\hat{w}^{l}_{C,t}}\right)^{\frac{1}{1-\eta}} \cdot R^{l}_t \,, \tag{A217}$$

$$L^{u,l}_{C,t} = \phi_C \cdot \left(\frac{\hat{w}^{l}_{C,t}}{w^{u,l}_{C,t}}\right) \cdot L^{l}_{C,t} \,, \tag{A218}$$

$$L^{s,l}_{C,t} = (1-\phi_C) \cdot \left(\frac{\hat{w}^{l}_{C,t}}{w^{s,l}_{C,t}}\right) \cdot L^{l}_{C,t} \,, \tag{A219}$$

$$P^{l}_{R,t} = (1-\eta) \cdot P^{l}_{C,t} \cdot \left(\frac{L^{l}_{C,t}}{R^{l}_t}\right)^{\eta} \,. \tag{A220}$$

Aggregate:

$$Y^{l}_{C,t} = \left(L^{l}_{C,t}\right)^{\eta} \left(R^{l}_t\right)^{1-\eta} \,. \tag{A221}$$

E.1.3 Nontradable Sector

Optimal decisions:

$$\hat{w}^{l}_{N,t} = \left[\phi_N (w^{u,l}_t)^{1-\gamma} + (1-\phi_N)(w^{s,l}_t)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \,. \tag{A222}$$

$$p^l_{N,t}\left(z_N\right) = \frac{\hat{w}^{d,l}}{\rho z_N}\,, \tag{A223}$$

$$q^l_{N,t}\left(z_N\right) = n^l_t \cdot \left(\frac{p^l_{N,t}\left(z_N\right)}{P^l_{N,t}}\right)^{-\sigma}\,, \tag{A224}$$

$$l^{u,l}_{N,t}\left(z_N\right) = \phi^N \cdot \left(\frac{\hat{w}^l_{N,t}}{w^{u,l}_t}\right)^{\gamma} \cdot \left(\frac{q^l_{N,t}}{z_N} + f^l_N\right)\,, \tag{A225}$$

$$l^{s,l}_{N,t}\left(z_N\right) = \left(1-\phi^N\right) \cdot \left(\frac{\hat{w}^l_{N,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left(\frac{q^l_{N,t}}{z_N} + f^l_N\right)\,. \tag{A226}$$

Profit:

$$\pi^l_{N,t} = \frac{p^l_{N,t}\left(z_N\right) \cdot q^l_{N,t}\left(z_N\right)}{\sigma} - \hat{w}^l_{N,t} \cdot f^l_N\,. \tag{A227}$$

Value Function:

$$W^l_{N,t}\left(z_N\right) = \max\left\{0, \pi^l_{N,t}\left(z_N\right) + (1-\delta_N)\beta \max\left\{0, W^l_{N,t+1}\left(z_N\right)\right\}\right\}\,. \tag{A228}$$

Cutoff:

$$0 = W^l_{N,t}\left(\underline{z}^l_{N,t}\right)\,. \tag{A229}$$

Free entry condition:

$$\int_{\bar{z}^l_{Nt}}^{\infty} W^l_{N,t}\left(z\right) g_N\left(z_N\right) dz_N = \hat{w}^l_{N,t} \cdot \left\{f^l_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\tilde{\mathcal{M}}^l_{N,t} - \overline{\mathcal{M}}^l_{N,e}}{\overline{\mathcal{M}}^l_{N,e}}\right) - 1\right]\right\}\,. \tag{A230}$$

Distribution of producers law of motion:

$$\mathcal{M}^l_{N,t+1}\mu^l_{N,t+1}(z_N) = (1-\delta_N) \cdot \mathcal{M}^l_{N,t} \cdot \mu^N_t(z_N) \cdot \mathbb{I}_{\left\{z_N \geq \underline{z}^l_{N,t+1}\right\}} + \tilde{\mathcal{M}}^l_{N,t+1} \cdot g_N(z_N) \cdot \mathbb{I}_{\left\{z_N \geq \underline{z}^l_{N,t+1}\right\}}\,. \tag{A231}$$

Mass of producers law of motion:

$$\mathcal{M}^l_{N,t+1} = (1-\delta_N)\cdot \mathcal{M}^l_{N,t} \int_{\underline{z}^l_{N,t+1}}^{\infty} \mu^N_t(z_N)dz_N + \tilde{\mathcal{M}}^l_{N,t+1} \int_{\underline{z}^l_{N,t+1}}^{\infty} g(z_N)dz_N \,.. \tag{A232}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^{u,l}_{N,p,t} = \mathcal{M}^N_t \int_{\underline{z}^{u,l}_{N,t}}^{\infty} l^{u,l}_{N,t}\left(z_N\right) \mu^l_{N,t}(z_N)dz_N \,,$$
$$L^{s,l}_{N,p,t} = \mathcal{M}^N_t \int_{\underline{z}^{s,l}_{N,t}}^{\infty} l^{s,l}_{N,t}\left(z_N\right) \mu^l_{N,t}(z_N)dz_N \,.$$

- Total skilled and unskilled labor for fixed entry cost

$$L^{u,l}_{N,e,t} = \phi^u_N \cdot \left(\frac{\hat{w}^l_{N,t}}{w^{u,l}_t}\right)^{\gamma} \cdot \left\{ f^l_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\mathcal{M}^l_{N,e,t} - \overline{\mathcal{M}}^l_{N,e}}{\overline{\mathcal{M}}^l_{N,e}}\right) - 1\right]\right\} \,,$$
$$L^{s,l}_{N,e,t} = \phi^d_N \cdot \left(\frac{\hat{w}^l_{N,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left\{ f^l_{Ne} + \xi_{Ne}\left[\exp\left(\frac{\mathcal{M}^l_{N,e,t} - \overline{\mathcal{M}}^l_{N,e}}{\overline{\mathcal{M}}^l_{N,e}}\right) - 1\right]\right\} \,.$$

- Total skilled and unskilled labor demand

$$L^{u,l}_{N,t} = L^{u,l}_{N,p,t} + L^{u,l}_{N,e,t}\,, \tag{A233}$$
$$L^{s,l}_{N,t} = L^{s,l}_{N,p,t} + L^{s,l}_{N,e,t}\,. \tag{A234}$$

- Total output

$$Y^l_{N,t} = \mathcal{M}^N_t \left[\int_{\underline{z}^l_{N,t}}^{\infty} \left(q^l_{N,t}\left(z_N\right)\right)^{\rho} \cdot d\mu^l_{N,t}(z_N)\right]^{\frac{1}{\rho}} \,. \tag{A235}$$

