Demand Shocks and Labor Market Dynamics: Firm Level Responses to a Commodity Boom

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VERY INCOMPLETE

Abstract

This paper studies the role of labor markets in the transmission of commodity price super cycles, including the causal association between dynamic labor distortions and recessions during cycle busts. Our theoretical contributions emerge from a three-sector model of a small open economy with firm heterogeneity, entry and exit decisions, and skilled and unskilled labor. We show that during the boom, the commodity and non-tradable sectors expand, the skill wage premium narrows, and the non-commodity export sector contracts. During the bust, on the other hand, downward wage rigidity generates dynamic misallocation between sectors, triggering a persistent recession characterized by unemployment and a sluggish recovery of non-commodity exporters. This opens a door for precautionary policy during the boom. We then present empirical evidence to asses these mechanisms. In particular, we study the case of Brazil between 1996-2013, a period in which large commodity price fluctuations provided a clean quasi-natural experiment. We examine linked employer-employee data and exploit variation across commodities and across regions to measure the direct impact of commodity prices on labor market outcomes of both commodity producing firms and firms in other sectors of the economy. Our empirical evidence support our theoretical implications.

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1 Introduction

Commodity price cycles are a fundamental source of volatility to emerging markets. Commodities represent more than a quarter of the exports of the median emerging economy and a significant share of government budgets.[1]. Price fluctuations influence aggregate economic activity, unemployment rates, and the ability of governments to balance their budget and to finance welfare programs. Often times, as Reinhart et al. (2016) document, the end of commodity price cycles is associated with deep crises and slow recoveries. All these features of the commodity price cycles suggest that understanding the transmission mechanisms from these prices to the rest of the economy is crucial.

This paper studies the role played by labor markets in the transmission of commodity price super cycles throughout the economy, and the role of labor market frictions in generating recessions during the cycle bust. Three factors are critical when studying this transmission mechanism. First, commodity production in emerging markets is intensive in low-skill labor and practically all of the production is exported. Therefore, commodity price booms raise the demand for low-skill workers, reduce the skill premium, and generate a negative cost shock to other low-skill-intensive sectors of the economy. Second, higher wages stimulate domestic demand for every good in the economy. Thus, firms that rely relatively more on domestic sales are likely to benefit from a commodity price boom. Third, labor markets in emerging markets are frictional, especially at the lower tail of the skill distribution, where minimum wages are likely to be binding. This rigidity can potentially keep wages to low-skill workers artificially high long after the commodity super cycle has ended. In this sense, the boom spread the seeds of a future recession characterized by persistent unemployment and labor misallocation across sectors.

In order to capture these three channels, we build a three-sector dynamic small open economy model with firm heterogeneity, entry and exit, and skilled and unskilled labor. In the model, firms in different sectors interact by hiring skilled and unskilled workers in a common labor market. We use Brazilian data to calibrate and evaluate the performance of the model. Brazil is an excellent laboratory to study the interplay of labor markets and commodity prices, for the following reasons. First, we have access to rich administrative linked employer-employee data with the universe of job-spells in the formal sector of the economy and detailed worker characteristics. Second, the Brazilian economy is a major commodity exporter but its market share in any particular commodity makes it a price-taker. Third, there is a rich geographic variation in the data that can be used to test the model exploiting variation in commodity-specialization across local labor markets.

The model in section 3 is a dynamic small open economy with three producing sectors,

[1]Fernandez et al. (2015) document commodity export shares across developed and developing countries.

each characterized by a continuum of firms with heterogeneous productivity. First, firms operating in the commodity good sector compete for a scarce resource and export all their output facing a fully elastic demand. Second, firms in the non-tradable sector produce an homogeneous good whose price clears the domestic market. Third, firms in the tradable sector sell heterogeneous goods and face an exporting decision. The three sectors interact by hiring skilled and unskilled labor in a common market. The only friction in the model is that unskilled labor is downward rigid.

Section 4 explores a preliminary calibration of the model to the Brazilian data. The first experiment compares two steady states with different commodity prices. In line with the economic intuition underlying the model, after a permanent increase in commodity prices, the skill premium decreases, the non-tradable sector benefits from a larger domestic absorption, and less productive exporters in the tradable sector leave the international market. Because the main feature of commodity super cycles is their low-frequency component, we then focus on a sequence of steady states that mimic a super cycle. The misallocation caused by downward wage rigidity can generate an aggregate recession with persistent unemployment even when after the cycle the commodity prices are above the pre-boom level. We are currently working on a perfect foresight equilibrium that should allow us a better understanding of the firm level responses to low-frequency commodity cycles.

Section 5 describes the linked employer-employee census used to test the model and provides some preliminary descriptive statistics on the variation of firm employment and wages across regions, sectors, and skill-groups.

The rest of the paper is structured as follows. Section 2 summarizes the related literature. Section 3 presents our model economy. Section 4 shows the preliminary calibration and quantitative results. Section 5 describes the data for our ongoing empirical analysis. Finally, section 6 concludes the paper.

2 Literature Review

Despite the attention of policymakers, the academic literature on the impact of commodity price fluctuations is divided. On the one hand, the calibrated theoretical macro models that follow Mendoza (1995) suggest that fluctuations in terms of trade can explain 40% of movements in output. On the other hand, the empirical study by Schmitt-Grohé and Uribe (2015) using data for 38 poor and emerging economies shows that fluctuations to terms of trade only account for 10% of output movements. Recent papers by Fernandez et al. (2015) and Shousha (2016) show that the discrepancy is likely to be due to the level of aggregation. In fact, the terms of trade are a basket that obscures the fluctuations of its components. These studies build country specific commodity baskets and uncover a strong relationship between the fluctuations of the prices of commodities produced by the country and its major macroeconomic variables. For Fernandez et al. (2015) the transmission mechanism hardwired into the model is an income effect on the workers. In their view, higher commodity prices translate into higher wages for commodity workers and therefore higher demand for every other good in the economy. Shousha (2016) assumes an exogenous link between commodity prices and the interest rate at which the country can borrow. Therefore, commodity booms are transmitted in the economy by lowering the interest rate for every other industry.

Our paper also contributes to the microeconomic literature on the impact of external shocks to labor markets in Brazil. These studies have focused mostly on the impact of trade liberalization or import competition from China on employment and wages. Menezes-Filho and Muendler(2011) and Dix-Carneiro and Kovak (2015) study labor market dynamics after Brazil's trade liberalization in the early 1990s. Costa, Garred and Pessoa (2016) analyze the impact on local labor markets of the rise in both import competition and demand for Brazilian exports (mainly commodities) from China. Using the 2000 and 2010 cross-sections of Brazil's demographic census, they find a relative decline in wages in regions facing larger increases in import competition, and a relative wage increase in regions facing a positive demand shock. Adao (2015) studies the sorting of workers in and out of industries as a response to the fluctuations in commodity prices faced by Brazil during the period 1991-2010.

