London School of Economics and Political Science

Essays in Applied Economics: Evidence from Brazil

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Declaration

I certify that the thesis I have presented for examination for the PhD degree of the London School of Economics and Political Science is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identied in it).

I warrant that this authorisation does not, to the best of my belief, infringe the rights of any third party.

I declare that my thesis consists of 37313 words.

Statement of Conjoint Work

The second and third chapters are the result of joint work by Jason Garred, João Paulo Pessoa and me. I have carried out most of the analytical and numerical analyses and written all the text of the second chapter. I have written around 70% of the third chapter. General decisions about the direction of the papers were made equally between the three authors.

Abstract

This thesis contains three essays.

In the first essay, I examine whether a temporary policy can affect long-run household behavior. I look at evidence from a nine-month compulsory rationing imposed on Brazilian households' electricity use in 2001, exploiting differences in the policy's implementation across regions as a quasi-experiment to test its short-and long-run impacts on households' electricity consumption patterns. I find that the rationing program led to a persistent reduction in electricity use of 14% even ten years later. Unique household level microdata on appliance ownership and consumption habits suggest that the main source of persistence is changes in the utilization of electricity services, rather than technology adoption.

In the second essay, we examine the effects of China's recent emergence into the world economy in local labour markets in Brazil. Much of the literature have viewed China as a competitor. However, China is also an increasingly large consumer of goods produced abroad, and an increasing share of its import demand is for primary goods. Using census data, we compare trends in migration, unemployment, employment structure (primary/manufacturing/services), informality and participation on *Bolsa Família* program in areas affected by the 'China competition shock' and the 'China demand shock'. We find significant and heterogeneous effects from these two 'shocks'.

In the third essay, we employ an unified theoretical framework to structurally estimate the effect of changes within China on the production in Brazil and in the rest of the world. Based on the Ricardian model of trade of Costinot et al. (2012), we perform counterfactuals exercises to analyze how countries and industries in Brazil would have performed in the absence of the recent Chinese ascension. Results suggest that changes in China's comparative advantage hampered manufacturing sector abroad. We find no support for the idea of China demand (taste) shock towards raw materials.

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In memory of my grandparents Nydia, Gabriel, Maria, Walter, Aldara, Julieta, and Otacílio.

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Chapter 1

Can Rationing Affect Long Run Behavior? Evidence from Brazil

1.1 Introduction

A whole class of economic models has multiple steady states. A common feature of these models is that temporary interventions can have long run effects by making individuals switch steady states. In policy terms, the possibility of addressing long run issues with temporary policies, rather than with permanent interventions, is appealing since it might only require transitory investments and would not necessarily be reliant on long term commitment of policy makers. Although the associated debate goes back as far as Rosenstein-Rodan (1943), the feasibility of using temporary interventions to generate such sustainable effects on individual behavior is still contentious as it lacks supporting empirical evidence. This paper presents a temporary intervention which had lasting impacts on households' behavior towards energy consumption.

The empirical literature shows that small interventions, such as nudges, affect individual behavior in the short run, but with limited long run effects, which is consistent with standard multiple-steady-state models.[1] On the other hand, persistent effects of major historical episodes have been observed,[2] suggesting that specific events can place otherwise identical economic agents in different steady states. It is therefore still an open question whether it is possible to use policy to induce long-run behavioral changes. Recent field experiments designed specifically to investigate this question have reached divergent conclusions. While Giné et al. (2010) and Dupas (2012) find that temporary programs can still affect individuals' health consumption patterns one year later, Kremer

[1]See Charness and Gneezy (2009), Thogersen (2009), Allcott and Mullainathan (2010), Acland and Levy (2011), Agarwal et al. (2011), Ferraro and Price (2011), John et al. (2011), Haselhuhn et al. (2012), or Gneezy et al. (2011) for a survey.

[2]See Bloom et al. (2003), Redding et al. (2010), Dell (2010), Acemoglu et al. (2012), and Bleakley and Lin (2012).

and Miguel (2007) finds that replacing subsidies with sustainable health control measures were ineffective.

The main contribution of this paper is to provide empirical evidence that a temporary policy - electricity rationing - can affect long run household behavior. I look at evidence from a rationing program in Brazil in 2001-2002, when households had to reduce electricity use by at least 20% for nine months. This episode is of particular interest for the above debate because it was a large demand response program which was limited to certain regions due to a combination of weather conditions and infrastructure constraints, generating a credible counterfactual. Evidence from administrative data suggest that the average household reduced electricity use by 14% in the long run - ten years later - by switching to a less energy-intensive steady state.

I first present a simple theoretical framework in which individual consumption optimization leads to multiple steady states. In theory, this multiplicity could emerge from many mechanisms, such as habits, beliefs, social norms, reference-dependency, or learning.[3] For example, biased beliefs about the returns to investing in energy-efficiency could sustain different levels of energy efficiency, or social norms could affect household electricity use (Allcott 2011a, 2011b). The model presented illustrates this class of phenomena using a simple mechanism: intertemporal complementarity of consumption (Becker and Murphy 1988). In this model, the past level of electricity use affects the individual's current utility from consuming electricity services. For example, the more one uses electrical appliances in the past, the bigger the disutility from not having access to their services in the present.

I then examine the Brazilian electricity rationing episode of 2001 in order to test whether this induced switching between steady states in consumption. In the beginning of 2001 the electricity generation capacity of some Brazilian states was severely reduced due to extremely low stream-flow level in the rivers that serve the hydroelectric powerplants in these states. Since the Brazilian electricity system is partitioned, it was not possible to reallocate electricity between regions. In order to prevent general blackouts, the government planned and implemented an emergency rationing program for the affected regions within a couple of months.[4] In June 2001, households in the Southeast and Midwest were asked to reduce electricity consumption by 20% relative to their historical average consumption for a period of nine months. Households were subject to fines and the threat of supply interruption if they did not meet their targets, and received bonuses for additional energy saved. At the same time, the government issued a national infor-

[3]For example, Naik and Moore (1996), Piketty (1995), Obstfeld (1984), Koszegi and Rabin (2006), and Lindbeck (1997).

[4]The rationing was a sudden change in government strategy, and as such was fairly unexpected by households. The electricity shortage was detected in March 2001. Until May, the government tried to solve the problem with other measures, such as pure price schemes and increasing the generation capacity of thermal power plants.

mation campaign, and introduced subsidies to energy-efficient appliances countrywide. After the end of the program in February 2002, electricity supply and prices went back to normal.

To estimate the rationing's impact on final household electricity consumption, I use a panel of average household electricity use and price by utility company, monthly from 1991 to 2011. This is administrative data from the Brazilian Electricity Regulatory Agency (ANEEL). The main empirical strategy of this paper is a difference-in-differences specification using households in the non-rationed states in the South of Brazil as a control group for the rationed households in the Southeast/Midwest. Under the assumption that households' electricity use in these regions would otherwise have followed a common trend during the period studied, the estimated regression coefficients can be interpreted as the average effect of the treatment on the treated.[5]

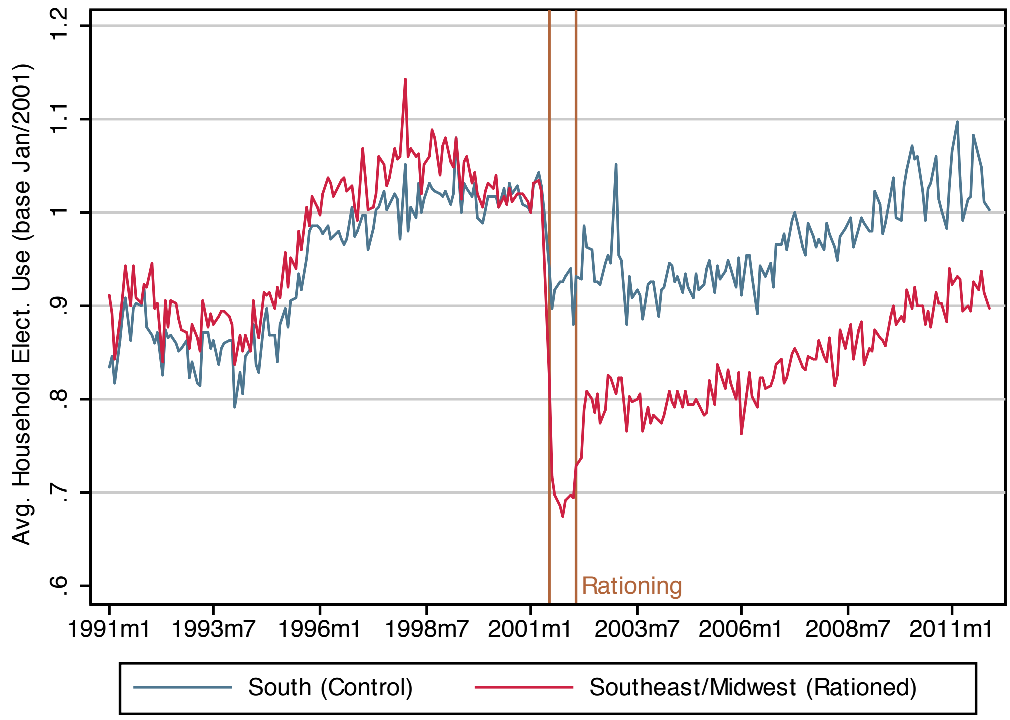

Figure 1.1: Average Household Electricity Use from 1991 to 2011 (relative to January 2001 levels)

Notes. This graph presents the monthly average household electricity consumption, relative to January 2001 levels, in the South (non-rationed) and in the Southeast/Midwest (rationed). The two vertical lines mark the rationing period. *Source*: Administrative data, at the utility company level, from the Regulatory Agency ANEEL.

[5]The Northeast region was rationed as well. However, as discussed in Section 2, the Northern states were at a very different initial development stage, and experienced a substantially different growth pattern during the 2000s. The common trend assumption required for identification thus does not hold for these regions. The main results still hold when all states are included in the analysis.

Figure 1.1 presents the monthly average household electricity consumption, relative to January 2001 levels, in the South (non-rationed) and in the Southeast/Midwest (rationed) from 1991 until the end of 2011. It is apparent that the average electricity use in the two regions followed a similar trend in the ten years before the electricity crisis. During the rationing, marked with the two vertical lines, electricity consumption fell in both regions, partially due to the national information campaign and subsidies to energy-efficient appliances. However, the rationing effect in the rationed region is captured by the relative difference between these two regions. Thus, during the rationing, the average monthly consumption of the rationed households dropped by 46 kWh/month (28%) relative to the non-rationed households. At the end of the rationing, the consumption growth in the rationed region did not offset the entire short run reduction. From 2002 until 2011, the average rationing effect on the rationed households is equal to a reduction of 25 kWh/month (14%) in average monthly electricity use. This long run effect is equivalent to replacing three 60W incandescent light bulbs by fluorescent ones, or to switching off a freezer for two weeks in every month. These results are robust to different specifications, controls and sub-samples. The energy saved has been equivalent to 1.5 months of electricity every year, for the last 10 years.

This persistent change gives some evidence that households settled into a new steady state with lower consumption levels after the rationing. Two non-competing mechanisms could be underlying this long run energy conservation: households could have changed how they use electrical appliances, and/or acquired more energy efficient appliances. It is important to distinguish these two channels because they relate to different economic models, and would have different policy interpretations. I use household level microdata to shed light on the channels supporting the long run reduction in electricity use.

To investigate the consumption habits channel, I exploit household level microdata from a survey of the appliance holdings and consumption habits of over eleven thousand families conducted by the Brazilian energy efficiency program PROCEL in 1998/1999 and 2004/2005. The picture emerging from this dataset supports the hypothesis that households actually changed the way they use electric appliances. Even three years after the rationing, I still find that rationed households maintain the thermostats of shower heads with electric heating at a lower level, and weakly use fewer freezers, relative to non-rationed households. These two results by themselves could account for all of the observed long run energy conservation in the Southeast/Midwest.

To assess if the energy-efficiency level of the inventory of appliances in these two regions is underlying the long run energy conservation, I use a second household level dataset of more than fifty thousand families from the Brazilian Geography & Statistics Institute (IBGE) from the three points in time 1996/1997, 2002/2003, and 2008/2009. This microdata suggests that the difference in composition of appliances between the two regions did not change substantially in the long run. During the rationing, affected households seem to have substituted old refrigerators and postponed investment in new freezers and air conditioners. By 2008-2009, however, I find no effect on the average stock of appliances - both quantity and vintage.[6] To rationalize these findings, I present in Appendix A an extended version of the baseline model, adding endogenous choice of appliances' characteristic as in Dubin and McFadden (1984).

Taken together, this is evidence that households adopted new consumption behaviors during the rationing, shifting to a new stable steady state with lower electricity use.[7] The identification of long run impacts obviously faces important challenges, namely: (i) omitted variables that lead to endogeneity between the outcome variables and the implementation of the rationing, (ii) initial cross-sectional differences, and (iii) divergence in the time series and potential general equilibrium effects that may emerge over the years. I address each issue in turn in Section 3.

This paper relates to different strands of the literature. First, it highlights the crucial importance of considering human behavior when designing energy and environmental policies. This is particularly related to the "energy efficiency gap" debate, which focuses on the difference between the available cost-effective, energy-efficient technologies and those actually adopted by consumers. Engineering analyses of the performance of different technologies estimates this gap to be worth over US$1.2 trillion in the US (McKinsey & Co. 2009). However, how people use new technologies needs to be taken into account in this calculation (Allcott and Greenstone 2012). A field experiment in Mexico shows that households increase final electricity use when old appliances are replaced by new energy-efficient ones (Davis et al. 2012). In the Brazilian case, most of the energy conservation after rationing seems to come from the utilization margin, which again suggests that we cannot discuss an "energy efficiency gap" without considering its behavioral counterpart.