- Ideal price index

$$P^l_{N,t} = \left[\int_{\underline{z}^l_{N,t}}^{\infty} \left(p^l_{N,t}\left(z_N\right)\right)^{1-\sigma} d\mu^l_{N,t}(z_N)\right]^{\frac{1}{1-\sigma}} \,. \tag{A236}$$

E.1.4 Tradable Sector

Optimal decisions:

$$\hat{w}^l_{T,t} = \left[\phi_T (w^{u,l}_t)^{1-\gamma} + (1-\phi_T)(w^{s,l}_t)^{1-\gamma}\right]^{\frac{1}{1-\gamma}} . \tag{A237}$$

$$p^l_{T,t}(z_T) = \frac{\hat{w}^l_{T,t}}{\rho \cdot z_T} , \tag{A238}$$

$$q^l_{T,t}(z_T) = \begin{cases} q^l_{d,t} = T^l_t \left[\frac{p^l_{T,t}(z_T)}{P^l_{T,t}}\right]^{-\sigma} , & \underline{z}^l_{d,t} < z_T < \underline{z}^l_{c,t} , \\ q^l_{d,t} + q^l_{c,t} = T^l_t \left[\frac{p^l_{T,t}(z_T)}{P^l_{T,t}}\right]^{-\sigma} + T^{\neg l}_t \left[\frac{p^l_t(z_T)}{P^{\neg l}_{T,t}}\right]^{-\sigma} , & \underline{z}^l_{c,t} < z_T < \underline{z}^l_{xt} , \\ q^l_{d,t} + q^l_{c,t} + q^l_{x,t} = T^l_t \left[\frac{p^l_{T,t}(z_T)}{P^l_{T,t}}\right]^{-\sigma} + T^{\neg l}_t \left[\frac{p^l_{T,t}(z_T)}{P^{\neg l}_{T,t}}\right]^{-\sigma} + \Gamma \left[p^l_{T,t}(z_T)\right]^{-\sigma} , & \underline{z}^l_{x,t} < z_T , \end{cases} \tag{A239}$$

$$l^{u,l}_{T,t}(z_T) = \begin{cases} l^{u,l}_d = \phi_T \left(\frac{\hat{w}^l_{T,t}}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)}{z_T} + f^l_d\right] , & \overline{z}^l_d < z_T < \overline{z}^l_c \\ l^{u,l}_d + l^{u,l}_c = \phi_T \left(\frac{\hat{w}^l_T}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)+q^l_{c,t}(z_T)}{z_T} + f^l_d + f^l_c\right] , & \underline{z}^l_c < z_T < \underline{z}^l_x \\ l^{u,l}_d + l^{u,l}_c + l^{u,l}_x = \phi_T \left(\frac{\hat{w}^l_T}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)+q^l_{c,t}(z_T)+q^l_{x,t}(z_T)}{z_T} + f^l_d + f^l_c + f^l_x\right] , & \underline{z}^l_x < z_T \end{cases} \tag{A240}$$

$$l^{s,l}_{T,t}(z_T) = \begin{cases} l^{s,l}_d = (1-\phi_T) \left(\frac{\hat{w}^l_{T,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)}{z_T} + f^l_d\right] , & \underline{z}^l_d < z_T < \underline{z}^l_c \\ l^{s,l}_d + l^{s,l}_c = (1-\phi_T) \left(\frac{\hat{w}^l_{T,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)+q^l_{c,t}(z_T)}{z_T} + f^l_d + f^l_c\right] , & \underline{z}^l_c < z_T < \underline{z}^l_x \\ l^{s,l}_d + l^{s,l}_c + l^{s,l}_x = (1-\phi_T) \left(\frac{\hat{w}^l_{T,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left[\frac{q^l_{d,t}(z_T)+q^l_{c,t}(z_T)+q^l_{x,t}(z_T)}{z_T} + f^l_d + f^l_c + f^l_x\right] , & \underline{z}^l_x < z_T \end{cases} \tag{A241}$$

Profits:

$$\pi^l_{T,t}(z_T) = \begin{cases} \pi^l_{d,t} = \frac{p^l_{T,t}(z_T) q^l_{d,t}(z_T)}{\sigma} - \hat{w}^l_{T,t} f^l_d, & \underline{z}^l_{d,t} < z_T < \underline{z}^l_{c,t} \\ \pi^l_{d,t} + \pi^l_{c,t} = \frac{p^l_{T,t}(z_T)\left[q^l_{d,t}(z_T) + q^l_{c,t}(z_T)\right]}{\sigma} - \hat{w}^l_{T,t}(f^l_d + f^l_c), & \underline{z}^l_{c,t} < z_T < \underline{z}^l_{x,t} \\ \pi^l_{d,t} + \pi^l_{c,t} + \pi^l_{x,t} = \frac{p^l_{T,t}(z_T)\left[q^l_{d,t}(z_T) + q^l_{c,t}(z_T) + q^l_{x,t}(z_T)\right]}{\sigma} - \hat{w}^l_{T,t}(f^l_d + f^l_c + f^l_x), & \underline{z}^l_{x,t} < z_T \end{cases} \tag{A242}$$

Value functions:

$$W^l_{T,t}(z_T) = \max\left\{W^l_{d,t}(z_T), W^l_{c,t}(z_T), W^l_{x,t}(z_T)\right\}, \tag{A243}$$

$$W^l_{d,t}(z_T) = \max\left\{0, \pi^l_{d,t}(z_T) + \beta(1-\delta_T) W^l_{T,t+1}(z_T)\right\}, \tag{A244}$$

$$W^l_{c,t}(z_T) = \max\left\{0, \pi^l_{d,t}(z_T) + \pi^l_{c,t}(z_T) + \beta(1-\delta_T) W^l_{T,t+1}(z_T)\right\}, \tag{A245}$$

$$W^l_{x,t}(z_T) = \max\left\{0, \pi^l_{d,t}(z_T) + \pi^l_{c,t}(z_T) + \pi^l_{x,t}(z_T) + \beta(1-\delta_T) W^l_{T,t+1}(z_T)\right\}. \tag{A246}$$

Cutoffs:

$$W^l_{d,t}(\underline{z}^l_{d,t}) = 0, \tag{A247}$$

$$\pi^l_{c,t}(\underline{z}^l_{c,t}) = 0, \tag{A248}$$

$$\pi^l_{x,t}(\underline{z}^l_{x,t}) = 0. \tag{A249}$$

Free entry condition:

$$\int_{\bar{z}^l_{Tt}}^{\infty} W^l_{T,t}(z_T)\, g_T(z_T)\, dz_N = \hat{w}^l_{T,t} \cdot \left\{ f^l_{Te} + \xi_{Te}\left[\exp\left(\frac{\mathcal{M}^l_{T,e,t} - \overline{\mathcal{M}}^l_{T,e}}{\overline{\mathcal{M}}^l_{T,e}}\right) - 1\right]\right\}. \tag{A250}$$