3 Model

3.1 Model Overview

Time is discrete in this deterministic small open economy model. There is a representative consumer that demands three class of goods: an imported good, a bundle of differentiated tradable goods, and a non tradable good. The tradable commodity good is the fourth good in the economy. The household supplies skilled and unskilled labor inelastically for production and borrows in international markets. The four class of goods are produced as follow. First, the imported good is produced abroad. Its price is exogenous and it is used as the numèraire of the economy. Second, the commodity good is produced by firms with heterogeneous permanent productivity using labor and a scarce natural resource with a decreasing return to scale technology. The price of the commodity is exogenous and all the production is exported. An endogenous productivity threshold determines what firms operate. The price of the scarce resource is endogenous. Third, the non tradable good is produced by firms with heterogeneous productivity using labor with a decreasing return to scale technology. An endogenous productivity threshold determines what firms operate. The price of this good is endogenous. Fourth, tradable goods are produced by firms with heterogeneous productivity using labor with an increasing return to scale technology. An endogenous productivity threshold determines what firms operate in the domestic market and another endogenous productivity threshold determines what firms have access to the external market. The international and the domestic demand for each variety is elastic, thus, prices are endogenously determined. Figure 1 shows a diagram of the model economy.

Summarizing, the model nests three heterogeneous firm models in the framework of Mendoza (1995) and allow each sector to affect each other trough their labor market interactions. For instance, an increase in the price of the commodity good puts upward pressure on wages. This increases local domestic demand for all goods through an income effect, but it also increases the production cost of every good in the economy. The magnitude and relative importance of these effects are heterogeneous across sectors and their intensity depends on the importance of the commodity sector in the economy. The commodity and non tradable sector are aligned with Hopenhayn (1992) model of firm dynamics, the tradable sector follows Melitz (2003). Note that the commodity sector clearly differs from the other two sectors. First, unlike the non tradable good, commodity producers export all their production at an exogenous price. Second, unlike the tradable exporters, commodity producers face an inelastic demand for their exports. The dynamics of the model are shaped by the interaction of commodity prices and labor market frictions. In particular, we include downward wage rigidity as in Schmitt-Grohé and Uribe (2016) on the unskilled labor to study if labor market frictions can generate a persistent recession at the end of a commodity super cycle due to

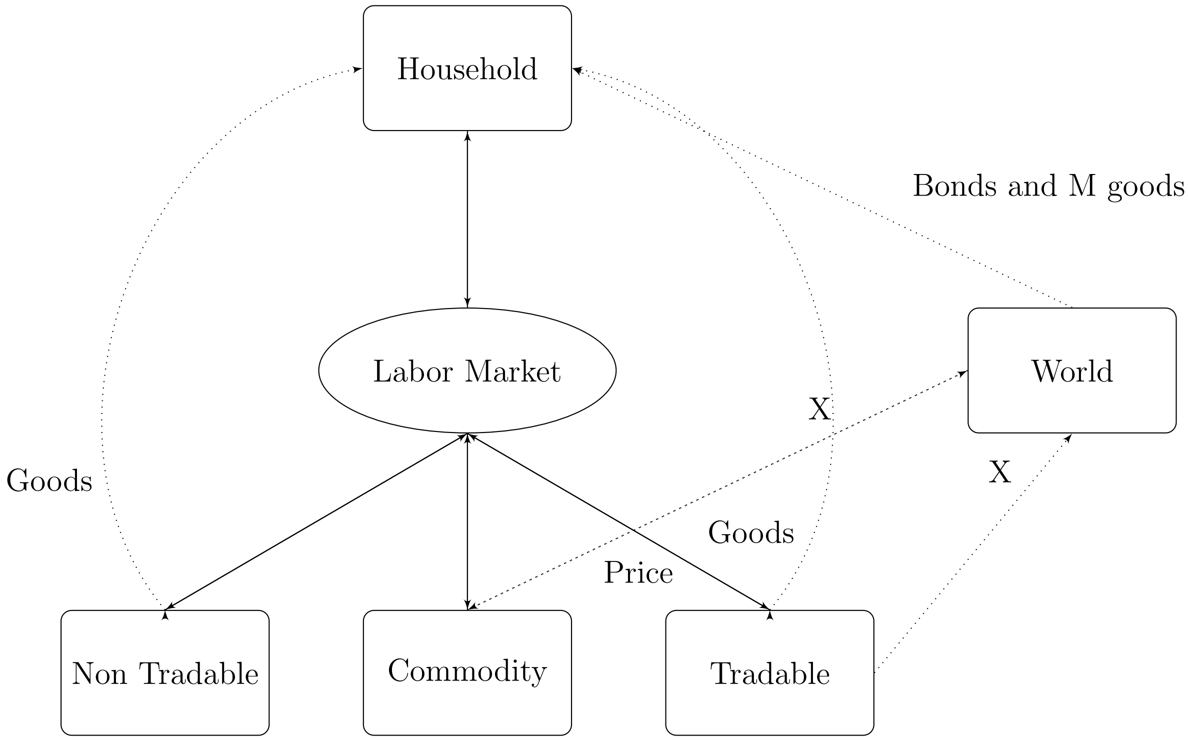


Figure 1: Model Economy

dynamic misallocation of labor between sectors. Therefore, opening a door for precautionary policy during commodity booms.

3.2 Representative Household

The representative household supplies skilled (L^s) and unskilled labor (L^u) inelastically, consumes imported goods (M), nontradable goods (N), and tradable goods (T^d). In particular, their lifetime utility function is given by:

$$U = \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\gamma^r} \left(\left(\alpha^M M_t^\theta + \alpha^N N_t^\theta + \alpha^T \left(T_t^d\right)^\theta \right)^{\frac{1}{\theta}} \right)^{1-\gamma^r}, \tag{1}$$

where $\theta \in (0,1)$ controls the elasticity of substitution between goods and $\gamma^r > 1$ the intertemporal elasticity of substitution.

Denote by P_t^* the exogenous commodity good price, P_t^N the endogenous nontradable good price, P_t^T the endogenous tradable bundle price, and the exogenous imported good price is normalized to one and used as numéraire. Then the representative household budget constraint is:

$$M_t + P_t^N N_t + P_t^T T_t^d + B_{t+1} + \frac{\psi}{2}(B_{t+1} - \bar{B})^2 \leq w_t^s L^s + w_t^u L^u + P_{R,t}\bar{R} + (1 + r^*)B_t + \Pi_t^T \ , \quad (2)$$

where bonds are in units of imported goods and their interest rate (r^*) is exogenous. Π_t^T collects the total profits from commodity, nontradable, and tradable sectors. Bond adjustment costs are used to determine the long-run wealth of the country ($\bar{B}$). The tradable bundle consumed by the household is given by:

$$T_t^d = \left[\int_{\zeta \in \mathfrak{Z}} q_d(\zeta)^\rho d\zeta\right]^{\frac{1}{\rho}} \ , \tag{3}$$

where ζ is an index for individual varieties (or operating firms), and $\mathfrak{Z}$ is an index set for individual varieties sold in domestic market. The bundle price is given by the following aggregation of variety prices:

$$P_t^T = \left[\int_{\zeta \in \mathfrak{Z}} p(\zeta)^{1-\sigma} d\zeta\right]^{\frac{1}{1-\sigma}} \ .$$