This paper also forms part of a wider literature on the economics of energy conservation. It has been shown that demand response programs are a promising avenue for promoting energy conservation. For example, Reiss and White (2008) show that public appeals during the 2000 California energy crisis led to a short run reduction of 7% in household electricity use. Allcott and Rogers (2012) find that households who receive energy conservation information by mail for two years maintain a 2% lower electricity use up to two years after the last letter.[8]

[6] I also find no effect on the average size of appliances. Further, I use microdata on appliances' prices collected in stores in both regions to assess the models of the appliances available in the shelves in these regions. As discussed in Appendix C.1, products available in the stores of the Southeast/Midwest became more likely to be available in the stores of the South after 2001.

[7] Time series analysis indicates that there is a structural break in electricity demand in 2001 (Maciel et al. 2009). In a paper not being circulated, Mation and Ferraz (2011) analyze the effects of the electricity crisis on firms' productivity.

[8] Others include Allcott and Mullainathan 2010), Allcott (2011b), Costa and Kahn (2011), Leighty and Meier (2011), and Jessoe and Rapson (2012).

In a closely related paper, Gerard (2012) also analyzes the impact of the 2001 Brazilian electricity crisis on short and long run households' electricity use. Gerard concentrates on understanding whether the impact of the rationing is consistent with a calibrated model of consumer behavior. In contrast, my work concentrates on disentangling the mechanisms underlying the long run energy conservation and I make use of richer household level microdata on consumer behavior, paired with a difference-in-differences strategy, to undertake this analysis. The two papers should be considered complementary.

The paper is organized as follows: I present the basic theoretical framework in Section 1. In Section 2 I describe the background and the data. In Section 3 I present the empirical methods and the results on electricity use. Section 4 examines the channels of persistence, consumption habits and stocks of appliances. Section 5 concludes.[9]

1.2 Theoretical Framework

This section outlines a simple model that illustrates how temporary restrictions can generate long run effects when multiple steady states exist. In this model, multiplicity emerges as a consequence of intertemporal complementarity of consumption, as in Becker and Murphy (1988). In order to derive further relevant predictions, Appendix A presents an extended version of the model which explicitly accounts for strategic investment in appliances' efficiency. In particular, I extend the classic tow-stage discrete choice model of Dubin and McFadden (1984) into a dynamic model where intertemporal complementarity of consumption generates multiple steady states. It is worthy to reiterate that this multiplicity could emerge from many mechanisms, which would lead to the same observable outcome in the context of the Brazilian electricity rationing. The model presented illustrates this class of phenomena using one simple mechanism.

Suppose an infinitely lived individual, with exponential time discount factor $\beta < 1$. Every period the individual chooses ordinary consumption, c_t, and services from electricity, e_t. Assume preferences are such that electricity services consumed at different points in time are complements, as in Becker and Murphy (1988). That is, the individual's current utility is represented by $u(c_t, e_t, s_t)$, where s_t captures the past electricity use relevant for current utility. This stock of past electricity use evolves according to $s_{t+1} = \delta s_t + e_t$, where $\delta < 1$ is depreciation in the stock of past consumption. Assume that u is strictly concave in c and e, and that $u_c > 0$, $u_e > 0$ for all $c, e, s \geq 0$.

Assumption 1. *Current and past consumption of electricity services are complements, that is, $u_{es} > 0$ for all $c, e, s \geq 0$.*

[9] Appendix A presents an extended version of the theoretical framework in Section 1, and Appendix B contains further empirical results. Online Appendix C presents the timeline of events, describes the data cleaning, and contains other specifications and robustness.

This assumption introduces some path dependency to the utility derived from the utilization of electricity services. It means that the higher the past electricity utilization, the higher the marginal utility of current utilization. For example, the more one uses electrical appliances, the greater the disutility from not having access to their services. Assume that the individual is fully aware of her preferences, and maximizes utility taking into account that her current choices affect the marginal utility of her future consumption choices.

Assume that the individual has fixed income y in every period, the price of ordinary consumption is normalized to 1, and the electricity price is p. Suppose also that there is no credit market.[10] Then, the individual solves the following dynamic optimization problem:

$$
\begin{aligned}
V\left(s_t\right) &= \max_{c_t, e_t} u\left(c_t, e_t, s_t\right) + \beta V(s_{t+1}) \\
s.t.\ c_t + pe_t &\leq y \\
s_{t+1} &= \delta s_t + e_t.
\end{aligned}
\tag{1.1}
$$

One can write this problem as a function of e_t and s_{t+1} by substituting the budget constraint into the utility function. Let $w(e_t, s_t) \equiv u\left(y - pe_t, e_t, s_t\right)$. The policy correspondence which describes the optimal consumption path is defined by $s^*(s) \equiv \{s'|V\left(s\right) = w\left(s' - \delta s, s\right) + \beta V(s')\}$. We call $\bar{s}$ a steady state if $\bar{s} \in s^*(\bar{s})$. Denote s^c a critical level if the optimal path diverges around s^c. I call a steady state stable if it is not a critical level.

Proposition 1. *Problem* (1.1) *has at least one stable steady state; any solution path for the stock of past consumption,* s_t*, monotonically approaches a stable steady state; and there is exactly one critical level between any two consecutive stable steady states.*

Proof. Proposition 1 in Orphanides and Zervos (1994), page 70. □

The Rationing (Dynamics)

Rationing in this setting can be interpreted as a temporary restriction on electricity use, such that the individual solves a constrained optimization problem. Denote by s_0 the individual stock of electricity services at the beginning of the rationing, and by τ the duration of the rationing. Let $e^*(s)$ be the optimal unconstrained electricity use when the stock of past consumption is s. Therefore, during the rationing the individual maximizes utility by solving problem (1.1) with the additional restrictions

$$e_t \leq \bar{e} < e^*\left(s_0\right) \text{ for all } t \in [0, \tau].$$

[10]The results are not affected if we assume a perfect credit market with interest rate $R^{-1} = \beta$.

As a consequence of the restrictions, the stock of electricity utilization must decrease during the rationing. Figure 1.2 provides a graphical illustration of the dynamics, with electricity use on the vertical axis and stock of consumption on the horizontal axis. Suppose an individual is initially at the steady state $s_0 = s_H$ on the figure. During the rationing she is forced to consume below $\bar{e}$, the horizontal line, reducing her stock of consumption over the period τ. If by the end of the rationing the stock of consumption $s_{\tau+1}$ is smaller than a critical point $s^c < s_0$, then the individual will enter a new optimal path that will converge to a new stable steady state with smaller electricity consumption s_L on the figure. If the stock of consumption does not decrease below any critical level, consumption will converge back to the original level after the rationing.

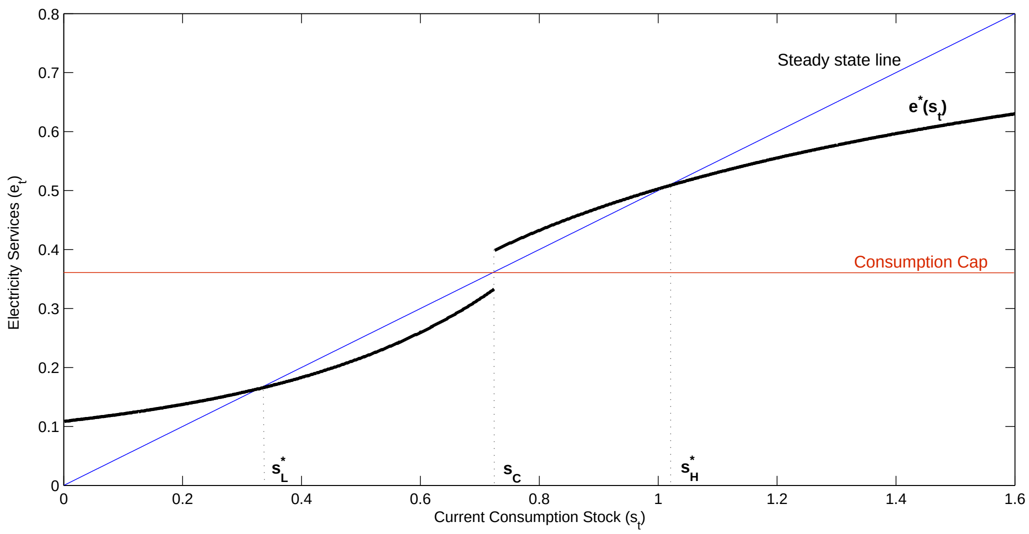

Figure 1.2: Illustration of Rationing Dynamics in an Optimization Problem with Multiple Steady States

Notes. Example using $u(c, e, s) = \mu \ln c + (1 - \mu) \ln e + \gamma s e$, with $\mu = 0.91$, $\gamma = 0.9$, $\beta = 0.9$, $\delta = 0.5$, and $y = p = 1$. The two stable steady states are s_L and s_H, and s_C is a critical point.

Prediction 1. *After the rationing, if the individual's stock of consumption falls below a critical point, she enters a new optimal path that converges to a steady state with lower utilization of electricity services.*

In sum, if the optimization problem of recurrent consumption decisions has multiple steady states, rationing can generate long run effects by making individuals switch steady states. I assumed one possible source of multiplicity of steady states, the intertemporal complementarity of consumption. The rationing dynamics would be similar across the whole class of models that generate multiplicity of steady states.

The source of multiplicity, however, is crucial when deriving welfare conclusions regarding the rationing and its dynamics. In this model, the individual is fully rational and takes into account that her current consumption choices affects her future utility.

Therefore, the rationing necessarily creates a net welfare loss to this individual by constraining her to consume below her long run utility maximizing level. The main issue with evaluating the net benefit of the rationing is that the transition costs have different interpretations according to each model. For example, steady states could be Pareto-ranked whether electricity use involves externalities or internalities. In fact, there is evidence that both externalities and internalities exist, via the social costs from power generation (Stern 2007; Finkenrath 2011; Nordhaus 2011) or individual misperceptions regarding energy use (Allcott and Mullainathan 2010; Allcott 2011b). If this is the case, then there could be aggregate gains from shifting consumption to steady states with smaller energy use. Since I cannot unveil the actual mechanism underlining the multiplicity of steady states, I cannot derive a clear welfare conclusion of this policy.

In contrast, consider the introduction of a temporary marginal incentive, such as a marginal price increase. For the duration of the incentives, all steady states will shift to lower levels. Once the incentive is removed, the stock of consumption will be close to its original steady state level and it will converge back to its original consumption levels. However, if the price change is large enough then the individual may switch to new stable steady states as in the constrained problem above.

The extended version of the model presented in Appendix A, which accounts for investment in durables, has analogous findings. Any persistent change in appliances' acquisition is due to switching to steady states with different utilization of electricity services. The extended model is closer to those found in the energy and durables literature, and contains predictions on how specific appliances should be affected by the rationing. These predictions will be discussed in the context of the empirical analysis in Secion 5.2.

1.3 Background and Data

In this section I explain the Brazilian electricity rationing, describe the data used, and provide summary statistics.

The Brazilian electricity system relies almost exclusively on hydrological resources. In 2000, 94% of the electricity used in the country was generated by hydroelectric power plants (ONS 2011). The national electricity grid is divided into four subsystems: South (S), Southeast/Midwest (SE), Northeast (NE), and North (N). The subsystems are connected with transmission lines which support limited exchange of electricity between regions.[11] I restrict attention to the period after the privatization of the Brazilian electricity sector and the creation of the Regulatory Agency (ANEEL) in 1996. Under the new reg-

[11]The only exception is the subsystem North that is not connected to the other three. The national grid is controlled by the National System Operator (ONS), which coordinates electricity generation and transmission.

ulatory framework, utility companies receive concessions to supply energy in delimited areas, and face no competition. The Regulatory Agency defines the electricity price.[12]

Since the states in the North and the Northeast were in an early development stage at the time of the rationing, I focus only on the most developed regions of Brazil: the South, Southeast and Midwest. While the electricity grid in the Southern states was already developed in 2000, with more that 97% of electricity penetration among households, in the Northern states electricity covered only around 80% of households.[13] Including the Northern states in the empirical analysis substantially changes the household sample composition, and undermines the common trend assumption which I will return in the next section.[14] Table 1.1 presents some relevant summary statistics for these regions from 2000 (i.e., before the rationing).

Only supply factors were responsible for the eminent collapse of the electricity system in 2001. Figure 1.3 shows the reservoirs' levels as a percentage of their maximum capacity for the subsystems Southeast/Midwest and South, from 1996 to 2010. The first half of the year is the wet season of subsystem Southeast/Midwest, when its power plants' reservoirs are filled to guarantee electricity supply later in the year. It happened that the stream-flow level of rivers which serve the powerplants in this subsystem was extremely low in the first months of 2001, recording some of the lowest levels of the historical series as shown in Figure 1.A1 in the Online Appendix. As a consequence, the reservoirs in the Southeast/Midwest reached critically low levels, and in March 2001 ONS asked the federal government for an intervention that would reduce demand by 20% in this region.[15]

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[12]There are two tariff bands, the regular tariff (B1) and a subsidized rate for households who receive transfers from the government.

[13]Lipscomb et al. (2013) investigates the effects of electrification across Brazil until 2000.

[14]In particular, at the beginning of this century, the federal government launched the program *Luz Para Todos* (Light For Everyone) which aims to bring electricity to every household in the country. The Northern states were the most affected by this policy, and electricity coverage in these states increased to nearly 95% in less than a decade.