Laws of Motion: Distribution and Mass of producers:

$$\mathcal{M}^l_{T,t+1}\mu^l_{T,t+1}(z_T) = (1-\delta_T)\cdot \mathcal{M}^l_{T,t}\cdot \mu^T_t(z_T)\cdot \mathbb{I}_{\left\{z_T \geq \underline{z}^l_{d,t+1}\right\}} + \mathcal{M}^l_{T,e,t+1}\cdot g_T(z_T)\cdot \mathbb{I}_{\left\{z_T \geq \underline{z}^l_{d,t+1}\right\}}, \tag{A251}$$

$$\mathcal{M}^l_{T,t+1} = (1-\delta_T)\mathcal{M}^l_{T,t}\int_{\underline{z}^l_{d,t+1}}^{\infty} \mu^l_{t+1}(z_T) dz_T + \mathcal{M}^l_{T,e,t+1}\int_{\underline{z}^l_{d,t+1}}^{\infty} g_T(z_T) dz_T. \tag{A252}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^{u,l}_{T,p,t} = \mathcal{M}^T_t \int_{\underline{z}^l_{T,t}}^{\infty} l^{u,l}_{T,t}\left(z_T\right) \mu^l_{T,t}(z_T) dz_T \,,$$

$$L^{s,l}_{T,p,t} = \mathcal{M}^T_t \int_{\underline{z}^l_{T,t}}^{\infty} l^{s,l}_{T,t}\left(z_T\right) \mu^l_{T,t}(z_T) dz_T \,.$$

- Total skilled and unskilled labor for fixed entry cost

$$L^{u,l}_{T,e,t} = \phi^u_T \cdot \left(\frac{\hat{w}^l_{T,t}}{w^{u,l}_t}\right)^{\gamma} \cdot \left\{ f^l_{Te} + \xi_{Ne} \left[\exp\left(\frac{\mathcal{M}^l_{T,e,t} - \overline{\mathcal{M}}^l_{T,e}}{\overline{\mathcal{M}}^l_{T,e}}\right) - 1 \right] \right\} ,$$

$$L^{s,l}_{T,e,t} = \phi^d_T \cdot \left(\frac{\hat{w}^l_{T,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left\{ f^l_{Te} + \xi_{Ne} \left[\exp\left(\frac{\mathcal{M}^l_{T,e,t} - \overline{\mathcal{M}}^l_{T,e}}{\overline{\mathcal{M}}^l_{T,e}}\right) - 1 \right] \right\} .$$

- Total skilled and unskilled labor demand

$$L^{u,l}_{T,t} = L^{u,l}_{T,p,t} + L^{u,l}_{T,e,t} \,, \tag{A253}$$

$$L^{s,l}_{T,t} = L^{s,l}_{T,p,t} + L^{s,l}_{T,e,t} \,. \tag{A254}$$

- Total tradable goods output produced in l that are sold domestically

$$\tilde{Y}^l_{T,t} = \left[\mathcal{M}^l_t \left(\int_{\underline{z}^l_{d,t}}^{\infty} \left[q^l_{d,t}(z_T)\right]^{\rho} \mu^l_{T,t}(z_T) dz_T + \int_{\underline{z}^l_{ct}}^{\infty} \left[q^l_{ct}(z_T)\right]^{\rho} \mu^l_{T,t}(z_T) dz_T \right) \right]^{\frac{1}{\rho}} . \tag{A255}$$

- Total domestic tradable output supplied to region l:

$$Y^l_{T,t} = \left[\left(\int_{\underline{z}^l_{d,t}}^{\infty} \mathcal{M}^l_t \cdot \left[q^l_{d,t}(z_T)\right]^{\rho} \mu^l_{T,t}(z_T) dz_T + \int_{\underline{z}^{\neg l}_{ct}}^{\infty} \mathcal{M}^{\neg l}_t \left[q^{\neg l}_{ct}(z_T)\right]^{\rho} \mu^{\neg l}_{T,t}(z_T) dz_T \right) \right]^{\frac{1}{\rho}} . \tag{A256}$$

- Value of tradable good output sold in foreign market

$$X^l_t = \mathcal{M}^l_{T,t} \int_{\underline{z}^l_{xt}}^{\infty} p^l_{T,t}(z_T) q^l_{xt}(z_T) \mu^l_{T,t}(z_T) dz_T \,. \tag{A257}$$

E.1.5 Aggregation and Market Clearing

Population and Employment:

$$\overline{H}^d = H_t^{d,A} + H_t^{d,B}\,, \tag{A258}$$

$$H_t^l = H_t^{s,l} + H^{u,l}\,, \tag{A259}$$

$$h_t^{d,l} = L_t^{d,l} \leq H_t^{d,l}\,. \tag{A260}$$

Aggregate Demand for Goods:

$$C_t^l = H_t^{u,l} \cdot c_t^{u,l} + H_t^{s,l} \cdot c_t^{s,l}\,, \tag{A261}$$

$$M_t^l = H_t^{u,l} \cdot t_t^{u,l} + H_t^{s,l} \cdot t_t^{s,l}\,, \tag{A262}$$

$$T_t^l = H_t^{u,l} \cdot t_t^{u,l} + H_t^{s,l} \cdot t_t^{s,l}\,, \tag{A263}$$

$$A_t^l = H_t^{u,l} \cdot a_t^{u,l} + H_t^{s,l} \cdot a_t^{s,l}\,, \tag{A264}$$

$$\Omega_t^l = H_t^{u,l} \cdot \omega_t^{u,l} + H_t^{s,l} \cdot \omega_t^{s,l}\,, \tag{A265}$$

$$N_t^l = H_t^{u,l} \cdot n_t^{u,l} + H_t^{s,l} \cdot n_t^{s,l}\,, \tag{A266}$$

$$G_t^l = H_t^{u,l} \cdot g_t^{u,l} + H_t^{s,l} \cdot g_t^{s,l}\,, \tag{A267}$$

$$C_{C,t}^{l,A} = H_t^{u,l} \cdot c_{C,t}^{l,A} + H_t^{s,l} \cdot c_{C,t}^{l,A}\,, \tag{A268}$$

$$C_{C,t}^{l,B} = H_t^{u,l} \cdot c_{C,t}^{l,B} + H_t^{s,l} \cdot c_{C,t}^{l,B}\,, \tag{A269}$$