Household demands are given by the following first order conditions:

$$N_t = \left(\frac{\alpha^N}{\alpha^M} \frac{1}{P_t^N}\right)^{\frac{1}{1-\theta}} M_t \tag{4}$$

and

$$T_t^d = \left(\frac{\alpha^T}{\alpha^M} \frac{1}{P_t^T}\right)^{\frac{1}{1-\theta}} M_t \ , \tag{5}$$

and the domestic demand for each tradable variety is given by:

$$q_d(\zeta) = T_t^d \left[\frac{p(\zeta)}{P_t^T}\right]^{-\sigma} \ , \tag{6}$$

where $0 < \rho < 1$ and $\sigma = \frac{1}{1-\rho} > 1$ is the elasticity of substitution between varieties. Finally, the Euler equation for bonds can be written as:

$$\Lambda_{t,t+1}(1 + r^*) = \left[1 + \psi(B_{t+1} - \bar{B})\right] \ , \tag{7}$$

where $\Lambda_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t}$ and

$$\lambda_t = \left[\alpha^M M_t^\theta + \alpha^N N_t^\theta + \alpha^T \left(T_t^d\right)^\theta\right]^{\frac{1-\theta-\gamma}{\theta}} \cdot \alpha^M M_t^{\theta-1} \tag{8}$$

3.3 Commodity Sector

Commodity good is produced by heterogeneous firms according to the following technology:

$$C_{i,t} = C(z_i; R_{i,t}, l_{i,t}^{s,C}, l_{i,t}^{u,C}) = z_i R_{i,t}^{\xi} \left(l_i^C \left(l_{i,t}^{s,C}, l_{i,t}^{u,C} \right) \right)^{\eta} ,$$

where z_i is a permanent idiosyncratic productivity, $l_{i,t}^{s,C}$ is the skilled labor input, $l_{i,t}^{u,C}$ the unskilled labor input, and $R_{i,t}$ the resource input used by firm i. Effective labor is defined as

$$l_{i,t}^C = l_i^C \left(l_{i,t}^{s,C}, l_{i,t}^{u,C} \right) \equiv \left[(\phi^C)^{\frac{1}{\gamma}} (l_{i,t}^{u,C})^{\frac{\gamma-1}{\gamma}} + (1-\phi^C)^{\frac{1}{\gamma}} (l_{i,t}^{s,C})^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}} ,$$

where $\phi^C \in (0,1)$ is share of unskilled labor in commodity sector and $\gamma > 1$ is the elasticity of substitution between skilled and unskilled labor. Note that the technology has decreasing return to scale and that firms are heterogeneous in their total factor productivity z_i. The resource input supply is fixed at $\bar{R}$. There is a fixed operating cost c^c measured in units of output and a fixed entry cost c_e^c measured in units of effective labor. Potential entrants draw their permanent productivity z_i from a discrete distribution. Denote by $\{\mathbf{f(z)}, \mathbf{z}\}$ the pair of probability ($\mathbf{f(z)}$) and payoff ($\mathbf{z}$) vectors of length N^C that characterize the discrete distribution. Profits of firm i in period t are given by:

$$\pi_{i,t} = \pi(l_{i,t}^{u,C}, l_{i,t}^{s,C}, R_{i,t}; z_i, w_t^u, w_t^s, P_{R,t}, P_t^*) = P_t^* \left[z_i R_{i,t}^{\xi} (l_{i,t}^c)^{\eta} - c^c \right] - l_{i,t}^C \hat{w}_t^C - P_{R,t} R_{i,t} \, , \quad (9)$$

with the price for effective labor given by:

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

Firms are subject to an exogenous exit probability δ^C each period. Firms can also endogenously exit when their value turns negative. Then, the value of a firm is given by:

$$W_t^c(z; \hat{w}_t^C, P_{R,t}, P_t^*) = \max \left\{ 0, \; \pi_t(z; \hat{w}_t^C, P_{R,t}, P_t^*) + (1-\delta^C) \Lambda_{t,t+1} W_{t+1}^c(z; \hat{w}_{t+1}^C, P_{R,t+1}, P_{t+1}^*) \right\} . \quad (10)$$

The operational productivity cut-off $\underline{z}_t = \underline{z}(\hat{w}_t^C, P_{R,t}, P_t^*, \hat{w}_{t+1}^C, P_{R,t+1}, P_{t+1}^*)$ is implicitly defined by:

$$W_t^c(\underline{z}_t; \hat{w}_t^C, P_{R,t}, P_t^*) = 0, \quad (11)$$

Define $\mathcal{F}(z) \equiv \sum_{j=1}^{z} f(z)$. Then, the time varying productivity distribution of entrants is given by:

$$\tilde{\mu}_t^C(z; \hat{w}_t^C, P_{R,t}, P_t^*, \hat{w}_{t+1}^C, P_{R,t+1}, P_{t+1}^*) = \begin{cases} \dfrac{f(z)}{1-\mathcal{F}(\underline{z}_t)} & \text{, if } z \geq \underline{z}_t \\ 0 & \text{, otherwise.} \end{cases} \tag{12}$$

The free entry condition can be written as:

$$\sum_{j=\underline{i}}^{N^C} W_t^c(z_j) f(z_j) = \hat{w}_t^C c_e^c \tag{13}$$

where N^C is the number of grid points, and $\underline{i}$ is the position of the cut-off $\underline{z}_t$. Denote by $\mathcal{M}_t^C$ and $\tilde{\mathcal{M}}_t^C$ the mass of incumbents and the mass of potential entrants, respectively. Then, the law of motion that characterize the evolution of the mass of incumbents is given by:

$$\mathcal{M}_{t+1}^C = (1-\delta^C)\left[\mathcal{M}_t^C + (1-\mathcal{F}(\underline{z}_t))\,\tilde{\mathcal{M}}_t^C\right] \tag{14}$$

The time varying distribution of incumbents is given by:

$$\mu_{t+1}^C(z) = \begin{cases} \frac{\left(1-\delta^C\right)\left[\mu_t^C(z)\mathcal{M}_t^C + f(z)\tilde{\mathcal{M}}_t^C\right]}{\mathcal{M}_{t+1}^C} & \text{, if } z \geq \underline{z}_{t+1} \\ 0 & \text{, otherwise.} \end{cases} \tag{15}$$

Note that the natural resource is in fixed supply, and the market clearing condition is:

$$\bar{R} = \left[\mathcal{M}_t^C + (1-\mathcal{F}(\underline{z}_t))\,\tilde{\mathcal{M}}_t^C\right] \sum_{j=\underline{i}}^{N^C} R_t(z_j)\mu_t^C(z_j) \tag{16}$$

Therefore, the mass of potential entrants and the natural resource price jointly adjust so that (13) and (16) hold every period.