[15]Notice that in the beginning of 2000, the reservoirs' levels in the Southeast/Midwest were at a critically low level similar to 2001, and the reservoirs in the South were below average as well. However, these regions experienced above average stream-flow in 2000, which saved the system from a collapse in that year. If both regions had experienced in 2000 the stream-flow of the Southeast/Midwest in 2001, both the Southeast/Midwest and the South would have been rationed in 2000 (Kelman 2001).

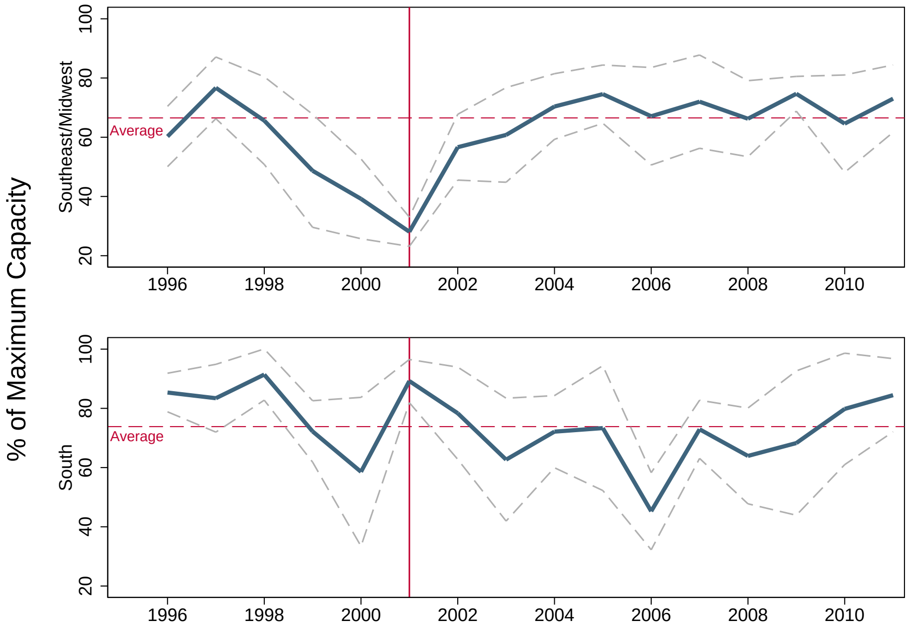

Figure 1.3: Annual Average Water Level in the Power Plants' Reservoir as Percentage of their Maximum Capacity (1996-2011)

Notes. The solid line is the annual average water level in the reservoirs as a percentage of their maximum capacity for each subsystem and year. The dashed lines demarcate an area within one standard deviation from the mean. *Source*: National System Operator (ONS).

Table 1.1: Summary Statistics (Year 2000)

	South (1)	Southeast/Midwest (2)	North (3)	Northeast (4)
Panel A. Electricity				
Share of households with electricity (%)	97.9	98.5	79.5	86.6
Number of households with electricity (millions)	6.1	22.4	1.9	9.2
Number of utility companies	17	27	8	11
Average household electricity use (kWh/month)	178.1 (6.1)	201.7 (6.5)	162.6 (5.3)	113.2 (5.6)
Average household electricity price (R$/kWh)	.157 (.009)	.162 (.006)	.152 (.007)	.148 (.005)
Share of households paying for electricity	.92 (.01)	.90 (.01)	.87 (.01)	.79 (.01)
Panel B. Macro Covariates				
Consumer Price Index (base 2001)	.89	.90	.92	.94
Average wage (R$)	654.1	809.9	650.9	523.4
Average temperature (^{o}c)	19.2	23.2	26.5	25.0
Panel C. Households' Characteristics				
Average household size	3.5 (1.6)	3.6 (1.8)	4.5 (2.4)	4.3 (2.3)
Share of households with refrigerators/freezers	.91 (.29)	.89 (.31)	.62 (.48)	.59 (.49)
Share of households with air conditioners	.07 (.26)	.07 (.26)	.09 (.29)	.04 (.44)

Notes. This table displays the descriptive statistics from the regions in columns. The share of households paying for electricity is from 1996/1997, all other statistics refer to 2000. Standard deviations in parentheses. The statistics in *Panel A* are from the Electricity Regulatory Agency (ANEEL) balance sheet, which is disaggregated at month-utility company level (528 observations in the year 2000); except the share of households connected to electricity from 2000 National Census; and the share of households paying for electricity from the Household Budget Survey 1996/1997 (POF/IBGE) microdata calculated using sampling weights. *Panel B*'s statistics come from three different sources: Consumer Price Index from INPC/IBGE, at month-metropolitan area level, relative to the index in January 2001; wages from the Ministry of Labor's register (RAIS) at year-state level; and temperature from the National Meteorology Institute (INMET). The statistics in *Panel C* are from the 2000 National Census (IBGE) microdata.

The government initially tried to boost supply via thermal generation with the Priority Thermal Program. However, this was not successful, and in April 2001, the demand reduction program started to be designed. In the middle of May the government announced in the national media that restrictions on household electricity use would be applied starting in June 2001. It was said that the restrictions would initially last 6 months, but could be extended. In the end, the restrictions lasted two months longer and were withdrawn in February 2002. I present a timeline of these events in Appendix C.1. As can be seen in Figure 1.3, the generation capacity in the South was secure in 2001, and therefore this region was not rationed.[16]

The restrictions and incentive structure imposed on households' electricity use were based on an individual target equal to 80% of the average consumption on the previous year using a 3-month rolling window.[17] Electricity billing in Brazil is monthly, and the majority of households have their own meter.[18] Households with monthly average consumption above 100 kWh[19] who failed to reach their target would pay fines and could have their electricity cut for up to six days. Those with monthly average consumption below 100 kWh were not subject to these penalties. All households received bonuses of up to R$2 for each R$1 saved below their target. Also, a non-linear tariff was temporarily implemented, with a 50% overcharge on the electricity consumed above 200 kWh and below 500 kWh, and a 200% overcharge on any consumption above 500kWh.

It is important to highlight that the government also issued a national information campaign through its energy efficiency program, PROCEL/Eletrobrás. Both the campaign and the rationing itself received massive coverage in the national media, affecting potentially both the rationed and the non-rationed states. In an extra effort to conserve electricity, energy-efficient appliances, such as fluorescent light bulbs, received tax exemptions from the federal government countrywide.

1.3.1 Data

Next I describe the four main data sets and other sources of information used in the paper. Table 1.A2 presents some information about the main datasets used, and Appendix C.2 presents details on the data cleaning and a complete list and description of all variables used.

[16]This was the only rationing episode in Brazil throught the period of analysis. From Figure 1.3, although the reservoir levels were low in 2006, there was no electricity rationing.

[17]I.e., in June 2001, each household should consume at most 80% of his own average consumption in May, June and July 2000.

[18]Note that smart meters is a technology that started to be tested in Brazil only very recently.

[19]These households represented more than 70% of all households, and more than 85% of total consumption in the Southeast/Midwest.

1.3.1.1 Electricity Data (ANEEL)

The electricity data is administrative data from the Brazilian Electricity Regulatory Agency (ANEEL), with the monthly records of each utility company from January 1991 until December 2011. This dataset contains the number of households connected to the utility company, the amount of electricity sold by the utility company to those households, and the total revenue from the electricity sold to households. For each utility company, average electricity use per household is calculated by dividing the total electricity sold to households by the number of households connected. Since each utility company is the only electricity supplier in each geographical region, this is analogous to have the average household electricity use per groups of cities.[20] There are 17 utility companies in the subsystem South and 27 in the subsystem Southeast/Midwest. The prices charged by each utility company are set by the Electricity Regulatory Agency (ANEEL), and there are two tariff bands for residential consumers: the regular tariff and a subsidized "social" tariff for low income households. Since there is no retrospective disaggregated data on the electricity consumption of households paying the social tariff, I cannot infer average prices paid by households from information on the prices set by ANEEL. Therefore, I instead calculate the average electricity price charged by each utility by dividing its total revenue by the amount of electricity it sold to households.

1.3.1.2 Habits of Energy Use (PPH)

The government's energy efficiency program PROCEL, from the national electricity company Eletrobrás, conducts a detailed survey every seven years to assess the characteristics and utilization habits of household electricity consumers. The Appliances and Habit of Use Survey (*Pesquisa de Posse de Equipamentos e Hábitos de Uso,* PPH) is designed by PROCEL with the assistance of academic institutions. Households in different cities are visited by an interviewer, as is done in a Census survey. The questionnaire includes both objective questions on household characteristics and habits, as well as qualitative questions. Although most of the information is self-reported, the interviewers were asked to check some of the information, for example, the number of lamps in the living room, and the characteristics of the main refrigerator and showers heads with electric heating.

I use the microdata from the two most recent surveys, the one conducted between July 1998 and June 1999, and the one conducted between July 2004 and June 2005. The data contains information on 14,254 households covering the concessions of ten utility companies. To the best of my knowledge, this is the first time this survey is being used in research in the social sciences. The main variables used in the paper are: the number of appliances permanently in use, appliances' characteristics, the quantity and

[20]The concession areas of the utility companies are stable over time.

thermosthats setting of shower heads with electric heating, and the adoption of ten energy-saving measures.[21] I also use this dataset to assess the quantity of lamps (per type of lamp).

1.3.1.3 Appliances Holdings (POF)

Microdata used to assess appliance holdings are from the Household Budget Survey (POF), a national survey conducted by the Brazilian Geography & Statistics Institute (IBGE), which is also responsible for the National Census. One of the main objectives of this survey is assessing households' expenses and consumption baskets to support the calculation of IBGE's consumer price index (INPC). I use the household level microdata from the three most recent surveys, which are from 1996/1997, 2002/2003 and 2008/2009. All surveys were conducted between July of the base year and June of the following year. The 1996/1997 survey covered only the main metropolitan areas of each region, while the two subsequent surveys covered rural areas as well. I use data from all areas, although results do not change if I restrict the sample to the urban areas only.

The data contains characteristics from around 61,342 households in eleven different states. The microdata contains the quantities of different types of appliances owned by the households and the year these appliances were bought. It does not have details about the model of these appliances, or whether the appliance were bought new or second-hand. To capture changes in recent acquisition patterns, I also create a dummy variable, New, which is equal to one if the appliance was bought within 2 years. Note that an appliance that was less than two years old in 2002/2003 was bought around the rationing period, so this variable will be used to capture unusual appliance acquisition during the rationing.

Finally, there is a relevant difference between the sampling of this survey and the sampling of the two datasets presented so far. The official records from the Electricity Regulatory Agency (ANEEL), and the Appliances and Habit of Use Survey (PPH) only contain households regularly connected to electricity. The Household Budget Survey (POF), however, aims to be representative of all households, including those who have irregular connections to electricity. Consequently, some households in POF own electrical appliances, but claim to have no expenses on electricity and not to own a generator. Since these households who do not pay for electricity were not subject to the rationing's incentives,[22] I exclude them from the main specifications of the paper.

[21] Namely: (1) Switch off the lamps when leave the room for more than 30 minutes; (2) Do not open the fridge/freezer door fully; (3) Do not store warm food in the fridge/freezer; (4) Do not dry clothes behind the fridge/freezer; (5) Verify the condition of fridge/freezer's rubber seals regularly; (6) Reduce shower time when using electric water heating; (7) Adjust the shower thermostat according to the ambient temperature; (8) Use washing machine with a full load; (9) Accumulate clothes to iron; (10) Switch off the TV when not watching.

[22] It is most likely these are household irregularly connected to electricity. Electricity theft is common in Brazil and I'll return to this point in the next section.

1.3.1.4 Appliances' Prices

Microdata on appliances' prices is collected as a component of consumer price index (IPC) produced by IBRE/FGV. From 2001 to 2005, prices were surveyed daily in eight major cities within the South and Southeast/Midwest: Porto Alegre, Curitiba, Florianopolis, São Paulo, Rio de Janeiro, Belo Horizonte, Goiania and Brasília. [23] From 2006 on, prices were surveyed only in Porto Alegre (in the South), and São Paulo and Rio de Janeiro (both in the Southeast). The smaller observational unit in the cross-section is a triple product*informer*store.

I use this data with two objectives. First, I use only the three capitals with a long time series to build an unweighted appliance price index for each region to investigate general equilibrium effects on appliances' prices, methodology described in Appendix C.2. Second, I use the description of the products to assess the rationing effect on the products available in the stores in both regions. Prices are surveyed in stores according to the products available on the shelves in that day. Since product descriptions are very detailed,[24] I compare the availability of products in both regions and how this changed over time. In this second exercise, I use all capitals and restrict attention to 2001-2005.

1.3.1.5 Other Data

Nominal wages and the number of workers in formal employment come from the RAIS dataset (Brazilian Ministry of Labor), aggregated by year-state, from 1997 to 2010. The consumer price index is INPC produced by IBGE, which contains monthly indices for the main metropolitan areas in each region. Unfortunately, Brazil does not have a periodic consumer price index for rural areas. I compute prices and wages in real terms by dividing nominal variables by the INPC index. Data on electricity generation, rivers' conditions and levels of reservoirs are from the National System Operator (ONS), the body responsible for running the electricity generation and transmission systems in Brazil. Weather data is from the National Meteorology Institute (INMET), and includes daily measures from 45 meteorological stations in the region. Data on total month-state consumption of of natural gas (GLP) and gasoline is from the National Agency of Petroleum, Natural Gas and Biofuels (ANP). Note that I could not find data on the quantity of these fuels consumed by households, so this data helps assessing if there was any significant change in the overall demand for these fuels. I use information on gas expentiture from the Household Budget Survey to complement this analysis. Remaining information is from the National Census 2000 (IGBE).