$$C_{C,t}^{A} = C_{C,t}^{A,A} + C_{C,t}^{B,A}\,, \tag{A270}$$

$$C_{C,t}^{B} = C_{C,t}^{A,B} + C_{C,t}^{B,B}\,. \tag{A271}$$

Market Clearing:

$$Y_{N,t}^l = N_t^l\,, \tag{A272}$$

$$Y_{T,t}^l = T_t^l\,, \tag{A273}$$

$$\overline{R}_t^l = R_t^l\,. \tag{A274}$$

Balance of Payments:

$$X_t = P^A_{C,t}\left(Y^A_{C,t} - C^A_{C,t}\right) + X^A_{T,t} + X^A_{T,t}\,, \tag{A275}$$

$$M_t = M^A_t + M^B_t\,, \tag{A276}$$

$$TB_t = X_t - M_t\,, \tag{A277}$$

$$B_{t+1} = (1+r^*)\,B_t + TB_t\,. \tag{A278}$$

E.1.6 Transition Equilibrium Definition

Given an exogenous sequence of commodity prices $\{P^l_{C,t}\}_{t=0}^T$, initial conditions for the net foreign asset (B_0) and sectoral firm distributions $(\mathcal{M}^l_{j,0}, \mu^l_{j,0}(z^j))_{j\in\{N,T\}}$, a competitive equilibrium consists of sequences of:

(i) firm value functions $\{(W^{j,l}_t(z^j))_{j\in\{N,T\}}\}_{t=0}^T$,

(ii) masses of producers and entrants $\{(M^l_{j,t}, M^l_{j,e,t})_{j\in\{N,T\}}\}_{t=0}^T$,

(iii) cutoffs for domestic operation, interregional exports, and international exports $\{(\bar{z}^{j,l}_t)_{j\in\{N,T\}}, \bar{z}^{T,l}_{c,t}, \bar{z}^{T,l}_{x,t}\}_{t=0}^T$,

(iv) firm distributions $\{\mu^l_{j,t}(z^j))_{j\in\{N,T\}}\}_{t=0}^T$,

(v) firm decision rules $\{p^{u,l}_{j,t}(z^j), q^{u,l}_{j,t}(z^j), l^{u,l}_{j,t}(z^j), l^{s,l}_{j,t}(z^j)_{j\in\{N,T\}}, L^{C,l,u}_t, L^{C,l,s}_t, R^l_t\}_{t=0}^T$,

(vi) total firm outputs $\{Y^l_{T,t},\, Y^l_{N,t},\, Y^l_{C,t}\}_{t=0}^T$,

(vii) consumption decisions $\{m^l_t, t^l_t(\zeta)_{\zeta\in\mathfrak{Z}^l_t}, n^l_t(\varphi)_{\varphi\in\mathfrak{P}^l_t}, c^{lA}_t, c^{lB}_t\}_{t=0}^T$,

(viii) household head's decisions $\{\tau^u_t, \tau^s_t\}_{t=0}^T$,

(ix) population $\{H^{u,l}_t, H^{s,l}_t\}_{t=0}^T$,

(x) employment $\{h^{u,l}_t, h^{s,l}_t\}_{t=0}^T$,

(xi) wages and prices $\{w^{u,l}_t, w^{s,l}_t, P^{N,l}_t, P^{T,l}_t, P^{R,l}_t\}_{t=0}^T$,

(xii) asset holdings $\{B_t\}_{t=0}^T$,

such that for all $t = 1, ..., T$:

1. Given prices in (xi), the value functions (i), cutoff rules (iii), and decision rules (v) solve the firms' problems in each sector and location according to (A238), (A239),(A240),(A241), (A223), (A224),(A225),(A226), (A219),(A218), and (A220).

2. Given prices in (xi) and value functions (i), the masses of entrants in each sector and region satisfy the free entry conditions (A230) and (A250).

3. Given prices in (xi), the sequences of firm distributions (iv) and firm masses (ii) are consistent with the firms' decisions. In particular, they follow the laws of motion from (A231), (A251), (A232), and (A252).

4. Given wages and prices in (xi) and transfers in (viii), the consumption decisions in (vi) solve the workers' static optimization problem from (A205)-(A214).

5. Given the sequence of wages and prices (x), the transfers in (viii) solve the household head's maximization problem. Namely, the transfers satisfy the first-order conditions in (A199) and (A200).

6. Given the sequence of wages, prices, transfers, employment, and population (v,viii,ix,x,xi), the law of motion for population is consistent with the individual workers' location choices in (A297).

7. All goods markets clear given total sectoral outputs ((A256)),(A235)), aggregate good demands ((A263),(A266)). In addition, the market for the natural resource clears ((A220),(A274)).

8. The sequence of asset holding in (xi) solves the household head's dynamic optimization problem and is consistent with the balance of payments condition in the economy (A278). In addition, in period $t = T$, the economy has settled in the new steady state with a finite and stable net foreign asset position.

E.1.7 Transition Algorithm

Assumptions

- The economy is in stationary equilibrium at $t = 0$, associated with known $P^A_{C,0}$ and $P^B_{C,0}$.

- The economy is in stationary equilibrium at $t = \infty$, associated with known $P^A_{C,\infty}$ and $P^B_{C,\infty}$.

- Full sequence $\{P^A_{C,t}, P^B_{C,t}\}_{t=1}^{\infty}$ is exogenously given. Transition is complete after T periods.

Algorithm

1. Fix T. Compute the initial steady state.

2. **Outer Loop.** Guess the marginal utility λ in the new steady state. Given λ we in fact obtain the full sequence $\{\lambda_t = \lambda\}_{t=1}^T$ from (A198) (permanent income).

3. For each level of λ, recover the implied new steady state.

4. **Inner Loop.** Guess sequences

   $\{w_t^{s,A}, w_t^{s,B}, w_t^{u,A}, w_t^{u,B}, P_{T,t}^A, P_{T,t}^B, P_{N,t}^A, P_{N,t}^B, h_t^{s,A}, h_t^{s,B}, h_t^{u,A}, h_t^{u,B}, H_t^{s,A}, H_t^{s,B}, H_t^{u,A}, H_t^{u,B}\}_{t=1}^T$.

5. **Backward Iteration Loop**. Use time-T value functions (at the new steady state) and the guessed sequences to find several decision rules. For each $t = T, ..., 1$.