3.4 Non Tradable Sector

The non tradable good is homogeneous and produced by heterogeneous firms with the following technology:

$$N(s_i, l_{i,t}^{u,N}, l_{i,t}^{s,N}) = s_i\left(l^N(l_{i,t}^{u,N}, l_{i,t}^{s,N})\right)^{\alpha},$$

Potential entrants draw their permanent productivity s_i from a discrete distribution. Denote by $\{\mathbf{h(s)}, \mathbf{s}\}$ the pair of probability ($\mathbf{h(s)}$) and payoff ($\mathbf{s}$) vectors of length N^N that characterize the discrete distribution. Effective labor is defined as

$$l^N\left(l^{s,N}_{i,t}, l^{u,N}_{i,t}\right) \equiv \left[(\phi^N)^{\frac{1}{\gamma}}(l^{u,N}_{i,t})^{\frac{\gamma-1}{\gamma}} + (1-\phi^N)^{\frac{1}{\gamma}}(l^{s,N}_{i,t})^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}} ,$$

with price

$$\hat{w}^N_t = \left[\frac{\phi^N}{(w^u)^{\gamma-1}} + \frac{1-\phi^N}{(w^s)^{\gamma-1}}\right]^{-\frac{1}{\gamma-1}} .$$

There is a fixed operating cost c_f measured in units of output. Therefore, profits are given by:

$$\pi(l^{u,N}_{i,t}, l^{s,N}_{i,t}; s_i, w^u_t, w^s_t, P^N_t) = P^N_t\left[s_i\left(l^N(l^{u,N}_{i,t}, l^{s,N}_{i,t})\right)^{\alpha} - c_f\right] - w^u_t l^{u,N}_{i,t} - w^s_t l^{s,N}_{i,t} , \tag{17}$$

There is an exogenous exit rate δ^N. Period-t value of an incumbent firm is given by:

$$W^N_t\left(s, \hat{w}^N_t, P^N_t\right) = \max\left\{0,\ \pi_t\left(s, \hat{w}^N_t, P^N_t\right) + (1-\delta^N)\,\Lambda_{t,t+1}\,W^N_{t+1}\left(s, \hat{w}^N_{t+1}, P^N_{t+1}\right)\right\} . \tag{18}$$

The operational productivity threshold in the nontradable sector $\underline{s}_t = \underline{s}(\hat{w}^N_t, P^N_t, \hat{w}^N_{t+1}, P^N_{t+1})$ is implicitly defined by:

$$W^N_t\left(\underline{s}_t; \hat{w}^N_t, P^N_t\right) = 0. \tag{19}$$

Define $\mathcal{H}(s) \equiv \sum_{j=1}^{h} h(s)$. Then, the time varying productivity distribution of entrants is given by:

$$\tilde{\mu}^N_t(s; \hat{w}^N_t, P^N_t, \hat{w}^N_{t+1}, P^N_{t+1}) = \begin{cases} \dfrac{h(s)}{1-\mathcal{H}(\underline{s}_t)} & \text{, if } s \geq \underline{s}_t \\ 0 & \text{, otherwise.} \end{cases} \tag{20}$$

There is an entry cost of c_e in units of effective labor to take a productivity draw. Therefore, the free entry condition can be written as:

$$\sum_{j=\underline{i}}^{N^N} W^n_t(s_j; \hat{w}^N_t, P^N_t)h(s_j) = \hat{w}^N_t c_e \tag{21}$$

where N^N is the number of grid points, and $\underline{i}$ is the grid point position associated with the cut-off $\underline{s}_t$. Denote by $\mathcal{M}^N_t$ and $\tilde{\mathcal{M}}^N_t$ the mass of incumbents and the mass of potential entrants. Then, the law of motion that characterize the evolution of the mass of incumbents is given by:

$$\mathcal{M}_{t+1}^{N} = (1-\delta^{N}) \left[\mathcal{M}_{t}^{N} + (1-\mathcal{H}(\underline{s}_t))\,\tilde{\mathcal{M}}_{t}^{N}\right] \tag{22}$$

The time varying distribution of incumbents is given by:

$$\mu_{t+1}^{N}(s) = \begin{cases} \frac{(1-\delta^{N})\left[\mu_t^N(s)\mathcal{M}_t^N + h(s)\tilde{\mathcal{M}}_t^N\right]}{\mathcal{M}_{t+1}^N} & \text{, if } s \geq \underline{s}_{t+1} \\ 0 & \text{, otherwise.} \end{cases} \tag{23}$$

The time varying mass of potential entrants and the endogenous price of the non tradable good dynamically make the free entry condition and the market for the non tradable good clear along the equilibrium transition path.

3.5 Tradable Sector

Tradable firms are heterogeneous in their productivity φ. They produce heterogeneous varieties indexed by ζ using the following technology:

$$q_t(\varphi) = q(\varphi; l_t^{s,T}, l_t^{u,T}) = \varphi\left(l^T\left(l_t^{s,T}, l_t^{u,T}\right) - f\right) ,$$

where φ is drawn from a discrete distribution. Denote by $\{g(\varphi), \varphi\}$ the pair of probability $(g(\varphi))$ and payoff (φ) vectors of length N^T that characterize the discrete distribution. f is an operational fixed cost in terms of effective labor, given by

$$l_t^T = l^T\left(l_t^{s,T}, l_t^{u,T}\right) \equiv \left[(\phi^T)^{\frac{1}{\gamma}}(l_t^{u,T})^{\frac{\gamma-1}{\gamma}} + (1-\phi^T)^{\frac{1}{\gamma}}(l_t^{s,T})^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}} ,$$

with price

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

Domestic production is subject to $f = f_d$, while production for foreign markets has a hire fixed cost $f = f_x > f_d$. Firms that only produce domestically face the following demand:

$$q_{d,t}(\zeta) = T_t^d\left[\frac{p_t(\zeta)}{P_t^T}\right]^{-\sigma} , \tag{24}$$

while exporting firms face a larger demand given by:

$$q_{ex,t}(\zeta) = q_{d,t}(\zeta) + q_{x,t}(\zeta) = \left[T_t^d (P_t^T)^{\sigma} + \gamma_0\right] p_t(\zeta)^{-\sigma} ,$$

where γ_0 denotes the size of the foreign market. Thus tradable variety ζ sold in foreign market is equal to $q_{x,t}(\zeta) = \gamma_0 p_t(\zeta)^{-\sigma}$. For simplicity we assume the same price elasticity for domestic and foreign demand. Therefore, the marginal revenue for both, exporters and non exporters, is given by:

$$MR_t(\zeta) = \rho p_t(\zeta)\ .$$

Regardless of its productivity, each firm faces a residual demand curve with constant elasticity σ and thus chooses the same markup $\sigma/(\sigma-1) = 1/\rho$ over marginal cost $\hat{w}_t^T/\varphi$. This yields the following pricing rule:

$$p_t(\varphi) = \frac{\hat{w}_t^T}{\rho\varphi}\ . \tag{25}$$

The revenue of a firm is given by:

$$r_t\left(\varphi; \hat{w}_t^T, P_t^T, T_t^d\right) = \begin{cases} r_{d,t}\left(\varphi\right) = P_t^T T_t^d \left[\dfrac{P_t^T \rho\varphi}{\hat{w}_t^T}\right]^{\sigma-1} & \text{, if nonexporter} \\ r_{d,t}\left(\varphi\right) + \gamma_0 \left(\dfrac{\rho\varphi}{\hat{w}_t^T}\right)^{\sigma-1} & \text{, if exporter} \end{cases}$$