[23] IPC methodology: http://portalibre.fgv.br/main.jsp?lumChannelId=402880811D8E34B9011D92B7350710C7

[24] For example, "REFRIGERADOR DOMESTICO 440 LITROS MOD:DOUBLE 44 ELECTROLUX (UNID)".

1.4 Empirical Method and Main Results

The main identification strategy to estimate the short and long run effects of the rationing is a difference-in-differences specification using the non-rationed South of Brazil as a control group for the rationed Southeast/Midwest. As mentioned in the introduction, any causal inference of this estimation hinges on a few assumptions. Before listing these and assessing their plausibility, I present the basic regression equation:

$$Y_{it} = \alpha + \beta_D During_t * Ration_i + \beta_P Post_t * Ration_i + \gamma_t + \gamma_i + \gamma X_{it} + \epsilon_{it} \quad (1.2)$$

where Y_{it} is the dependent variable measured at the level of utility i in year-month t. $During_t$ and $Post_t$ are dummies equal to one for months during and after the rationing respectively, $Ration_i$ is a dummy equal to one if the utility was rationed, γ_i and γ_t are utility and year-month fixed effects, and X_{it} is a vector of covariates - for example, real wage, and real electricity price. I do not impose any structure on the errors' correlation over time and cluster errors at the utility company level, i, as in Bertrand et al. (2004).

The parameters of interest are β_D and β_P. The estimates of β_D can be interpreted as the program's average short run effect on the treated[25] if there are no omitted variables associated with both the rationing allocation (timing and across locations) and with households' potential electricity use [*Assumption 1*], and if the evolution of household electricity use were following a common trend in the South and the Southeast/Midwest [*Assumption 2*].[26] The estimates of β_P capture the program's average long run effect on the treated if, in addition to these two assumptions, there would have been no divergence in the time series of electricity use and covariates over the years following the rationing [*Assumption 3*].

Section 2 provides clear evidence supporting *Assumption 1.* The official diagnosis of the energy crisis concludes that local supply factors aggravated by severe stream-flow levels triggered the rationing, and states: "the realized electricity consumption growth [from 1997 and 2000] corresponded to the growth forecast and had no influence on the generation crisis" (Kelman 2001, pg. 5).[27] Table 1.1 presents some summary statistics of all regions immediately before the rationing.

[25] It is worth highlighting that the treatment captured here is the rationing program faced by households net of the effects of pure information provision and subsidies, which were implemented in the South as well.

[26] See Manski and Pepper (2012) for a full discussion on identification.

[27] Table 1.A3 presents the realized electricity demand as a fraction of the forecasted demand from the Decennial Energy Plan 1997-2007 (PDE, 1997) for each year and region. From 1998 and 2000, the realized demand was below the expected one, even when considering households market only. That is, there was no unexpected growth of electricity demand in the years prior 2001. Further, the installed generation capacity would support the forecasted demand under regular natural conditions. The official report about the rationing's causes concludes that "no demand factor contributed to the unbalancing of the system and the collapse in 2001" (Kelman, 2001).

Figure 1.1 shows that average electricity use in the South and Southeast/Midwest had been following roughly the same trend since 1991. In the period between the privatization of the electricity sector and the rationing (from 1997 to 2001), I reject a common pre-trend hypothesis, and thus *Assumption 2*. However, the treatment effects turn out to be big compared to the estimated differences in trends. Also, I allow for different trends in the specification, meaning that I only need Assumptions 1 and 3 for identification.

Assumption 3 is the key challenge of assessing long run impacts of any policy: maintaining a meaningful counterfactual for several years. In order to overcome this issue, I use different regression specifications controlling for a series of time-varying covariates. Figure 1.A2 plots the evolution over time of electricity prices and wages in these regions. We cannot observe a discontinuity in these graphs as we do in Figure 1.1.[28] Table 1.A1 presents a set of simple difference-in-differences estimates of the rationing effects on time-varying covariates. I find no significant differences between the two regions specific to the post-rationing period, for any of the variables examined. The only exception is temperature, which seems to have increased by an additional $0.2^{o}c$ in the South over the last decade, meaning that the estimates of the long run effects of rationing are downwards biased.[29][30] Furthermore, I do not find evidence of economically meaningful migration across the regions,[31] or that households evaded rationing by spreading usage across more meters or irregular connections.[32]

Table 1.A4 presents the same difference-in-differences estimation to illustrate the different evolution between the North and the Northeast regions specific to the post-rationing period. One cannot reject the hypothesis that, during the years studied, more households were connected to electricity in the Northeast than in the North, and that the share of households paying for electricity increased, the number of employed workers increased, and the average wage decreased in the Northeast relative to the North. Since the Northern states fail to satisfy Assumptions 2 and 3, and the inclusion of these states would

[28] I also do not find evidence of a change in the total consumption of other sources of energy. Figure 1.A3 plots the evolution over time of monthly total sales of two alternative fuels - natural gas (GLP) and gasoline - divided by the number of employed households in each region. Again, we fail to observe a discontinuity in these graphs as we do in Figure 1.1. and Table 1.A1 (Part 2) presents the statistical tests.

[29] Temperature in the Southeast/Midwest virtually did not change relative to the late nineties. I would find similar results if I count the number of days above $32^{o}c$ in these regions.

[30] Some of these variables investigated have a small number of clusters what can lead to an over rejection of the null hypothesis. To address this issue I estimate standard errors using the wild-cluster bootstrap estimator (Cameron, Gelbach and Miller 2008) in all cases in which the dependent variable has less than 40 clusters.

[31] Oliveira and Oliveira (2011) documents that the Southeast experienced a net out-migration in the periods from 2000 to 2004 and from 2005 to 2009. The magnitude of these numbers are no larger than 0.2% of the Southeast population, and 0.5% of the South population.

[32] Data from the Regulatory Agency shows no difference in the evolution of the number of meters in the two regions. I find no difference in the number of households irregularly connected to electricity in the POF data, and the PPH data shows no difference in the number of households with a home business.

substantially change the household sample composition, I discard them in the empirical analysis. The main results still hold when all states are included in the analysis.

This evidence, together with the robustness checks, supports the plausibility of the identification strategy. Further potential issues with the identification will be discussed in Section 4.

1.4.1 Main Results

Table 1.2 presents the estimates of equation (1.2), using various different sets of controls and samples. The base specification suggests that during the rationing, households in the Southeast/Midwest reduced consumption by 46.7 kWh per month relative to the ones in the South region in the same period, a reduction of 28%; other specifications yield similar estimates. This is equivalent to each rationed household switching off a freezer or a medium sized refrigerator across the nine months of the rationing. The long run effect is about half of this value in all specifications - i.e., households in the Southeast/Midwest reduced consumption by 25.7 kWh per month (or 14%) relative to the ones in the South region in every month after February 2002. That is, it appears that households took some temporary measures to reduce electricity consumption during the rationing, however part of these new consumption pattern remained in place after the crisis.

As previously discussed, the evolution of covariates such as wages and prices could affect electricity demand over the years, especially because general equilibrium effects could emerge. To deal with this issue I control for real electricity prices, real wages and temperature as shown in columns 2 to 4. I also control for a cubic polynomial of these variables, in column 6, and results are largely unaffected. To address the issue of non-parallel trends, I run one specification with a specific time trend for each of the rationed and non-rationed regions, in column 5. The estimated rationing impacts get even larger in this case, and I cannot reject that the coefficients of the two trends are equal.

A further concern is that since households in both regions are heterogeneous, they could respond differently to covariates. That is, even if prices and wages evolved similarly in the two regions after the rationing, households could have different elasticities.[33] The specification in column 7 addresses this point by permitting utility-specific price and wage elasticities. I control for the interactions “price × utility dummy” and “wage × utility dummy”. This is the specification under which the rationing had the smallest estimated short and long run effects, about 12% smaller than the base specification. Even so, I find that long run electricity use decreased 22.6 kWh per month in the Southeast/Midwest relative to the South using this specification, which can be interpreted as a lower-bound estimate. Column 8’s specification uses all controls together. I cannot reject the null

[33] For example, if households in the Southeast were more price elastic than those in the South, a common price increase in both regions would lead to different consumption changes.

hypothesis of equality of the long run effects across all eight specifications.

Table 1.2: Estimation Results

	Dependent Variable: Average Household Electricity Use (kWh/month)									
	Regions South, Southeast, and Midwest								Synthetic Control	All Brazil
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
During*Rationing, β_D	-46.696***	-45.978***	-45.126***	-45.801***	-47.306***	-45.103***	-43.630***	-47.295***	-43.134***	-38.068***
	(2.831)	(2.836)	(2.656)	(2.858)	(3.074)	(2.648)	(2.726)	(3.082)	(2.901)	(3.297)
Post*Rationing, β_P	-25.683***	-25.539***	-24.982***	-25.316***	-31.655***	-24.716***	-22.624***	-31.885***	-28.424***	-17.576***
	(2.259)	(2.315)	(2.239)	(2.284)	(2.993)	(2.391)	(2.703)	(3.845)	(2.128)	(2.523)
Real Elect. Price	.	✓	✓	✓	✓	✓	✓	✓	.	.
Real Wage	.	.	✓	✓	✓	✓	✓	✓	.	.
Temperature	.	.	.	✓	.	.	.	✓	.	.
Different Trends	.	.	.	.	✓	.	.	✓	.	.
Cubic Polynomial	.	.	.	.	.	✓	.	✓	.	.
Covariates-Utility Interacted.		.	.	.	.	.	✓	✓	.	.
Observations	7686	7686	7202	6606	7202	7202	7202	6606	5908	10902
Utilities, i (cluster level)	44	44	44	44	44	44	44	44	48	63
Months, t	179	179	168	168	168	168	168	168	168	179
R-squared	0.883	0.885	0.887	0.889	0.888	0.889	0.900	0.905	0.909	0.921

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and after the intervention, captured by β_D and β_P from equation (2). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of the coefficients is kWh/month. *Sample* in columns 1 to 8 comprises all of the 17 utility companies from the subsystem South and the 27 from the Southeast/Midwest, monthly from January 1997 until December 2010. The Sample in column 9 constitutes synthetic sample creating a "synthetic control", as Abadie and Gardeazabal (2003), for each rationed utility company as explained in Section 4.1. The sample in Column 10 constitutes all utility companies in Brazil, excluding Pará where the rationing had a different timing and target. All regressions are weighted by the number of households connected to each utility company. *Standard errors* are clustered by utility company. *Controls.* All regressions with constant, year-month and utility company fixed effects. "Different Trends" includes a specific time trend for the rationed region. "Cubic terms" stands for a cubic polynomial of real prices and wages. "Covariates-Utility Interacted" stands for the interaction RealPrice*Utility and RealWage*Utilities, which aim to capture utility-specific price and wage sensitivity. *Source.* Average household electricity use and nominal average electricity price from the Electricity Regulatory Agency (ANEEL) records, which is at month-utility company level. Nominal wage from the Ministry of Labor's register (RAIS) at year-state level. I compute prices and wages in real terms by dividing nominal variables by the Consumer Price Index (INPC/IBGE), at state-month level. Temperature is from the National Meteorology Institute (INMET). A Levin–Lin–Chu Test rejects the hypothesis that these variables are non-stationary series. ***p<.01, **p<.05, *p<.1.

We can see the evolution of the rationing effect over time in Figure 1.4. It presents the estimated effect of the rationing in each month from 1997 until the end of 2010, using the specification in Table 1.2, column (1).[34] Consumption in the Southeast was decreasing relative to the South before the rationing, but we do not observe strong anticipatory effects in the first half of 2001. Also, we can see that the long run effect stabilizes two years after the rationing.

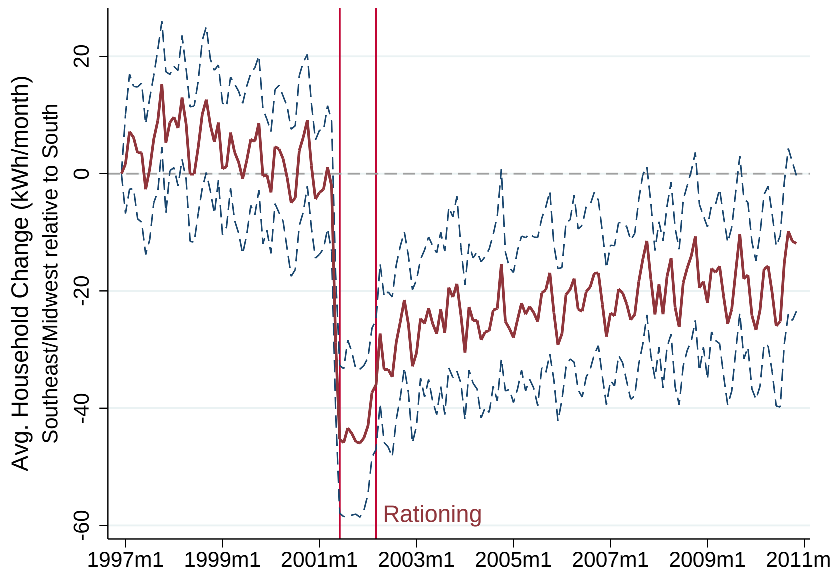

Figure 1.4: Rationing Effect on Average Household Electricity Use (1997-2010)

Notes. The blue solid line represents the estimated difference-in-differences effect of the rationing on the rationed households in each year-month; i.e., the coefficient β_t estimated from the equation in footnote 4. The dependent variable is average household electricity use in kWh, per month and utility company. The controls are utility and year-month fixed effects. The two dashed lines are the 95% confidence intervals, where standard errors are clustered by utility (44 clusters). Source: Electricity Regulatory Agency (ANEEL).