   - Recover prices of all good bundles from (A201), (A202), (A203), and (A204).
   - Solve (A199) and (A200) simultaneously for τ_t^u and τ_t^s.
   - Recover per capita expenditure and consumption from (A205) and (A206). With per capita consumption and prices, recover per capita demand for each good bundle from (A207)-(A214).
   - Evaluate the value functions (A243) and (A228), to get the productivity cutoffs for production, interregional exports, and international exports ($\underline{z}_{N,t}^l$,$\underline{z}_{d,t}^l$,$\underline{z}_{c,t}^l$,$\underline{z}_{x,t}^l$) using (A229),(A247), (A248), and(A249).
   - Given value functions and cutoffs, recover the masses of entrants from the free entry conditions (A250) and (A230).

6. **Forward Iteration Loop**. Use the initial masses and distributions, the guesses, and the cutoff rules, to iterate the sectoral distributions forward. For each $t = 1, ..., T$.

   - Get the mass $\mathcal{M}_{N,t}^l$ and distribution $\mu_{N,t}^l(z_N)$ in the N sector using (A232) and (A231).
   - Get the mass $\mathcal{M}_{T,t}^l$ and distribution $\mu_{T,t}^l(z_T)$ in the T sector using (A252) and (A251).

7. **Update Guesses**

   - Get implied sequence $\{P_{T,t}^l\}_{t=1}^T$ from domestic tradable market clearing conditions (A273), using total regional supply and demand from (A256) and (A263).

- Get implied sequence $\{P^l_{N,t}\}_{t=1}^T$ from domestic tradable market clearing conditions (A272), using total regional supply and demand from (A235) and (A266).
- Get labor aggregates from (A218), (A219), (A233), (A234), (A253), and (A254).
- Get implied sequences $\{w_t^{u,l}, w_t^{s,l}\}_{t=1}^T$ jointly from both labor market clearings (A260).
- Recover the implied sequences of population across regions $\{H_t^{u,A}, H_t^{s,A}, H_t^{u,B}, H_t^{s,B}\}_{t=1}^\infty$ from (A297).
- Recover the implied sequences of regional employments $\{h_t^{u,A}, h_t^{s,A}, h_t^{u,B}, h_t^{s,B}\}_{t=1}^\infty$ from (A260).
- Update guesses for wages, prices, population, and employment using a weighted average of the initial guess and the model implied values.
- Go back to step 4 and repeat until convergence.

8. **Update Guess for λ.**

- Compute total regional demand and supply for commodity goods from (A268)-(A271) and (A221).
- Compute total exports, imports, and trade balance from (A275), (A276), and (A277).
- Compute the implied net foreign assets by iterating the balance of payment equation (A278) forward.
- Check the transversality condition for bond holdings and update the guess for marginal utility λ using a bisection rule:
  - If the economy accumulates too many assets, decrease the guess for λ.
  - If the economy accumulates too much debt, increase the guess for λ.
- Go back to step 2 and repeat until convergence.

E.2 Steady State System

E.2.1 Household Head

$$1 = \beta(1 + r)\,, \tag{A279}$$

$$\lambda = \frac{H^{u,A} \cdot \left(\overline{U}^{u,A}\right)' (\tau^u) + H^{u,B} \cdot \left(\overline{U}_t^{u,B}\right)' (\tau^u)}{H^{u,A} + H^{u,B}}\,, \tag{A280}$$

$$\lambda = \frac{H^{s,A} \cdot \left(\overline{U}^{s,A}\right)' (\tau^s) + H^{s,B} \cdot \left(\overline{U}_t^{s,B}\right)' (\tau^s)}{H^{s,A} + H^{s,B}}\,. \tag{A281}$$

Prices:

$$P_\Omega^l = P_M^l \left[1 + \left(\frac{\alpha_T \left(P_M^l\right)^{\theta_1}}{\left(P_T^l\right)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{\theta_1 - 1}{\theta_1}}\,, \tag{A282}$$

$$P_G^l = P_\Omega^l \left[1 + \left(\frac{\alpha_N \left(P_\Omega^l\right)^{\theta_2}}{\left(P_N^l\right)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{\theta_2 - 1}{\theta_2}}\,, \tag{A283}$$

$$P_A^l = P_C^A \left[1 + \left(\frac{P_C^A}{P_C^B}\right)^{\frac{\theta_1}{1-\theta_1}}\right]^{\frac{\theta_1 - 1}{\theta_1}}\,, \tag{A284}$$

$$P_t^l = P_G^l \left[1 + \left(\frac{\alpha_A \left(P_G^l\right)^{\theta_3}}{\left(P_A^l\right)^{\theta_3}}\right)^{\frac{1}{1-\theta_3}}\right]^{\frac{\theta_3 - 1}{\theta_3}}\,. \tag{A285}$$

Expenditure and Consumption:

$$E^{d,l} = w^{d,l} \cdot \frac{h^{d,l}}{H^{d,l}} + \tau^d\,, \tag{A286}$$

$$c^{d,l} = \frac{E^{d,l}}{P^l}\,. \tag{A287}$$

$$\tag{A288}$$

Demands:

$$g^{d,l} = c^{d,l}\left[1 + \left(\frac{\alpha_A\left(P_G^l\right)^{\theta_4}}{\left(P_A^l\right)^{\theta_4}}\right)^{\frac{1}{1-\theta_4}}\right]^{\frac{-1}{\theta_4}}, \tag{A289}$$

$$\omega_t^{d,l} = g^{d,l}\left[1 + \left(\frac{\alpha_N\left(P_X^l\right)^{\theta_2}}{\left(P_N^l\right)^{\theta_2}}\right)^{\frac{1}{1-\theta_2}}\right]^{\frac{-1}{\theta_2}}, \tag{A290}$$

$$m^{d,l} = \omega^{d,l}\left[1 + \left(\frac{\alpha_T\left(P_M^l\right)}{\left(P_T^l\right)^{\theta_1}}\right)^{\frac{1}{1-\theta_1}}\right]^{\frac{-1}{\theta_1}}, \tag{A291}$$

$$a^{d,l} = \left(\frac{\alpha_A \cdot P_{G,t}^l}{P_{A,t}^l}\right)^{\frac{1}{1-\theta_4}} \cdot g^{d,l}, \tag{A292}$$

$$t^{d,l} = \left(\frac{\alpha_T \cdot P_{M,t}^l}{P_T^l}\right)^{\frac{1}{1-\theta_1}} \cdot m^{d,l}, \tag{A293}$$

$$n^{d,l} = \left(\frac{\alpha_N \cdot P_{X,t}^l}{P_N^l}\right)^{\frac{1}{1-\theta_2}} \cdot \omega^{d,l}, \tag{A294}$$

$$c_C^{d,l,A} = a^{d,l}\left[1 + \left(\frac{P_C^A}{P_{C,t}^B}\right)^{\frac{\theta_3}{1-\theta_3}}\right]^{\frac{-1}{\theta_3}}, \tag{A295}$$

$$c_C^{d,l,B} = c_C^{d,l,A}\left(\frac{P_C^A}{P_C^B}\right)^{\frac{1}{1-\theta_1}}. \tag{A296}$$