The profits can be written as

$$\pi_t\left(\varphi; \hat{w}_t^T, P_t^T, T_t^d\right) = \begin{cases} \pi_{d,t}\left(\varphi\right) = \dfrac{r_{d,t}}{\sigma} - \hat{w}_t^T f_d & \text{, if nonexporter} \\ \pi_{ex,t}\left(\varphi\right) = \pi_{d,t}\left(\varphi\right) + \dfrac{r_{x,t}}{\sigma} - \hat{w}_t^T f_x & \text{, if exporter} \end{cases} \tag{26}$$

Given an exogenous exit rate of δ^T, the value of a firm $j = \{d, ex\}$ is:

$$W_{j,t}^T\left(\varphi; \hat{w}_t^T, P_t^T, T_t^d\right) = \max\left\{0\ , \pi_{j,t}\left(\varphi, \hat{w}_t^T, P_t^T, T_t^d\right) + \left(1-\delta^T\right)\Lambda_{t,t+1} W_{j,t+1}^T\left(\varphi; \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right)\right\} \tag{27}$$

The operational and exporting cut-offs ($\varphi_t^* = \varphi^*\left(\hat{w}_t^T, P_t^T, T_t^d, \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right)$ and $\varphi_{x,t}^* = \varphi_x^*\left(\hat{w}_t^T, P_t^T, T_t^d, \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right)$, respectively) are implicitly defined by the conditions:

$$W_{d,t}^T\left(\varphi^*; \hat{w}_t^T, P_t^T, T_t^d\right) = 0 \tag{28}$$
$$W_{ex,t}^T\left(\varphi_x^*; \hat{w}_t^T, P_t^T, T_t^d\right) = 0. \tag{29}$$

Define $\mathcal{G}(\varphi) \equiv \sum_{j=1}^{g} g(\varphi)$. Therefore, the time-varying productivity distribution of entrants is given by:

$$\tilde{\mu}_t^T \left(\varphi; \hat{w}_t^T, P_t^T, T_t^d, \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right) = \begin{cases} \dfrac{g(\varphi)}{1-\mathcal{G}\left(\varphi_t^*\right)} & \text{, if } \varphi \geq \varphi_t^* \\ 0 & \text{, otherwise,} \end{cases} \tag{30}$$

The time-varying probabilities of entering ($p_{in,t}$) and being and exporter ($p_{x,t}$) as:

$$p_{in,t}\left(\varphi^*\left(\hat{w}_t^T, P_t^T, T_t^d, \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right)\right) = 1-\mathcal{G}\left(\varphi_t^*\right)$$
$$p_{x,t}\left(\varphi^*\left(\hat{w}_t^T, P_t^T, T_t^d, \hat{w}_{t+1}^T, P_{t+1}^T, T_{t+1}^d\right)\right) = \frac{1-\mathcal{G}\left(\varphi_{x,t}^*\right)}{1-\mathcal{G}\left(\varphi_t^*\right)}.$$

There is an entry cost of f_e in units of effective labor to take a productivity draw. Therefore, free entry condition is given by:

$$\sum_{j=\underline{i}}^{N^T} W_t^T\left(\varphi_j\right) g\left(\varphi_j\right) = \hat{w}_t^T f_e. \tag{31}$$

where N^T is the number of grid points, and $\underline{i}$ is the grid point position associated with the cut-off φ_t^*. Denote by $\mathcal{M}_t^T$ and $\tilde{\mathcal{M}}_t^T$ the mass of incumbents and the mass of entrants, respectively. Then, the law of motion that characterize the evolution of the mass of incumbents is given by:

$$\mathcal{M}_{t+1}^T = \left(1-\delta^T\right)\left[\mathcal{M}_t^T + \left(1-\mathcal{G}(\varphi_t^*)\right)\tilde{\mathcal{M}}_t^T\right] \tag{32}$$

The time varying distribution of incumbents is given by:

$$\mu_{t+1}^T(\varphi) = \begin{cases} \frac{\left(1-\delta^T\right)\left[\mu_t^T(\varphi)\mathcal{M}_t^T + g(\varphi)\tilde{\mathcal{M}}_t^T\right]}{\mathcal{M}_{t+1}^T} & \text{, if } \varphi \geq \varphi_{t+1}^* \\ 0 & \text{, otherwise.} \end{cases} \tag{33}$$

3.6 Labor Market Friction

In order to introduce labor market rigidity in a tractable way we follow Schmitt-Grohé and Uribe (2016) and introduce downward wage rigidity on the unskilled workers. This is a particularly suitabke assumption in the context of Brazil, one of the most rigid labor markets in Latin America with a wide use of firing costs and minimum wages. We impose the following restriction in the evolution of wages:

$$w_{t+1}^u \geq 0.99 w_t^u$$

The following slackness condition emphasizes that employment is demand determined.

$$\left(w_{t+1}^u - 0.99w_t^u\right)\left(l - \bar{l}\right) = 0$$

Note that, either the restriction is not binding and the economy is at full employment, or the restriction binds and there is involuntary unemployment.

4 Quantitative Analysis

In this section we present a preliminary calibration and show that the model delivers cross sector transmission of commodity super cycles. Moreover, te preliminary dynamic analysis shows that labor rigidity can generate recessions at the end of a commodity super cycle.