Columns 9 and 10 address potential issues with the sample of the data. Column 9 presents the rationing effects when a "synthetic control" group analogous to Abadie and Gardeazabal (2003) is constructed. For each rationed utility company, I construct a "synthetic utility", which is the weighted combination of all non-rationed utilities, that resemble the characteristics of the rationed utility before the rationing in a data-driven procedure. These synthetic utilities are used as the control group in the regression in

[34] Formally, it plots the estimated coefficients of the interactions of year-month and rationed region dummies, β_t, in the equation below

$$Y_{it} = \alpha + \sum_t (\beta_t dYearMonth_t * Ration_i) + \gamma_i + \gamma_t + \epsilon_{it}$$

where Y_{it} is the log of average household electricity use in utility i, in year-month t, γ_i and γ_t are utility and year-month fixed effects.

column 9.[35] Column 10 presents results pooling all 63 utility companies in the country, including those in the North and Northeast. In both cases, the estimated effects are not severely affected.

Also, one can interpret the difference-in-difference estimates of the rationing effects on time-varying covariates presented in Table 1.A1 as a placebo. As discussed above, I find that the rationing had statistically significant effects in the case of only one of the nine variables, temperature, which would bias downwards the long run results on electricity use.

Overall, there is evidence that the temporary demand response program did change final household electricity demand in the long run, i.e., for the ten-year period studied. This effect, a conservation of around 25 kWh/month per household, is economically meaningful. The total energy saved in the Southeast/Midwest during the nine years after the rationing adds up to 59.4 TWh, the equivalent to 50% of the wind energy generated in the USA in 2011 (EIA 2012). Also, this effect is robust to a range of specification and is flat since 2003, consistent with a scenario in which some affected households switched between steady states in electricity consumption.

1.5 Channels of Persistence

In this section I use household level microdata to shed light on the channels supporting the long run reduction in electricity use in the region affected by the rationing. There are two non-competing stories which could be underlying the long run energy conservation: households could have changed how they use electrical appliances, and/or invested in more energy efficient appliances.[36] It is important to disentangle the intensive and extensive margin of consumption because these relate to different economic mechanisms, and would lead to different policy conclusions.

The first channel would require that for given prices, income and technology, households would be using appliances differently. This mechanism can emerge from economic models in which the individual optimization problem has multiple steady states; as in the model presented in Section 1, through consumption complementarity, or because of habits, beliefs, or social norms. In the first part of this section I present direct evidence from household level microdata that individuals' utilization of electrical appliances was affected by the rationing.

At the same time, the rationing could have affected households' investments in energy

[35]The weights used to create the synthetic control are estimated based on using Abadie and Gardeazabal (2003) procedure. Observable characteristics used are average household electricity use, real electricity price, real wage, number of households connected to electricity and consumer price index.

[36]Households could have substituted electricity by other sources of energy, such as natural gas (GLP) and gasoline. I address this issue in Section 4.2.

efficiency. In this case, households marginally indifferent between keeping an old appliance and replacing it with a new one would have been prompted to buy a new appliance by the rationing. The acquisition of a new appliance which consumes less electricity would have lasting impacts on final household energy demand, because appliances are kept for a long time. To illustrate this point, I present in Appendix A an extended version of the model, adding endogenous choice of appliances' characteristic. In Subsection 4.2, I investigate the contribution of this mechanism to the long run energy conservation. I exploit household level microdata which gives me snapshots of the quantity and vintage of households' appliances holdings in different periods. Evidence suggests that the difference in composition of appliances between the two regions did not change substantially in the long run.[37]

I restrict attention to the five appliances which represent 85% of average household electricity use (PROCEL, 2007): shower heads with electric heating, refrigerators, freezers, air conditioners, and lamps. I use the same identification strategy described in the previous section, performing the following difference-in-differences estimation:

$$Y_{hit} = \alpha + \sum_{t>0} \beta_t dYear_t * Ration_i + \gamma_t + \gamma_i + \gamma X_{hit} + \epsilon_{hit} \tag{1.3}$$

where Y_{hit} is the dependent variable of household h, in region i and year t (region i can be utility company or state according to the dataset), $dYear_t$ are dummies for years, $Ration_i$ is a dummy equal to one if the region i was rationed, γ_i and γ_t are region and year fixed effects, and X_{hit} is a vector of controls with household characteristics. I do not impose any structure on the errors' correlation over time and cluster errors by region i using wild-cluster bootstrap estimator to deal with the small number of clusters (Cameron, Gelbach and Miller 2008).

There is one caveat for identification in this section. By the nature of the data (repeated cross-section), I cannot explicitly test the common trend hypothesis for the dependent variables. To attenuate this issue, I control for many household characteristics which may be correlated with different trends.

[37]Note that I do not investigate appliances' optimal life cycle. To precisely assess if households attitudes towards technology adoption changed in the period, one would need data with the flow of new appliances bought by households and the flow of the destination of the old appliances (i.e., if old appliances are displaced or sold in the second hand market). Unfortunately, this data does not exist. I use stock data which only provides indirect evidence on appliances' life cycle. However, the data used does provide direct evidence on the average energy efficiency of households' inventory of appliances in different points in time.

1.5.1 Electricity Consumption Habits

This subsection presents results on consumption behaviors using data from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005. Table 1.3 presents descriptive statistics of the appliance inventories and habits of electricity utilization of the average household in the two regions and years. As we can see, the three electricity services which account for most of the average household's electricity use are shower heads with electric heating, refrigerators and lighting. In 1998/1999 the average household in the Southeast/Midwest had an overall higher utilization of appliances than the average household in the South; except freezer and lighting. We also see that households in the Southeast/Midwest used to adopt less energy-saving measures than those in the South.

Table 1.4 presents the estimates of difference-in-differences regression (1.3) for each of these variables, controlling for utility company and year fixed effects, income, squared income, number of household members, residence build-up area,[38] and dummies for rich neighborhood and for proximity to slums ("favelas"). As indicated in the table, I present results in units of kWh/month whenever it is possible.[39]

The use of shower heads with electric heating corresponds to more than a fifth of average electricity use. The regression results presented in column 1 suggest that the rationing affected households' choice of shower temperature, generating savings of around 15 kWh per month.[40] I do not find that the rationing had a statistically significant impact on any of the other variables, including utilization of refrigerators, freezer, lighting and air conditioners, as shown in columns 2 to 7. However, all point estimates are negative. I would like to draw attention to one of these appliances: freezers. As shown in column 3, the point estimate suggest that households in the Southeast/Midwest reduced freezer utilization due to the rationing, saving around 10 kWh per month on average. This result is not statistically significant because the standard errors estimated with the wild-cluster bootstrap estimator are large, but it turns to be significant when other estimators are used. These two results by themselves could account for most of the observed long run energy conservation in the Southeast/Midwest. As shown in column 8, the rationing had no statistically significant impact on the probability of households adopting at least one of the ten energy-saving measures described in Section 2.1.2.[41]

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[38]Build-up area is the area enclosed within the walls of the residence, plus the thickness of walls.

[39]I convert each variable to kWh/month by calculating: [Number of appliances per type and intensity of use] * [Average electricity consumption per type and intensity of use].

[40]The thermostat of a shower head with electric heating can be switched off or set at "Low Power" (*Modo Verão*) or "High Power" (*Modo Inverno*). A shower set at Low Power consumes on average 30% less electricity than one set at High Power.

[41]Table 1.A6 in the Appendix presents the rationing effect on the adoption of each of these 10 measures, using a logit estimation. I find a statistically significant increase in the adoption of four of these ten measures, all relating to refrigerator, freezer or shower utilization (for example, "reduce shower time when using electric water heating" in column 6, and "adjust the shower thermostat according to the ambient temperature" in column 7). I find no statistically significant effect on the remaining six measures.

Table 1.3: Baseline Average Household Appliance Inventory and Utilization Habits

	Year 1998/1999				Year 2004/2005			
	South		Southeast/Midwest		South		Southeast/Midwest	
	Raw	kWh/month	Raw	kWh/month	Raw	kWh/month	Raw	kWh/month
Electric Showers								
Quantity	.96 (.48)	39.85	.97 (.63)	46.43	1.14 (.50)	47.79	1.12 (.57)	41.96
Thermostat Low Power	.74 (.55)		.46 (.61)		.18 (.43)		.72 (.66)	
Thermostat High Power	.06 (.24)		.40 (.59)		.76 (.65)		.21 (.47)	
Refrigerators								
Quantity	.96 (.37)		1.00 (.40)		1.03 (.27)		1.01 (.30)	
Quantity Always On	.94 (.37)	40.93	.97 (.40)	42.42	1.00 (.29)	43.40	.98 (.32)	42.69
Age	8.11 (6.36)		7.67 (6.37)		7.98 (5.34)		7.69 (5.94)	
Freezers								
Quantity	.25 (.47)		.20 (.43)		.42 (.52)		.19 (.42)	
Quantity Always On	.22 (.44)	12.90	.18 (.41)	10.86	.36 (.50)	21.38	.13 (.35)	7.57
Age	5.93 (4.30)		5.24 (4.08)		6.81 (4.16)		6.68 (4.24)	
Air Conditioners								
Quantity	.03 (.22)		.10 (.40)		.27 (.63)		.09 (.38)	
Quantity Frequently Used	.01 (.12)	1.63	.04 (.27)	8.95	.03 (.14)	7.26	.01 (.08)	2.08
Age	5.57 (5.11)		5.94 (4.77)		6.77 (4.65)		5.59 (4.03)	
Incandescent Light Bulbs								
Quantity	8.14 (6.01)		7.3 (5.12)		4.59 (5.57)		5.36 (6.76)	
Quantity Frequently Used	5.02 (5.33)	45.18	2.83 (3.89)	25.46	2.49 (3.44)	22.41	2.06 (2.64)	18.52
Fluorescent Light Bulbs								
Quantity	1.02 (2.51)		1.16 (2.91)		4.63 (4.91)		3.29 (6.35)	
Quantity Frequently Used	.81 (2.14)	1.88	.74 (2.21)	1.70	2.53 (3.42)	5.83	1.63 (4.41)	3.77
Adopt Energy-saving Measures								
Share of Households	.85 (.36)		.79 (.40)		.94 (.24)		.92 (.27)	
Total Estimated Electricity Use		142.37		135.82		148.07		116.59
Realized Average Electricity Use		176.4		210.3		156		160.5

Notes. This table displays the summary statistics of households in the regions in the columns from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005. Columns labelled *Raw* present the average sample level in the units of each variable. Columns labelled *kWh/month* present the imputed monthly electricity use of each variable, converted using estimates from PROCEL presented in Table A5, considering appliance's utilization. Quantity is the number of appliances owned. "Always On" is the number of appliances permanently switched on. "Frequently Used" is the number of appliances used more than four times a week. "Adoption of Energy-Saving Measures" refers to the actions described in Section 2.1. Standard deviation in parentheses. "Realized Average Electricity Use" is from the Regulatory Agency ANEEL. No sample weights.

Table 1.4: Results on Consumption Habits

	Electric Shower Thermostat (kWh)	Appliances Always Switched On: Fridge (kWh)	Appliances Always Switched On: Freezer (kWh)	Appliances Frequently Used: AC (kWh)	Appliances Frequently Used: Lamps All (kWh)	Appliances Frequently Used: Lamps Incandescent (kWh)	Appliances Frequently Used: Lamps Fluorescent (kWh)	Adoption of Energy-Saving Measures (Mg. Eff.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Rationing Effect in 2005 (β_{05})	-15.801**	-1.601	-11.477	-8.768	-4.850	-2.474	-2.376	.022
	(7.990)	(2.166)	(13.579)	(6.660)	(9.726)	(9.522)	(3.515)	(.039)
2005 Dummy(γ_{05})	15.218	3.350	11.782	7.097	4.074	-.628	4.701	.109***
	(.000)	(4.494)	(14.610)	(6.461)	(6.424)	(8.203)	(6.702)	(.023)
Sample Mean	43.6	42.1	9.9	4.7	29.3	26.9	2.3	.85
Estimation Method	OLS	OLS	OLS	OLS	OLS	OLS	OLS	Logit
Utilities i (cluster level)	10	10	10	10	10	10	10	10
Observations	11071	11070	11068	11071	11071	11071	11071	10589
R-squared	.386	.082	.166	.067	.278	.247	.118	.034

Notes. This table displays the difference-in-differences estimates of the rationing effects on different proxies for consumption habits, from equation (3) in Section 5. Each column corresponds to a regression with a different dependent variable and appliance. Columns 1 to 7 present the coefficients of OLS estimation expressed in units of kWh/month. Column 8 present the marginal effects of logit estimation. Household level microdata is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the Brazilian energy efficiency program PROCEL. *Sample* comprises a set of households in the concessions of ten utility companies from the subsystems South and Southeast/Midwest. All regressions contain utility company fixed effects, year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". "Electric shower thermostat" in column 1 is the total electricity use of electric showers considering adjustments on the thermostat regulation which can be Off, Low Power or High Power. In columns 2-3, "Appliances Always Switched On" stand for the number of appliances that are in permanent use. "Appliances Frequently Used" in columns 4-7 corresponds to the number of AC units and light bulbs used more than four times a week. "Energy-Saving Measures" in column 8 corresponds to the adoption of at least one of the ten actions to save energy, described in Section 3. Standard errors in parentheses are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by utility company. Dataset does not contain sample weights. ***p<.01, **p<.05, *p<.1.

These findings suggest that households changed their regular usage patterns for electricity services, even controlling for a series of individual characteristics. These results are largely unaffected when using different specifications. Furthermore, responses to qualitative questions asked to rationed households in 2004/2005 are consistent with these findings, as shown in Table 1.A9. This is further evidence that the rationing did make households switch steady states.