Migration:

$$\frac{H^{d,l}}{\overline{H}^d} \equiv \sigma^{d,l} = \frac{\exp\left(U\left(\frac{E^{d,l}}{P^l}\right)\right)^{1/\xi_d}}{\exp\left(U\left(\frac{E^{d,l}}{P^l}\right)\right)^{1/\xi_d} + \exp\left(U\left(\frac{E^{d,\neg l}}{P^{\neg l}}\right)\right)^{1/\xi_d}}. \tag{A297}$$

E.2.2 Commodity Sector

Optimal Decisions:

$$\hat{w}_C^l = \left[\phi_C(w^{u,l})^{1-\gamma} + (1-\phi_C)(w^{s,l})^{1-\gamma}\right]^{\frac{1}{1-\gamma}}, \tag{A298}$$

$$L_C^l = \left(\frac{\eta \cdot P_C^l}{\hat{w}_C^l} \right)^{\frac{1}{1-\eta}} \cdot R_t^l \, , \tag{A299}$$

$$L_C^{u,l} = \phi_C \cdot \left(\frac{\hat{w}_C^l}{w_C^{u,l}} \right) \cdot L_C^l \, , \tag{A300}$$

$$L_C^{s,l} = (1 - \phi_C) \cdot \left(\frac{\hat{w}_C^l}{w_C^{s,l}} \right) \cdot L_C^l \, , \tag{A301}$$

$$P_R^l = (1 - \eta) \cdot P_C^l \cdot \left(\frac{L_C^l}{R^l} \right)^{\eta} \, , \tag{A302}$$

$$\tag{A303}$$

Aggregate:

$$Y_C^l = \left(L_C^l \right)^{\eta} \left(R^l \right)^{1-\eta} \, . \tag{A304}$$

E.2.3 Nontradable Sector

Optimal decisions:

$$\hat{w}_N^l = \left[\phi_N (w^{u,l})^{1-\gamma} + (1 - \phi_N)(w^{s,l})^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \, , \tag{A305}$$

$$p_N^l \left(z_N \right) = \frac{\hat{w}^{d,l}}{\rho z_N} \, , \tag{A306}$$

$$q_N^l \left(z_N \right) = n_t^l \cdot \left(\frac{p_N^l \left(z_N \right)}{P_N^l} \right)^{-\sigma} \, , \tag{A307}$$

$$l_N^{u,l} \left(z_N \right) = \phi^N \cdot \left(\frac{\hat{w}_N^l}{w^{u,l}} \right)^{\gamma} \cdot \left(\frac{q_N^l}{z_N} + f_N^l \right) \, , \tag{A308}$$

$$l_N^{s,l} \left(z_N \right) = \left(1 - \phi^N \right) \cdot \left(\frac{\hat{w}_N^l}{w^{s,l}} \right)^{\gamma} \cdot \left(\frac{q_N^l}{z_N} + f_N^l \right) \, . \tag{A309}$$

$$\tag{A310}$$

Profit:

$$\pi^l_{N,t} = \frac{p^l_{N,t}\left(z_N\right) \cdot q^l_{N,t}\left(z_N\right)}{\sigma} - \hat{w}^l_{N,t} \cdot f^l_N \, .$$

Value Function:

$$W^l_N\left(z_N\right) = \max\left\{0, \frac{\pi^l_N(z_N)}{1-\beta\left(1-\delta_N\right)}\right\} \, . \tag{A311}$$

Cutoff:

$$0 = W^l_{N,t}\left(\underline{z}^l_N\right) \, . \tag{A312}$$

Free entry condition:

$$\int_{\bar{z}^l_{Nt}}^{\infty} W^l_{N,t}\left(z\right) g_N\left(z_N\right) dz_N = \hat{w}^l_{N,t} \cdot \left(f^l_{Ne}\right) \, . \tag{A313}$$

Productivity Distributions and Firm Masses:

$$\mu^l_N(z_N) = \begin{cases} \frac{g_N(z_N)}{1-G_N(\underline{z}^l_N)} & z_N \geq \underline{z}^l_N \\ 0 & \text{otherwise} \end{cases} \tag{A314}$$

$$\delta_N \cdot \mathcal{M}^l_N = \left[1 - G_N(\underline{z}^l_N)\right] \mathcal{M}^l_{N,e} \, . \tag{A315}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^{u,l}_{N,p} = \mathcal{M}^N \int_{\underline{z}^{u,l}_N}^{\infty} l^{u,l}_N\left(z_N\right) \mu^l_N(z_N) dz_N \, , \tag{A316}$$

$$L^{s,l}_{N,p} = \mathcal{M}^N \int_{\underline{z}^{s,l}_N}^{\infty} l^{s,l}_N\left(z_N\right) \mu^l_N(z_N) dz_N \, . \tag{A317}$$

- Total skilled and unskilled labor for fixed entry cost

$$L_{N,e}^{u,l} = \phi_N^u \cdot \left(\frac{\hat{w}_N^l}{w^{u,l}}\right)^\gamma \cdot \left(f_{Ne}^l\right) \,, \tag{A318}$$

$$L_{N,e}^{s,l} = \phi_N^d \cdot \left(\frac{\hat{w}_N^l}{w^{s,l}}\right)^\gamma \cdot \left(f_{Ne}^l\right) \,. \tag{A319}$$

- Total skilled and unskilled labor demand

$$L_N^{u,l} = L_{N,p}^{u,l} + L_{N,e}^{u,l} \,, \tag{A320}$$

$$L_N^{s,l} = L_{N,p}^{s,l} + L_{N,e}^{s,l} \,. \tag{A321}$$

- Total output

$$Y_N^l = \mathcal{M}^N \left[\int_{\underline{z}_N^l}^{\infty} \left(q_N^l\left(z_N\right)\right)^\rho \cdot d\mu_N^l(z_N)\right]^{\frac{1}{\rho}} \,. \tag{A322}$$

- Ideal Price Index

$$P_N^l = \left[\int_{\underline{z}_N^l}^{\infty} \left(p_N^l\left(z_N\right)\right)^{1-\sigma} d\mu_N^l(z_N)\right]^{\frac{1}{1-\sigma}} \,. \tag{A323}$$