4.1 Calibration

Table 1 shows the set of externally calibrate parameters.

parameter	description	value
β	time discount factor	0.9615
γ^r	risk aversion	1.5
θ	consumption bundle aggregation	0.80
ρ	tradable sector D-S aggregator weight	0.75
ψ	portfolio adjustment cost	10^{-4}
ξ	commodity sector resource share	0.38
η	commodity sector labor share	0.25
α	nontradable sector labor share	0.65
P^*	commodity price	1.2
$\bar{B}$	steady state bond level	0
L^s	total skilled labor supply	4.9
L^u	total unskilled labor supply	5.1
δ^C	commodity sector firm death rate	0.164
δ^N	nontradable sector firm death rate	0.171
δ^T	tradable sector firm death rate	0.172
α^M	preference on imported goods	1.1
α^N	preference on nontradable goods	1.2
α^T	preference on tradable goods	1
μ	TFP distribution for every sector, mean	0.50
σ	TFP distribution for every sector, stdev	0.50
γ	substitution skilled and unskilled labor	1.51

Table 1: Externally Calibrated Parameters

Table 2 show a set of 12 internally calibrated parameters. The preliminary nature of this draft is clear as the number of targeted moments in Table 3 is just 8.

parameter	description	value
$\bar{R}$	commodity sector total natural resource	4.0
γ_0	tradable sector foreign market scale	2.31
c_C	commodity sector fixed operating cost	0.581
c_N	nontradable sector fixed operating cost	1.218
f_d	tradable sector fixed operating cost, domestic	1.248
f_x	tradable sector fixed operating cost, foreign	3.152
c_e^c	commodity sector fixed entry cost	1.315
c_e	nontradable sector fixed entry cost	4.992
f_e	tradable sector fixed entry cost	5.739
ϕ^C	unskilled labor share, commodity sector	0.53
ϕ^N	unskilled labor share, nontradable sector	0.38
ϕ^T	unskilled labor share, tradable sector	0.43

Table 2: Externally Calibrated Parameters

Moments	data	model
fraction of exporters in tradable sector	0.12	0.12
share of total employees in commodity sector	0.3	0.29
share of total employees in nontradable sector	0.3	0.19
share of total employees in tradable sector	0.4	0.53
share of unskilled labor, commodity sector	0.82	0.59
share of unskilled labor, nontradable sector	0.49	0.44
share of unskilled labor, tradable sector	0.64	0.49
skill premium	1.18	1.18

Table 3: Targeted Moments

4.2 Steady State Comparison

Table 4 shows the percentage change after a 5% permanent increase in the commodity price in the main endogenous variables for three regions with different degree of commodity intensity.

variables	$R = 3.0$	$R = 4.0$	$R = 5.0$
wage, skilled	0.66%	0.68%	0.61%
wage, unskilled	1.18%	1.31%	1.35%
skill premium	-0.50%	-0.62%	-0.73%
share of total labor, commodity	9.25%	9.06%	9.10%
share of total labor, nontradable	2.11%	2.69%	3.51%
share of total labor, tradable	-4.17%	-5.90%	-8.30%
share of unskilled labor, within commodity	-0.31%	-0.38%	-0.46%
share of unskilled labor, within nontradable	-0.42%	-0.52%	-0.62%
share of unskilled labor, within tradable	-0.38%	-0.48%	-0.57%
operation cut off, exporting	1.20%	1.29%	1.25%
operation cut off, domestic sale on tradable	-0.24%	-0.22%	-0.18%
fraction of exporters	-5.54%	-5.98%	-5.87%
GDP, commodity	10.41%	10.31%	10.34%
GDP, nontradable	3.03%	3.68%	4.48%
GDP, tradable	-3.27%	-4.95%	-7.39%
GDP, total	2.47%	2.83%	3.10%

Table 4: Different Commodity Prices

- Non tradable sector expands, exporters in tradable contracts, skill premium decreases.
- Effects are stronger the more commodity intensive the region is.

4.3 Commodity Cycles

As a first approach to the effects of labor market rigidity on the transmission of commodity super cycles we solve for a sequence of steady states where the price of the commodity increases by 25% for only one period and then goes back to the pre boom price. Figure 2 Because unskilled wages cannot decrease after the boom, the transition is characterized by unemployment and a persistent decrease on skill premium. Figure 3 shows the cross sector dynamics triggered by the commodity cycle. In line with the evolution of the skill premium, every sector increases the skill intensity. Moreover, the dynamic labor distortion triggers a persistent misallocation between the tradable and the non tradable sector. In particular, the non tradable sector has a persistent boom while the tradable sector in plunged in a recession. Finally, Figure 4 shows that aggregate output decreases and remains persistently below the long run level well after commodity prices have returned to their steady state value.