1.5.2 Electrical Appliances Holdings

This section shows that a newer and more energy-efficient stock of appliances cannot account for the long run relative reduction in electricity demand in the rationed region. In order to assess whether the rationing affected the average stock of appliances, I use microdata from the Household Budget Survey (POF) 1996/1997, 2002/2003 and 2008/2009, and Appliances and Habit of Use Survey (PPH) 1998/1999 and 2004/2005. As discussed above, I characterize the inventory of appliances using three variables: the quantity of appliances owned, the age of each appliance, and the dummy New which is equal to one for appliances bought within the last two years.

The first part of Table 1.5 presents the estimates of the difference-in-differences regression (1.3) using POF data controlling for state fixed effects, year fixed effects, income, squared income, number of bedrooms, number of household members, and a dummy for rural regions. These are sample weighted regressions using only those households who pay for electricity, that is, those regularly connected to electricity as described in Section 2.1.3.

Consistent with the habits of use data, in column 4 we can see that the rationing had a negative, but not statistically significant, effect on the average number of freezers in the Southeast/Midwest relative to the South. Although one cannot reject the equality of the coefficients capturing the short and long run effects on the quantity of freezers, I find that the short run effect is statistically significant when standard errors are estimated using other methods rather than the wild-cluster bootstrap estimator. The short run effects of changes in the stock of freezers would be responsible for the conservation of around 4 kWh per month. Columns 1 and 7 also show no effect on the quantity of refrigerators and air conditioners either in the short or long run.

Although the quantity of appliances does not seem to have been significantly affected, the rationing could have influenced the households' decision to replace old appliances with more efficient ones. Columns 2 and 3 provide evidence that households in the Southeast strategically substituted refrigerators during the rationing. In 2002/2003, while the rationing did not affect the number of refrigerators owned (column 1), it did reduce the average age of refrigerators (column 2), and increased by 2.5% the share of households who bought a refrigerator in the previous two years (column 3). However, this effect dissipates over time and I find no effect on the stock - quantity and vintage - of refrigerators in 2008/2009.

Columns 6 and 9 suggest that the share of households who bought freezers or air conditioners in the previous two years became relatively smaller in the rationed region both in the short and long run. We also see in column 8 that the average air conditioner became relatively older in the Southeast/Midwest. This is indirect evidence that the rationing reduced the replacement rate of these appliances in the Southeast/Midwest. All these results are robust to different specifications and to restricting to sub-samples, such as to metropolitan areas.

The POF dataset does not contain information on lamps and showers, or on the characteristics of appliances. I use data from the PPH to examine the stock of these appliances and their characteristics. As shown in Table 1.5 (Part 2), I find no significant change in the number of lamps or shower heads with electric water heating in the Southeast/Midwest relative to the South. Note that when we compare these results with those in Table 1.4, we see that it is the intensive margin of utilization which is driving the reduction in the electricity consumption of shower heads with electric water heating.

Although these results suggest that the quantity and vintage of the stock of appliances owned by households were not affected, it could be that households in the Southeast/Midwest started to acquire smaller or more energy-efficient appliances. Table 1.A7 presents the estimates of the difference-in-differences regression (1.3) using PPH data on the average size of refrigerators and freezers (measured in liters) and the power of air conditioners (measured in BTUs). I find that the rationing had no effect on the characteristic of these appliances. Another issue to be considered is that retail stores in the Southeast/Midwest could have specialized in energy-efficient products potentially not available in the South. In Appendix C.3, I use microdata on appliances' prices collected in stores to investigate this issue. As presented in Table 1.A8, products available in the stores of the Southeast/Midwest became more likely to be available in the stores of the South after 2001.

These results together are consistent with the standard model of appliance acquisition and utilization (Dubin and McFadden 1984) when extended to allow for multiplicity of steady states, as described in Appendix A. In this model, appliances that provide price-elastic electricity services (e.g., freezers) are less likely to be utilized during the rationing, reducing the incentives to invest in new appliances in the short run. In the long run, price-elastic services will be the most affected when individuals converge to a new steady state with less services from electricity. A smaller utilization of electricity services reduces the incentives to invest in newer and more energy-efficient technologies, leading to long run effects on the stock and utilization of appliances.

Table 1.5: Results on Appliances Holdings (Part 1)

	Refrigerator			Freezer			AC		
	Quantity (kWh)	Age (Years)	New (Mg. Eff.)	Quantity (kWh)	Age (Years)	New (Mg. Eff.)	Quantity (kWh)	Age (Years)	New (Mg. Eff.)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Rationing Effect in 2002 (β_{02})	.316	-1.174**	.025**	-4.152	-.450	-.009***	9.606	2.099**	-.004*
	(1.292)	(.588)	(.012)	(3.225)	(1.698)	(.003)	(7664.4)	(.949)	(.002)
Rationing Effect in 2008 (β_{08})	.289	-.072	.009	-3.806	-.422	-.006***	-.716	1.737	-.005***
	(.633)	(.170)	(.010)	(3.219)	(.405)	(.001)	(571.3)	(2.329)	(.001)
2002 Dummy (γ_{02})	-.646***	-.370	-.028**	-1.400	1.782***	-.007***	-22.520	-1.759	.000
	(.224)	(.331)	(.011)	(2.721)	(.576)	(.001)	(17968.4)	(8.712)	(.002)
2008 Dummy (γ_{08})	-.007	-1.636	-.003	-4.983**	2.790**	-.008***	-18.331	-2.185	.002***
	(.000)	(1.150)	(.008)	(2.310)	(1.199)	(.001)	(14626.1)	(2.392)	(.001)
Sample Mean	39.7	6.8	.087	11.0	7.4	.012	23.7	6.2	.009
Estimation Method	OLS	OLS	Logit	OLS	OLS	Logit	OLS	OLS	Logit
States, i (cluster level)	11	11	11	11	11	11	11	11	11
Observations	52805	48733	52805	52805	11279	52805	52805	4356	52805
R-squared	.048	.025	.005	.154	.069	.073	.204	.044	.128

Notes. This table displays the difference-in-differences estimates of the rationing effects on the average stock of appliances, from equation (4) in Section 5. Each column corresponds to the results of the regression of a different dependent variable and appliance, measured in the units indicated in the columns. Household level microdata is from the Household Budget Survey 1996/1997, 2002/2003 and 2008/2009 (POF/IBGE). *Sample* comprises all the eleven states from the subsystems South and Southeast/Midwest. *Quantity* means the number of appliances in the domicile converted to its electricity use (kWh/month). *Age* is the number of years since the appliance was bought. Regressions of these two dependent variables are estimated using OLS. *New* is a dummy variable equal to 1 if an appliance was bought less than two years ago, and zero otherwise. Regressions of New use logit estimation, and I report the marginal effects. Note that an appliance observed in 2002/2003 with less than two years old was bought exactly in 2001 or 2002. Therefore, the rationing effects in 2002 in columns 3, 6 and 9 captures the rationing impact on the share of households who bought appliances in the period. All regressions *controls* for state fixed effects, year fixed effects, income, squared income, number of household members, and dummy for rural regions. Standard errors in parentheses are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by state. All regressions use sampling weights. ***p<.01, ** p<.05, * p<.1.

Table 1.5: Results on Appliances Holdings (Part 2)

	Dependent Variable: Appliance Quantity			
	Electric Shower (kWh)	Lamps All (kWh)	Lamps Incandescent (kWh)	Lamps Fluorescent (kWh)
	(1)	(2)	(3)	(4)
Rationing Effect in 2005 (β_{05})	.033	1.017	3.255	-2.238
	(.660)	(.000)	(103.876)	(3.365)
2005 Dummy(γ_{05})	7.703	-6.724	-14.284	7.560
	(11.315)	(11.595)	(23.250)	(10.416)
Sample Mean	46.5	64.5	60.5	4.0
Estimation	OLS	OLS	OLS	OLS
Utilities i (cluster level)	10	10	10	10
Observations	11071	11071	11071	11071
R-squared	.234	.391	.337	.171

Notes. This table displays the difference-in-differences estimates of the rationing effects on the average stock of appliances, from equation (4) in Section 5. Each column corresponds to a regression of a different dependent appliance, and present the coefficients of OLS estimation expressed in units of kWh/month. Household level microdata is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the Brazilian energy efficiency program PROCEL. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. *Quantity* is number of appliances in the domicile converted in electricity use (kWh/month) *without* accounting for change in utilization pattern. All regressions contain utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". Standard errors in parentheses are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by utility company. Dataset does not contain sample weights. ***p<.01, **p<.05, *p<.1.

In sum, the microdata suggests that a newer and more efficient stock of appliances cannot account for the long run reduction in electricity use. While the estimated reduction in the quantity of freezers saved around 4 kWh/month, the estimated reduction in the utilization of freezers saved 10 kWh/month, as discussed above. Analogously, without accounting for showers' utilization margin, we estimate that the rationing effect on the quantity of shower heads with electric heating is equal to 0 kWh/month. However, data suggests that the changes in shower utilization (i.e., thermostat setting) saved 15 kWh/month. Therefore, changes in the intensive margin of consumption appears to be the main channel underlying the persistent reduction on electricity use.

1.6 Conclusion

Both economic theory and empirical evidence recognize that economic problems may have multiple steady states. However, the feasibility of using temporary interventions to induce individuals to switch steady states with sustainable effects is still being discussed by the empirical literature and policy makers. This paper contributes to this discussion by analyzing households' response to an electricity rationing program in Brazil in 2001-2002. The main contribution of this paper is to provide empirical evidence that a temporary intervention appears to have promoted sustained changes in consumption behavior. The results suggest that households can switch to steady states with smaller energy consumption in response to a temporary demand response program. The long run effect observed is stable over time, and the energy saved has been equivalent to 1.5 months of electricity every year, for the last 10 years, and counting.

The picture emerging from the household level microdata shows that the temporary rationing had a lasting impact on people's behavior and appliances utilization, rather than increasing long run adoption of energy-efficient technology. From an energy perspective, this is important because it suggests that we cannot discuss an "energy efficiency gap" solely on the basis of technology, we should consider its behavioral counterpart as well.

A caveat of this paper is that I cannot empirically disentangle which economic mechanisms are underlying the long run effects. The design of the quasi-experiment studied here restricts the identification of the precise mechanism within a class of economic models which generate similar revealed preferences in this context. Understanding the precise model driving the results is crucial in order to estimate the welfare cost of the transition between steady states. In particular, if these mechanisms involve externalities or internalities of electricity use (Stern 2007; Nordhaus 2011; Allcott and Mullainathan 2010), then there could be aggregate welfare gains from shifting consumption to steady states with smaller energy use.

A key difference between this paper and the literature that assesses the persistence of large historical events is that the policy studied here could be feasibly replicated. And a difference between this policy and most of the demand response programs in the literature is that it was not a nudge, or a surgical incentive given to individuals, but a nationwide intervention. In particular, its breadth allows for general equilibrium effects to take place, as well as potential complementarity between different economic mechanisms, such as price, information, social norms, and habits.

1.A Appendix

1.A.1 Extended Theoretical Framework with Durables Acquisition

Suppose a two-stage decision process. In the first stage, the individual chooses between I appliances portfolios, each with characteristics Θ_i. One of these characteristics is energy efficiency, and for simplicity, let the I portfolios be ordered in increasing energy efficiency, i.e., $i = I$ is the most energy-efficient portfolio. The rental price of appliance portfolio i is r_i in annualized terms. The first stage optimization problem can be represented by

$$W(s_t) = \max_{i \in 1,2,\ldots,I} \{V(\Theta_1, s_t), \ldots, V(\Theta_I, s_t)\}$$

where $V(\Theta_i, s_t)$ is the conditional indirect utility of choosing appliance portfolio Θ_i when the individual has stock of electricity use s_t, as described in Section 1.

In the second stage, the individual chooses consumption and utilization of services from electricity conditional on the durable portfolio chosen in the first stage Θ_i. That is, this second stage is similar to the model in Section 1, with the additional feature that services from electricity, e_t, is a function of the appliances portfolio and the actual electricity use. Let E_t be actual electricity use; then services from electricity is given by $e_t = f(E_t|\Theta_i)$, where f is the production function of services from electricity given appliances Θ_i and electricity consumption E_t. Therefore, the individual optimization problem is

$$W(s_t) = \max_{i \in 1,2,\ldots,I} \{V(\Theta_1, s_t), \ldots, V(\Theta_I, s_t)\} \tag{1.4}$$

$$V(\Theta_i, s_t) = \max_{c_t, e_t} u(c_t, e_t, s_t) + \beta W(s_{t+1}) \tag{1.5}$$

$$\begin{aligned} s.t.\ c_t + pe_t &\leq y - r_i \\ s_{t+1} &= \delta s_t + e_t \\ e_t &= f(E_t|\Theta_i). \end{aligned}$$

This problem can be greatly simplified by assuming that the electricity production function has constant returns to scale (Pollak and Wachter 1975). In this case, the marginal cost of producing e is constant and the indirect utility function can be written as a standard consumption optimization with budget constraint $c_t + \pi(p|\Theta_i)\, e_t \leq y - r_i$, where $\pi(p|\Theta_i)$ is the marginal cost of producing one extra unit of electricity services, e_t.

Proposition 1 in Section 1 characterizes the solution of the second stage problem (3) for a given portfolio choice Θ_i. We argued that for each appliance portfolio Θ_i, utilization monotonically converges to a stable steady state. Since more energy-efficient portfolios have a lower marginal cost of electricity services, $\pi\left(p|\Theta_i\right)$, the individual consumes more services from electricity, assuming the income effect associated with electricity prices changes to be sufficiently small. Therefore, more energy-efficient portfolios are associated with steady states with a higher utilization of services from electricity. For any initial stock of electricity use s_t, the optimal appliance choice and utilization of electricity services will thus monotonically converge to the steady state of one of the appliances portfolios Θ_i.