E.2.4 Tradable Sector

Optimal decisions:

$$\hat{w}_T^l = \left[\phi_T (w^{u,l})^{1-\gamma} + (1-\phi_T)(w^{s,l})^{1-\gamma}\right]^{\frac{1}{1-\gamma}} \,, \tag{A324}$$

$$p_T^l\left(z_T\right) = \frac{\hat{w}_T^l}{\rho \cdot z_T} \,, \tag{A325}$$

$$
q^l_T(z_T) = \begin{cases} q^l_d = T^l_t \left[\frac{p^l_T(z_T)}{P^l_T}\right]^{-\sigma}, & \underline{z}^l_{d,t} < z_T < \underline{z}^l_{c,t} \\ q^l_d + q^l_c = T^l_t \left[\frac{p^l_T(z_T)}{P^l_T}\right]^{-\sigma} + T^{\neg l}\left[\frac{p^l_t(z_T)}{P^{\neg l}_T}\right]^{-\sigma}, & \underline{z}^l_{c,t} < z_T < \underline{z}^l_x \\ q^l_d + q^l_c + q^l_x = T^l \left[\frac{p^l_T(z_T)}{P^l_T}\right]^{-\sigma} + T^{\neg l}\left[\frac{p^l_T(z_T)}{P^{\neg l}_T}\right]^{-\sigma} + \Gamma\left[p^l_T(z_T)\right]^{-\sigma}, & \underline{z}^l_x < z_T \end{cases} \tag{A326}
$$

$$
l^{u,l}_T(z_T) = \begin{cases} l^{u,l}_d = \phi_T\left(\frac{\hat{w}^l_{T,t}}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)}{z_T} + f^l_d\right], & \overline{z}^l_d < z_T < \overline{z}^l_c \\ l^{u,l}_d + l^{u,l}_c = \phi_T\left(\frac{\hat{w}^l_T}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)+q^l_c(z_T)}{z_T} + f^l_d + f^l_c\right], & \underline{z}^l_c < z_T < \underline{z}^l_x \\ l^{u,l}_d + l^{u,l}_c + l^{u,l}_x = \phi_T\left(\frac{\hat{w}^l_T}{w^{ld}}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)+q^l_c(z_T)+q^l_x(z_T)}{z_T} + f^l_d + f^l_c + f^l_x\right], & \underline{z}^l_x < z_T \end{cases} \tag{A327}
$$

$$
l^{s,l}_T(z_T) = \begin{cases} l^{s,l}_d = (1-\phi_T)\left(\frac{\hat{w}^l_{T,t}}{w^{s,l}_t}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)}{z_T} + f^l_d\right], & \underline{z}^l_d < z_T < \underline{z}^l_c \\ l^{s,l}_d + l^{s,l}_c = (1-\phi_T)\left(\frac{\hat{w}^l_T}{w^{s,l}}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)+q^l_c(z_T)}{z_T} + f^l_d + f^l_c\right], & \underline{z}^l_c < z_T < \underline{z}^l_x \\ l^{s,l}_d + l^{s,l}_c + l^{s,l}_x = (1-\phi_T)\left(\frac{\hat{w}^l_T}{w^{s,l}}\right)^{\gamma} \cdot \left[\frac{q^l_d(z_T)+q^l_c(z_T)+q^l_x(z_T)}{z_T} + f^l_d + f^l_c + f^l_x\right], & \underline{z}^l_x < z_T \end{cases} \tag{A328}
$$

Profits:

$$
\pi^l_T(z_T) = \begin{cases} \pi^l_d = \frac{p^l_T(z_T)q^l_{d,t}(z_T)}{\sigma} - \hat{w}^l_T f^l_d, & \underline{z}^l_d < z_T < \underline{z}^l_c \\ \pi^l_d + \pi^l_c = \frac{p^l_T(z_T)\left[q^l_d(z_T)+q^l_c(z_T)\right]}{\sigma} - \hat{w}^l_T(f^l_d + f^l_c), & \underline{z}^l_c < z_T < \underline{z}^l_x \\ \pi^l_d + \pi^l_c + \pi^l_{x,t} = \frac{p^l_T(z_T)\left[q^l_d(z_T)+q^l_c(z_T)+q^l_x(z_T)\right]}{\sigma} - \hat{w}^l_T(f^l_d + f^l_c + f^l_x), & \underline{z}^l_x < z_T \end{cases} \tag{A329}
$$

Value functions:

$$W_T^l(z_T) = \max\left\{W_d^l(z_T), W_c^l(z_T), W_x^l(z_T)\right\}\ , \tag{A330}$$

$$W_d^l(z_T) = \max\left\{0, \frac{\pi_d^l(z_T)}{1-\beta(1-\delta_T)}\right\}\ , \tag{A331}$$

$$W_c^l(z_T) = \max\left\{0, \frac{\pi_d^l(z_T)+\pi_c^l(z_T)}{1-\beta(1-\delta_T)}\right\}\ , \tag{A332}$$

$$W_x^l(z_T) = \max\left\{0, \frac{\pi_d^l(z_T)+\pi_c^l(z_T)+\pi_x^l(z_T)}{1-\beta(1-\delta_T)}\right\}\ . \tag{A333}$$

$$\tag{A334}$$

Cutoffs:

$$W_d^l(\underline{z}_d^l) = 0\,, \tag{A335}$$

$$\pi_c^l(\underline{z}_c^l) = 0\,, \tag{A336}$$

$$\pi_x^l(\underline{z}_x^l) = 0\,. \tag{A337}$$

Free entry condition:

$$\int_{\bar{z}_{Tt}^l}^{\infty} W_{T,t}^l\left(z_T\right) g_T\left(z_T\right) dz_N = \hat{w}_{T,t}^l \cdot f_{Te}^l\,. \tag{A338}$$

Productivity Distributions and Firm Masses:

$$\mu_T^l(z_T) = \begin{cases} \frac{g_T(z_T)}{1-G_N(\bar{z}_d^l)} & z_T \geq \bar{z}_d^l \\ 0 & \text{otherwise} \end{cases} \tag{A339}$$

$$\delta_T \cdot \mathcal{M}_T^l = \left[1 - G(\bar{z}_d^l)\right] \mathcal{M}_{T,e}^l\,. \tag{A340}$$

Aggregate variables:

- Total skilled and unskilled labor for production

$$L^{u,l}_{T,p} = \mathcal{M}^T_t \int_{\underline{z}^l_T}^{\infty} l^{u,l}_T(z_T)\, \mu^l_T(z_T) dz_T \,, \tag{A341}$$

$$L^{s,l}_{T,p} = \mathcal{M}^T_t \int_{\underline{z}^l_T}^{\infty} l^{s,l}_T(z_T)\, \mu^l_T(z_T) dz_T \,. \tag{A342}$$