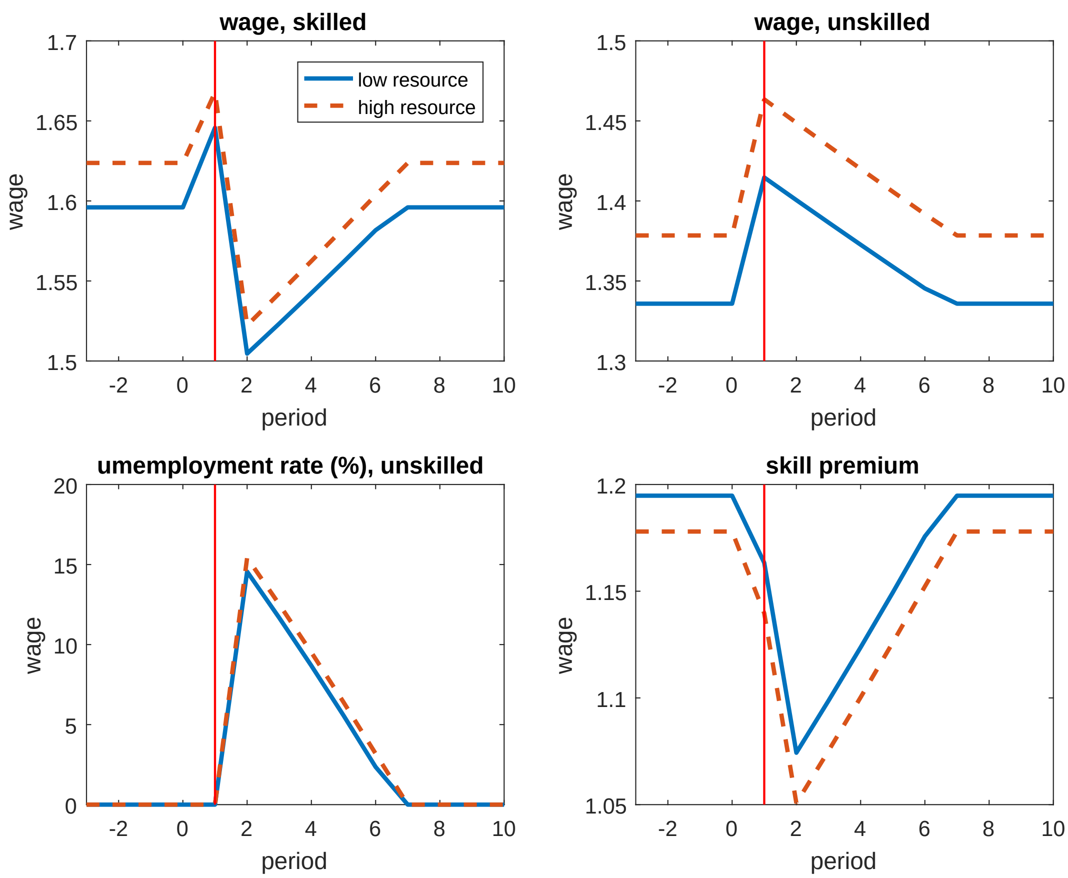


Figure 2: Labor Rigidity and Super Cycles: Wages

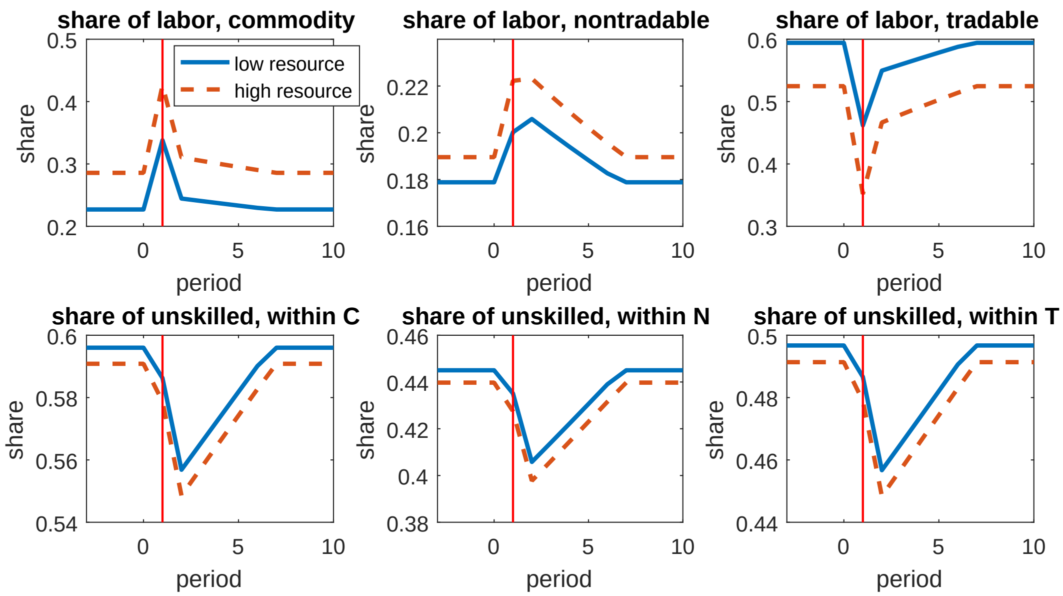


Figure 3: Labor Rigidity and Super Cycles: Labor

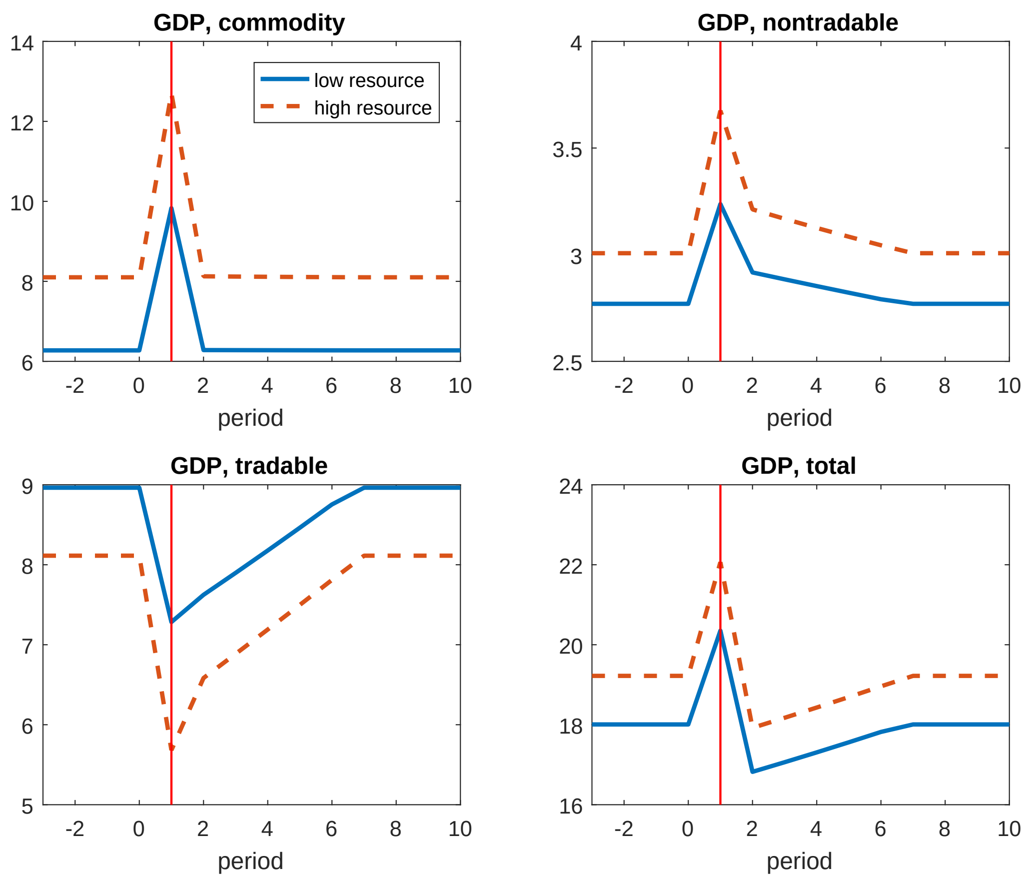


Figure 4: Labor Rigidity and Super Cycles: GDP

5 Empirical Analysis

5.1 Data Description

5.1.1 Employer-Employee Census.

We use a linked administrative census of workers and firms in Brazil with annual information spanning the period 1996-2013. The data is collected by Brazil's Labor Ministry and contains 97 percent of the formal-sector labor force. We observe information on firms' industries and geographic regions and information on each worker they employ, including their age, gender, educational attainment, and occupation.

Firm Panel. We construct a firm-level panel by aggregating these worker-level records. Firms' annual total employment is defined as the annual average of firms' monthly employment. We also compute employment for three skill groups in each firm. Workers' educational attainment is divided into 9 categories, which we aggregate into the following broader groups: workers with at most a primary degree, workers with at most a secondary degree, and workers with tertiary education. Firms' annual mean wage is computed as a weighted average across workers, with weights equal to workers' spell in each year within the firm. We also construct mean wages in each firm separately for each of the skill-groups described earlier. Wages are deflated using the Brazilian CPI.

Sample Selection. We restrict the panel to male workers due to their stronger labor force attachment. In commodity-producing sectors, male workers represent more than 80 percent of employment on average. We restrict the sample to workers aged 20 to 60. We exclude firms in the government sector, as well as firms in education and health which belong to a large extent to the public sector.

Industries. Establishments' industries are reported according to the Brazilian CNAE classification. This is reported at the 5 digit level, which is useful for accurately identifying firms producing specific commodities. In the case of multi-establishment firms, we assign the firm the industry classification with the largest employment.

Geographic Regions. We observe the geographic location of firms and establishments up to the municipal level, but use broader microregions to characterize local labor markets. Brazil is divided in 27 states, 5 macroregions, 558 microregions and more than five thousand municipalities.