The Rationing (Dynamics)

Rationing in this setting can be interpreted as a temporary restriction on electricity use, E_t. That is, the individual optimization problem has an extra constraint $E_t \leq \bar{E} < E^*_{i^*}$, where $E^*_{i^*}$ is her initial optimal choice. This can be written as a restriction on the utilization of appliance portfolios. During the rationing, for any appliance portfolio i, the optimal services from electricity is $\min\left\{e^*\left(p, y - r_i|\Theta_i\right); f(\bar{E}|\Theta_i)\right\}$.

As discussed in Davis, Fuchs, and Gertler (2012), the optimal appliance portfolio choice during the rationing - i.e. whether or not one invests in more energy-efficient appliances - depends on the price elasticity of the electricity services of each appliance. Durables that provide inelastic services which cannot be substituted with less energy-intensive services, such as basic food refrigeration, would be substituted with more energy-efficient appliances in order to maintain the service level. On the other hand, appliances that provide elastic services which can be substituted with less energy-intensive technologies, such as air conditioners, would be less utilized and, consequently, would receive smaller investments. This yields two additional predictions.

Prediction 2. *During the rationing, the average stock of appliances that provide inelastic (elastic) services tend to become more (less) energy-efficient.*

The results from Section 4 are consistent with this prediction. The evidence suggests that during the rationing households substituted old refrigerators with new and more efficient ones. At the same time, households switched off freezers and utilized fewer air conditioners, postponing the acquisition of these appliances.

Once the rationing is over, incentives regarding durables are back to normal, and the individual is back to the unconstrained problem (4) and (5). Therefore, any long run effects will emerge through new steady states in the consumption of electricity services. In particular, appliances portfolios can be affected in two directions. An individual who invested in energy-efficiency during the rationing would be able to sustain a higher utilization level and her consumption stock would be less likely to fall below a critical level and converge to a lower steady state. Alternatively, an individual who postponed investments in appliances and reduced utilization during the rationing, would have a smaller stock of services from electricity by the end of the rationing and would be more likely to switch steady states.

Prediction 3. *After the rationing, the individual enters an optimal path that monotonically converges to a steady state with weakly lower consumption of services from electricity, and a portfolio with weakly less energy-efficient appliances.*

An individual who joins a new optimal path and converges to a steady state with lower services utilization will have less incentive to invest in appliances' efficiency, because her marginal utility of utilization is smaller than initially. Thus, her new optimal portfolio choice will be weakly less energy-efficient than her original one. Evidence from freezers presented in Section 4 is consistent with this prediction.

1.A.2 Appendix Tables

Table 1.A1: (Part 1) Placebo Estimation (South and Southeast/Midwest)

	Households Connected to Electricity (1000s)	Real Electricity Price (R$)	Consumer Price Index	Appliances Price Index	Share of Households Paying for Electricity	Average Household Size
	(1)	(2)	(3)	(4)	(5)	(6)
During*Rationing (β_D)	38.62	.008**	-.041	-.549	.065	-.059
	(35.58)	(.004)	(.026)	(.556)	(.280)	(.061)
Post*Rationing (β_P)	83.12	.002	.040	-.304	.175	-.103
	(97.10)	(.005)	(.035)	(.307)	(.299)	(.105)
Data source	ANEEL	ANEEL	IBGE	FGV	POF	POF
Mean	770.3	.18	1.34	1.22	.88	3.31
Observations	7686	7686	1253	40	61311	52820
Cluster level, i	44	44	7	8	11	11
Periods, t	179	179	105	5	2	2
R-squared	.976	.611	.995	.952		.019

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention, captured by β_D and β_P from equation (2). Each column corresponds to a regression with a different dependent variable. *Sample* comprises the subsystems South and Southeast/Midwest. *Data sources:* administrative data from the Regulatory Agency (ANEEL) is at month-utility company level, between January 1997 and December 2010; Price Index from INPC (IBGE), at month-metropolitan area level; appliances price data used to calculate consumer price index IPC from IBRE (FGV), at month-metropolitan area level; household level microdata from the Household Budget Survey 1996/1997 (POF), estimated with sampling weights. All regressions with constant, period t and cluster level i fixed effects. Standard errors in parentheses are clustered by i according to data source as indicated, and standard errors in columns 3 to 11 are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008). ***p<.01, **p<.05, *p<.1.

Table 1.A1: (Part 2) Placebo Estimation (South and Southeast/Midwest)

	Average Wage (R$) (7)	Employment (1000s) (8)	Total Sales Natural Gas (GLP) per Household (m^3) (9)	Total Sales Gasoline per Household (m^3) (10)	Average Temperature (^0c) (11)
During*Rationing (β_D)	72.63	-63.61	.036**	.000	-1.139***
	(48.41)	(90.00)	(.016)	(.018)	(.167)
Post*Rationing (β_P)	151.30	54.00	.021	-.030	-.196*
	(128.71)	(337.16)	(.042)	(.033)	(.102)
Data source	RAIS	RAIS	ANP	ANP	INMET
Mean	1037.1	2192.0	.35	.78	22.6
Observations	154	154	121	121	7530
Cluster level, i	11	11	11	11	48
Periods, t	14	14	11	11	168
R-squared	.918	.968	.919	.878	.889

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention, captured by β_D and β_P from equation (2). Each column corresponds to a regression with a different dependent variable. *Sample* comprises the subsystems South and Southeast/Midwest. *Data sources:* average wage and employment from Ministry of Labor's register (RAIS) at year-state level; total state monthly natural gas (GLP) and gasoline consumption divided by the number of workers from the National Agency of Petroleum, Natural Gas and Biofuels (ANP); and temperature from the National Meteorology Institute (INMET), at month-state level. All regressions with constant, period t and cluster level i fixed effects. Standard errors are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered at i. ***p<.01, **p<.05, *p<.1.

1.A.3 Rationing Timeline

Late 1999	The National System Operator (ONS) presented simulations of hydrological scenarios for 2000 based on the actual reserve levels in 30 November of 1999. The report concludes that the reservoir levels in some regions would hit zero (i.e., no electricity) in 13% of these scenarios.
Feb 2000	The Ministry of Mining and Energy (MME) creates the Priority Thermal Program (PPT) to increase the generation capacity of thermal power plants as the "unique solution" to a possible collapse of the system.
Early 2000	The Priority Thermal Program becomes the Emergency Thermal Program.
Jul 2000	In a meeting with the President and his economic advisors, the minister of the MME dismisses the chances of any energy crisis during 2000-2003.[42]
Dec 2000	ONS forecasts a scenario for 2001 with no energy crisis.
Feb 2001	Hydrological conditions reach 70% of the long run average, and ONS radically change the forecast for 2001.
Mar 2001	ONS officially request that the federal government intervene to assure a 20% load reduction.
Mar 2001	*First time the regulatory agency (ANEEL) publicly addressed a possible imminent electricity shortage.* It proposes the Consumption Reduction and Supply Increase Plan (RECAO), which was abandoned shortly afterwards.
Apr 2001	The Priority Thermal Program (PPT) fails and MME starts designing the load reduction program.
May 2001	Government announces a six month rationing to be implemented in June 4th.
Jun 2001	Household restrictions are implemented.
Feb 2002	Household restrictions are withdrawn.

[42]Based on documents from the National System Operator (ONS), the minister stated: "considering the Priority Thermal Program (PPT), even if we observe an increase in demand larger than expected, we will not face energy supply and peak problems during 2000-2003 as long as the hydrological conditions are above 85% of the long run average".

1.A.4 Data Cleaning

I convert all variables I can in units of electricity utilization (kWh/month). The hypothetical average electricity use of appliances was calculated by the Brazilian energy efficiency program PROCEL based on technical characteristics of appliances and hypothetical utilization. Table 1.A5 presents these values.

Electricity Data (ANEEL). I discard December 2011 from the sample because values had not been revised by the Regulatory Agency (ANEEL). I use *synth* state function to generate the synthetic controls in the estimation (http://www.mit.edu/~jhainm/software.htm).

Habits of Energy Use (PPH). Quantity of appliances is the number of appliances owned by the household multiplied by the appliance utilization in Table 1.A5. Appliances frequently use stand for appliances utilized more than four times a week. Shower thermostats could be regulated at three different levels: Off, Low Power (*Mode Verão*), or High Power (*Modo Inverno*). A shower regulated in Low Power consumes 30% less energy than one regulated in High Power. I calculate the electricity inputed in each shower by multiplying [number of people who uses the shower]*[shower electricity use for its thermostat setting]. I consider the average shower time reported in the 2004/2005 survey, which is 12 minutes.

Appliances Holdings (POF). In the Household Budget Survey (POF), a household may declare having more than one house, I discard second houses and restrict attention to the main domicile. As discussed in the text, I restrict the sample of the regressions to the households who pay for electricity. I define a household who do not pay for electricity as a household who own at least one electrical appliance and claim no expenses on electricity or own an electricity generator. I truncate appliances' *age* at 15 years, because the year an old appliance was bought is subject to severe measurement errors.

Appliances' Prices. The smaller unit in the cross-section is a triple product*informer*store. An informer*store i is located in the capital of state s, and a product k is a specific model of appliance a - e.g., product, k, may be "Fluorescent light bulb universal 20/40W General Eletrics", which is a model of appliance, a, "Lamp". That is, the unit of observation is the price observed by informer i, in state s, of product k on date t: $p_{i,s,k,t}$. I construct price indeces following the (unweighted) methodology of the official price indexes from IBRE/FGV, who provided the microdata. This price index constitutes of calculating the month inflation rate per observational unit (informer & product) and aggregate it using geometric average. Hence, the inflation rate of product k, and appliance a, on state s month t are respectively:

$$\Delta p_{s,k,t} = \left(\Pi_i \frac{p_{i,s,k,t}}{p_{i,s,k,t-1}}\right)^{\frac{1}{\#i}}, \text{ and } \Delta p_{s,a,t} = (\Pi_k \Delta p_{s,k,t})^{\frac{1}{\#k}}$$

where $\#i$ and and $\#k$ are the number of informers and product models in state s, appliance a, respectively. I use the monthly inflation rate to create the accumulated price index relative to January 2001, the first month in the sample for which I have observations in the South, $I_{s,a,t} = \Pi_{\tau=1}^{t} \Delta P_{s,a,\tau}$.

1.A.5 Retailer Market Composition

Another issue to consider is if retailers are stocking and advertising different appliances in different regions, what would affect the type of appliances available in the stores across the regions. I use microdata on appliances' prices collected in stores by IBRE/FGV to investigate this issue. Prices are surveyed in stores according to the products available on the shelves. Since product descriptions are very detailed,[43] I can compare the availability of products in the shelves in both regions and how this changed over time.

I aggregate products observed, k, by year, t, and rationed region, r, and verify for each product if it is present in both rationed regions in that year. Let C_{ktr} be a dummy equal to one if product k in region r year t is also present in region $-r$ in the same year. Because I only observe prices in both regions from 2001 on, I test if the share of products being sold in both regions changed after 2001 by performing a logit regression:

$$C_{ktr} = \alpha + \beta_P Post_t * Ration_r + \gamma_r + \gamma_t + \epsilon_{ktr} \tag{1.6}$$

where $Ration_r$ is a dummy equal to one for the rationed regions, $Post_t$ is a dummy equal to one for years 2002 to 2005, and γs are region and year fixed effects. I also run one specification with appliance fixed effects, and weighting the regressions with the number of stores selling each product. I display standard errors robust and clustered at the appliance level.

Table 1.A7 presents the results. Since the baseline in this regression is 2001, I read these results with caution. First, we see that around eighty percent of products are available in stores in both regions. Also, the logit estimates suggest that products available in the stores of the Southeast/Midwest became more likely to be present in the stores of the South as well. This is evidence against the hypothesis that the composition of products in the stores of the Southeast/Midwest specialized in products not available in the South region.

[43] For example, "REFRIGERADOR DOMESTICO 440 LITROS MOD:DOUBLE 44 ELECTROLUX (UNID)".

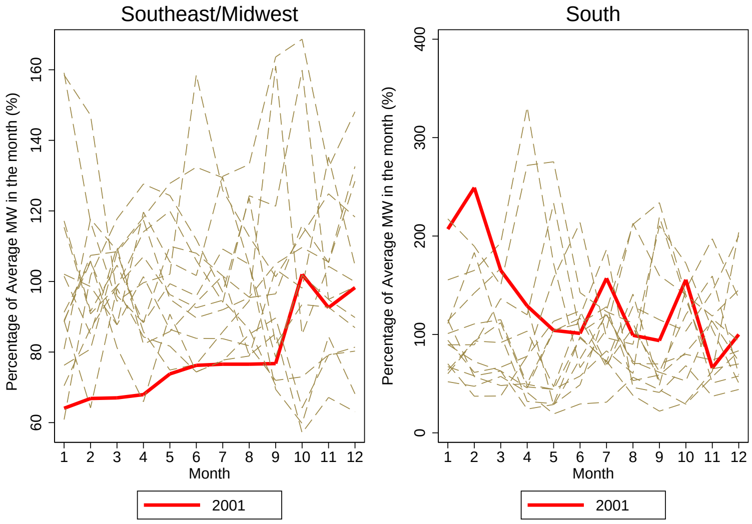


Figure 1.A1: Stream-flow Energy of Rivers as Percentage of Subsystems' Historical Average (1996-2010)

Notes. This figure presents the stream-flow energy level of the rivers in each month as a percentage of the subsystem's historical average for each month. That is, a value 100 means that in that month-year the stream-flow level was equal to the average stream-flow level in that month of the year. Each line represents a different year from 1996-2010. As we can see, the stream-flow level in the subsystem Southeast/Midwest in the first half of 2001 is practically the lower envelope of the historical series in the first months of the year. This low stream-flow level triggered the rationing in early 2001. Source: National System Operator (ONS).