- Total skilled and unskilled labor for fixed entry cost

$$L^{u,l}_{T,e} = \phi^u_T \cdot \left(\frac{\hat{w}^l_T}{w^{u,l}}\right)^{\gamma} \cdot \left(f^l_{Te}\right) \,, \tag{A343}$$

$$L^{s,l}_{T,e} = \phi^d_T \cdot \left(\frac{\hat{w}^l_T}{w^{s,l}}\right)^{\gamma} \cdot \left(f^l_{Te}\right) \,. \tag{A344}$$

- Total skilled and unskilled labor demand

$$L^{u,l}_T = L^{u,l}_{T,p} + L^{u,l}_{T,e} \,, \tag{A345}$$

$$L^{s,l}_T = L^{s,l}_{T,p} + L^{s,l}_{T,e} \,. \tag{A346}$$

- Total tradable goods output produced in l that are sold domestically

$$\tilde{Y}^l_T = \left[\mathcal{M}^l \left(\int_{\underline{z}^l_d}^{\infty} \left[q^l_d(z_T)\right]^{\rho} \mu^l_T(z_T) dz_T + \int_{\underline{z}^l_c}^{\infty} \left[q^l_c(z_T)\right]^{\rho} \mu^l_T(z_T) dz_T\right)\right]^{\frac{1}{\rho}} \,. \tag{A347}$$

- Total domestic tradable output supplied to region l:

$$Y^l_T = \left[\left(\int_{\underline{z}^l_d}^{\infty} \mathcal{M}^l \cdot \left[q^l_d(z_T)\right]^{\rho} \mu^l_T(z_T) dz_T + \int_{\underline{z}^{\neg l}_c}^{\infty} \mathcal{M}^{\neg l} \left[q^{\neg l}_{ct}(z_T)\right]^{\rho} \mu^{\neg l}_T(z_T) dz_T\right)\right]^{\frac{1}{\rho}} \,. \tag{A348}$$

- Value of tradable good outputs sold in foreign market

$$X^l = \mathcal{M}^l_T \int_{\underline{z}^l_x}^{\infty} p^l_T(z_T) q^l_x(z_T) \mu^l_T(z_T) dz_T \,. \tag{A349}$$

E.3 Aggregation and Market Clearing

Population and Employment:

$$\overline{H}^{d} = H^{d,A} + H^{d,B}\,, \tag{A350}$$

$$H^{l} = H^{s,l} + H^{u,l}\,, \tag{A351}$$

$$h^{d,l} = L^{d,l} \leq H^{d,l}\,. \tag{A352}$$

Aggregate Demand for Goods:

$$C^{l} = H^{u,l} \cdot c^{u,l} + H^{s,l} \cdot c^{s,l}\,, \tag{A353}$$

$$M^{l} = H^{u,l} \cdot t^{u,l} + H^{s,l} \cdot t^{s,l}\,, \tag{A354}$$

$$T^{l} = H^{u,l} \cdot t^{u,l} + H^{s,l} \cdot t^{s,l}\,, \tag{A355}$$

$$A^{l} = H^{u,l} \cdot a^{u,l} + H^{s,l} \cdot a^{s,l}\,, \tag{A356}$$

$$\Omega^{l} = H^{u,l} \cdot \omega^{u,l} + H^{s,l} \cdot \omega^{s,l}\,, \tag{A357}$$

$$N^{l} = H^{u,l} \cdot n^{u,l} + H^{s,l} \cdot n^{s,l}\,, \tag{A358}$$

$$G^{l} = H^{u,l} \cdot g^{u,l} + H^{s,l} \cdot g^{s,l}\,, \tag{A359}$$

$$C_C^{l,A} = H^{u,l} \cdot c_C^{l,A} + H^{s,l} \cdot c_C^{l,A}\,, \tag{A360}$$

$$C_C^{l,B} = H^{u,l} \cdot c_C^{l,B} + H^{s,l} \cdot c_C^{l,B}\,, \tag{A361}$$

$$C_C^{A} = C_C^{A,A} + C_C^{B,A}\,, \tag{A362}$$

$$C_C^{B} = C_C^{A,B} + C_C^{B,B}\,. \tag{A363}$$

Market Clearance:

$$Y_N^{l} = N^{l}\,, \tag{A364}$$

$$Y_T^{l} = T^{l}\,, \tag{A365}$$

$$\overline{R}^{l} = R^{l}\,. \tag{A366}$$

Balance of Payments:

$$X = P_C^A \left(Y_C^A - C_C^A\right) + P_C^B \left(Y_C^B - C_C^B\right) + X_T^A + X_T^{\mathbf{A}} \,, \tag{A367}$$

$$M = M^A + M^B \,, \tag{A368}$$

$$TB = X - M \,, \tag{A369}$$

$$B = -\frac{TB}{r^*} \,. \tag{A370}$$

E.3.1 Steady State Algorithm

Assumption

- Symmetric regions.

Algorithm

1. Guess unskilled wages $\left(w^{u,A}, w^{s,A}\right)$ and import demands $\left(m^A, m^B\right)$. Given the skill premium, guesses for unskilled wages imply guesses for skilled wages.

2. Recover all good bundle prices from (A282)-(A285) and demands from (A289)-(A296). Also, compute aggregate demands for tradable, nontradable, and commodity bundles from (A355), (A356), (A362), and (A363).

3. Evaluate the firm value functions in the tradable and nontradable sectors using (A330) and (A311). Then, solve for the cutoffs for operation, interregional trade, and international exporting from (A312), (A335), (A336), and (A337).

4. Using the firm value functions, recover the fixed entry cost implied by the free entry conditions (A313) and (A338).

5. Given operational cutoffs, define the steady state productivity distributions using (A314) and (A339). Then, compute the total firm masses using the market clearing conditions (A322), (A364), (A348), and (A365). Given firm masses, recover the mass of entrants from (A315) and (A340).

6. Recover total labor demands from tradable, nontradable, and commodity sectors using (A300), (A301), (A320), (A321), (A345), and (A346),

7. Compute the steady state net foreign asset position from (A370).

8. Update guesses until markets for skilled and unskilled labor clear and the net foreign asset position matches the target $\overline{B}$.

Terminal Steady State. The terminal steady state is characterized by a value of λ. Given λ from the transition algorithm as well as the guesses for prices and wages, we recover expenditure and consumption from (A286) and (A287). Then, we guess the share of skilled and unskilled population in region A and recover aggregate demands for goods bundle. After computing labor demands from the three sectors, we check if the distribution of skilled and unskilled population across regions is consistent with the initial guesses. If not, we update the initial guesses as a convex combination of the previous guesses and the implied values until they are consistent with each other.

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