5.1.2. Commodity Prices.

We use monthly price data for a set of 15 agricultural and mining commodities. These are all the commodities for which we can match activity classifications in our employment census to prices. They represent a large share of employment in agriculture and mining. Commodity prices are obtained from the World Bank's Global Economic Monitor.

5.2 Descriptive Evidence

Table 5 reports the number of firms and mean firm employment and wages in each macroregion of Brazil and in each sector in years 2000 and 2010. There in firm size both across sectors and across regions. Agricultural firms in the South, for instance, are much larger and pay higher wages than those in the North and Northeast. Firms in mining are smaller than those in other sectors, but typically pay much higher wages. Table 6 reports mean firm employment and wages in each skill-group by sector. In each of these sectors there is a large gap between the wages with workers with different degrees of educational attainment. The within-firm skill distribution varies significantly across sectors, with a larger share of low-education workers in agriculture.

Table 5: Summary Statistics.

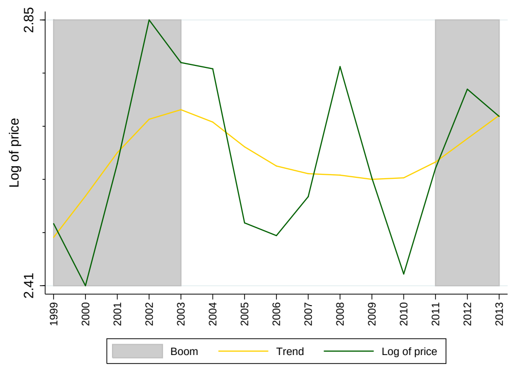
Macro-Region	Sector	Number of Firms		Mean Employment		Mean Wage	
		2000	2010	2000	2010	2000	2010
North	Agriculture	1124	1814	24.1	36.8	304.1	421.2
	Mining	128	305	29.5	27.8	549.1	602.8
	Manufacturing	5691	8358	25.9	32.0	325.2	432.7
	Services	34747	72942	10.6	12.3	292.9	394.1
Northeast	Agriculture	3782	5628	45.9	52.8	243.7	368.7
	Mining	597	900	23.6	32.3	334.4	530.0
	Manufacturing	23903	37463	23.5	26.7	256.3	357.4
	Services	162709	311569	9.2	10.3	268.4	362.3
Central-West	Agriculture	8019	15754	89.7	57.8	328.6	437.5
	Mining	3063	3218	31.3	56.7	466.7	724.1
	Manufacturing	114445	142496	24.6	29.7	448.4	538.8
	Services	668581	1017387	10.2	11.6	426.0	488.4
Southeast	Agriculture	4358	6063	49.3	37.8	324.1	459.0
	Mining	1302	1277	11.2	15.0	392.2	527.3
	Manufacturing	62757	89978	20.4	22.8	366.8	487.2
	Services	254946	428555	6.7	7.5	363.4	446.4
South	Agriculture	2366	3823	60.2	71.3	355.5	501.4
	Mining	312	564	20.8	24.9	439.2	576.4
	Manufacturing	12350	19976	15.8	20.3	297.5	425.7
	Services	83948	163605	9.2	10.1	319.0	419.7

Notes: This table reports summary statistics on the number of firms and mean firm employment and wages by macro-region and sector in 2000 and 2010. Wages are reported in real Reais of 2000.

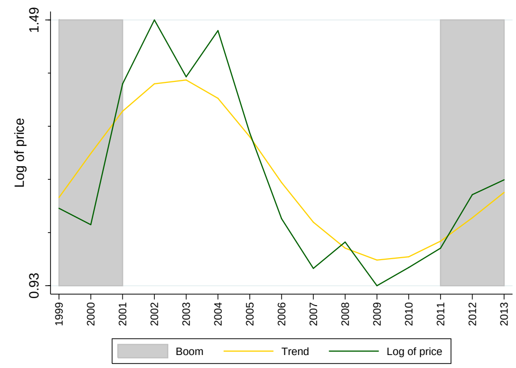
Table 6: Summary Statistics.

Sector	Skill-Group	Mean Employment		Mean Wage	
		2000	2010	2000	2010
Agriculture	Low	42.4	21.0	271.0	397.8
Agriculture	Medium	17.3	21.5	314.5	413.7
Agriculture	High	5.3	11.2	573.5	555.5
Mining	Low	6.6	3.8	368.5	526.6
Mining	Medium	8.0	9.0	411.0	535.2
Mining	High	10.4	27.7	731.2	784.6
Manufacturing	Low	5.0	2.7	377.5	474.7
Manufacturing	Medium	11.6	9.7	373.5	464.6
Manufacturing	High	6.2	14.3	535.9	531.6
Services	Low	1.8	0.8	383.8	445.6
Services	Medium	4.3	3.5	353.8	420.7
Services	High	3.2	6.1	454.9	474.7

Notes: This table reports summary statistics on mean firm employment and wages by sectors and skill-groups in 2000 and 2010. Skill-groups correspond to workers with low, mediun and high educational attainment. Wages are reported in real Reais of 2000.



(a) Sao Paulo



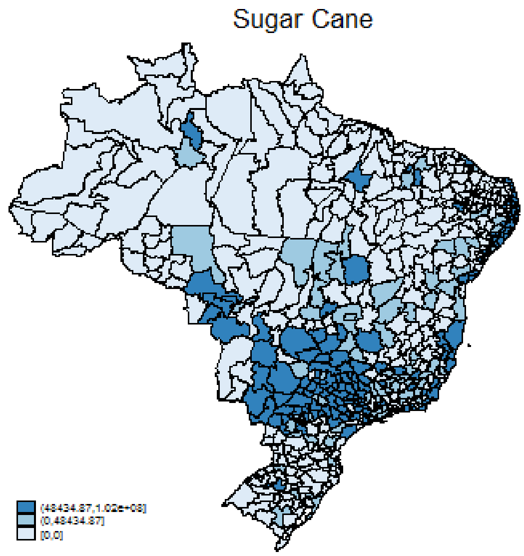
(b) Rio de Janeiro

Note: We first construct labor shares by sector and region in 1999. We use the shares to construct a weighted price index by region. We apply the HP filter to (log) series, and construct their first differences. When the resulting series change signs from negative to positives and the magnitude is larger than 0.01 (-0.01), we identify a boom (bust).

Figure 5: Identifying booms and busts

- Wide geographical variation in commodity production.
- We can identify local commodity booms.

FIGURE 6: GEOGRAPHIC SPECIALIZATION IN COMMODITIES.



NOTES: Regional distribution of employment in sugar in 2003. Darker shades indicate a higher share of regional employment.

6 Conclusion

Conclusion:

- Multisector small open economy model with firm heterogeneity.
- Commodity boom propagates via common labor markets and income effects.
- Positive spillover to non tradable sector but negative spillover to tradable sector.
- Downward wage rigidity can explain the persistence and painful end of a commodity super cycle.

Future work:

- Test predictions of the model: use regional variation on commodity intensity and skill composition of the labor force.
- Solve a perfect foresight commodity boom and evaluate precautionary policy during the boom.

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