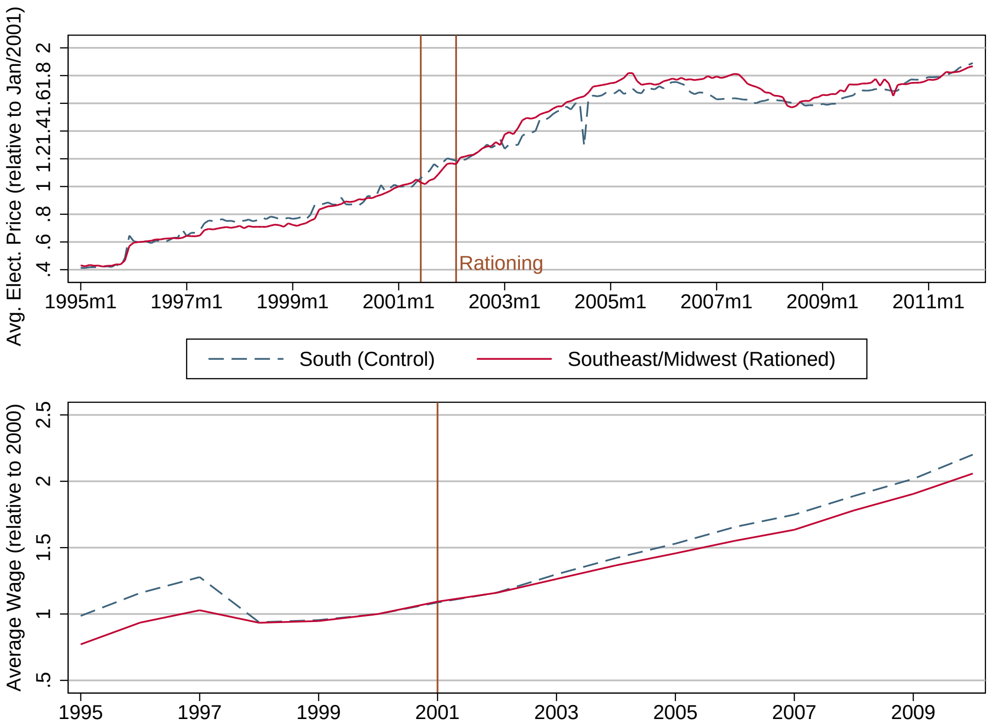


Figure 1.A2: Evolution of Electricity Prices and Wages Normalized to Pre-Rationing Levels

Notes. The first graph presents the monthly average electricity prices in the South and Southeast/Midwest, normalized to prices of January 2001. The two vertical lines mark the rationing period. Data from the Regulatory Agency ANEEL. The second graph presents the annual average wage in the South and Southeast/Midwest, normalized to wages of 2000 (before the rationing). The vertical line marks 2001, the rationing year. Data from the Ministry of Labor's register (RAIS).

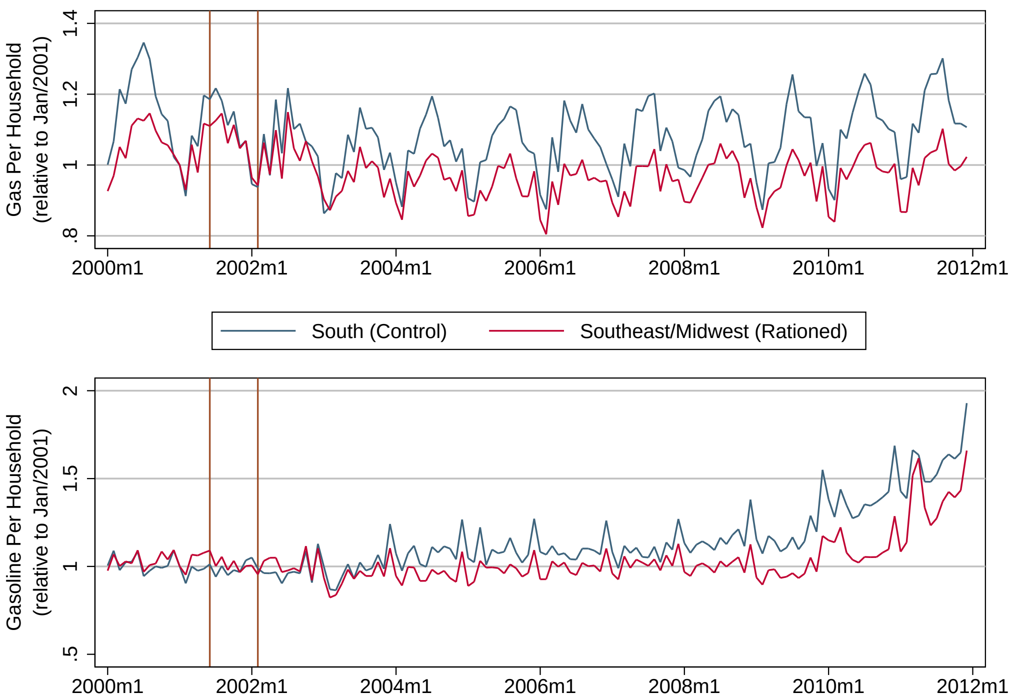


Figure 1.A3: Evolution of Total State Natural Gas and Gasoline Per Household Normalized to Pre-Rationing Levels

Notes. The first graph presents the total state monthly natural gas (GLP) consumption divided by the number of households in the South and Southeast/Midwest, normalized to levels of January 2001. The second graph presents the total state monthly gasoline consumption divided by the number of households in the South and Southeast/Midwest, normalized to levels of January 2001. The two vertical lines mark the rationing period. Data at the state level from the National Agency of Petroleum, Natural Gas and Biofuels (ANP).

Table 1.A2: Main Datasets Descriptive Statistics

	Electricity Data (ANEEL) (1)	Habits of Energy Use (PPH) (2)	Appliances Holdings (POF) (3)
Type	Administrative, panel	Survey, repeated cross section	Survey, repeated cross section
Time Period	Jan/97 - Dec/10, Monthly	1998/99 and 2004/05	1996/97, 2002/03, and 2008/09
Observation Unit	Utility Co.	Household	Household
Cluster Unit	Utility Co.	Utility Co.	State
Number of Clusters	44	10	11
Number of Observations	7686	14254	61342

Table 1.A3: Realized Electricity Demand as Percentage of Demand Forecast (%)

	Southeast	**Midwest**	**South**	**Brazil**
	(1)	(2)	(3)	(4)
1998	99.6	98.5	97.9	99.4
1999	95.6	96.4	97.5	95.6
2000	96.2	95.7	98.5	95.6

Notes. This table presents realized electricity demand in each subsystem and year as as a percentage of the demand forecast from the 1997-2007 Decennial Energy Plan (PDE) produced by the National System Operator along with the Mining and Energy Ministry. That is, the 99.6 in the first cell means that the energy used in the Southeast in 1998 was 99.6 percent of the forecast demand for that region and year in PDE (1997).

Table 1.A4: Placebo Estimation (North and Northeast)

	Households Connected to Electricity (1000s)	Real Electricity Price (R$)	Consumer Price Index	Average Wage (R$)	Employment (1000s)	Share of Households Paying for Electricity	Average Household Size
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
During*Rationing (β_D)	71.029*	.007	-.003	-62.749*	67.671*	.170***	-.175***
	(36.203)	(.007)	(.006)	(35.640)	(39.700)	(.030)	(.056)
Post*Rationing (β_P)	250.041*	.000	-.042	-102.583*	172.598*	.209***	-.205
	(122.158)	(.008)	(.041)	(55.872)	(97.374)	(.026)	(.048)
Dataset	ANEEL	ANEEL	IBGE	RAIS	RAIS	POF	POF
Mean	694.3	.16	1.35	767.20	1121.6	.79	3.84
Observations	3216	3216	537	210	210	59110	46341
Cluster level, i	18	18	4	15	15	16	16
Periods, t	179	179	179	14	14	3	3
R-squared	.956	.129	.998	.982	.945	.044	.029

Notes. This table displays the difference-in-differences estimates of the rationing effects on the rationed households during and post the intervention, captured by β_D and β_P from equation (2). Each column corresponds to the regression of a different dependent variable. *Sample* comprises the subsystems North and Northeast, excluding Para where the rationing had a particular timming and target. *Data sources:* administrative data from the Regulatory Agency (ANEEL) is at month-utility company level, between January 1997 until December 2010; Price Index from INPC (IBGE), at month-metropolitan area level; Ministry of Labor's register (RAIS) at year-state level; household level microdata from the Household Budget Survey 1996/1997 (POF), estimations with sampling weights. All regressions with constant, period t and cluster level i fixed effects. Standard errors in parentheses are clustered by i according to data source as indicated.

Table 1.A5: Hypothetic Average Appliances Electricity Consumption

	Appliance Specification	Daily Use	Average Monthly Consumption (kWh)
		(1)	(2)
Air Conditioner	Wall, 9001-14000 BTU	8 hours	181.6
Electric Shower	Low Power	26 minutes*	45.5
	High Power	26 minutes*	65.0
Freezer		24 hours	54.0
Refrigerator	1 Door, Frost Free	24 hours	39.6
Light Bulbs	Incandescent 60 Watts	5 hours	9.0
	Fluorescent 15 Watts	5 hours	2.25

Notes. This table presents the *hypothetical* average electricity use of appliances, calculated by the Brazilian energy efficiency program PROCEL based on technical characteristics of appliances and hypothetical utilization. I use these values to convert the effects in Section 5 into kWh. (*) The shower calculation is based on 3.25 household members using the shower (number obtained from PPH 1998) and an average shower time of 8 minutes. The complete table can be found in the website www.eletrobras.com/procel.

Table 1.A6: Adoption of Energy-Saving Measures

	Energy Saving Measures									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rationing Effect in 2005 (β_{05})	.004	-.014	.037*	.026	.206***	.414***	.280***	-.007	-.054	.011
	(.082)	(.015)	(.018)	(.023)	(.021)	(.024)	(.023)	(.041)	(.047)	(.053)
2005 Dummy(γ_{05})	.184***	.415***	.374***	.381***	.126***	-.002	.116***	.341***	.416***	.375***
	(.010)	(.010)	(.021)	(.023)	(.011)	(.011)	(.011)	(.022)	(.019)	(.024)
Mean	.789	.298	.294	.266	.177	.375	.263	.200	.315	.326
Observations	10747	10747	10747	10747	10747	10747	10747	10747	10747	10747
Utilities, i (cluster level)	10	10	10	10	10	10	10	10	10	10
R-squared	.054	.322	.446	.466	.359	.239	.344	.280	.170	.176

Notes. This table displays the difference-in-differences estimates of the rationing effects on the adoption of ten different energy-saving measures which are proxies for consumption habits, from equation (4) in Section 5. Each column corresponds to the regression of a different energy-saving measure as dependent variable, and present the marginal effects of logit estimation. Household level microdata is from the Appliances and Habits of Use Survey (PPH/PROCEL) 1998/1999 and 2004/2005. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. All regressions contain utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". Standard errors in parentheses are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by utility company. Dataset does not contain sample weights. Energy-Saving Measures: *(1)* Switch off the lamps when leave the room for more than 30 minutes; *(2)* Do not open the fridge/freezer door fully; *(3)* Do not storing warm food in the fridge/freezer; *(4)* Do not dry clothes behind the fridge/freezer; *(5)* Verify the condition of fridge/freezer's rubber seals regularly; *(6)* Reduce shower time when using an electric shower; *(7)* Adjust the shower thermostat according to the ambient temperature; *(8)* Use washing machine in full load; *(9)* Accumulate clothes to iron; *(10)* Switch off the TV when not watching. ***p<.01, ** p<.05, * p<.1.

Table 1.A7: Results on Appliances Holdings' Characteristics

	Fridge Size (Liters) (1)	Freezer Size (Liters) (2)	AC Power (BTU) (3)
Rationing Effect in 2005 (β_{05})	-31.233	-19.936	1207.393
	(40.268)	(33.681)	(1542.094)
2005 Dummy(γ_{05})	22.137	7.462	-162.232
	(49.693)	(15.762)	(4975.346)
Sample Mean	295.1	234.7	8081.7
Estimation	OLS	OLS	OLS
Utilities i (cluster level)	10	10	10
Observations	6682	1578	551
R-squared	.065	.030	.112

Notes. This table displays the difference-in-differences estimates of the rationing effects on different proxies for electrical appliances' characteristics, from equation (3) in Section 5. Each column corresponds to a regression with a different dependent variable and appliance. Columns 1 to 2 present the coefficients of OLS estimation expressed in units of liters (the size of fridge and freezer), while column 3 presents the coefficients of OLS estimation expressed in BTU (power of air conditioners). Household level microdata is from the Appliances and Habits of Use Survey (PPH) 1998/1999 and 2004/2005 conducted by the Brazilian energy efficiency program PROCEL. *Sample* comprises ten utility companies from the subsystems South and Southeast/Midwest. All regressions contain utility company, and year fixed effects, income, squared income, number of household members, build up area, and dummies for rich neighborhood and for proximity to "favelas". Standard errors in parentheses are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by utility company. Dataset does not contain sample weights. ***p<.01, **p<.05, *p<.1.

Table 1.A8: Results on Retail Market Composition

	Dependent Variable: Product Available in Both Regions (C_{ktr})							
	All Appliances				Fridge	Freezer	AC	Lamps
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(9)
Post*Rationing (β_P)	.222***	.224***	.222***	.233***	.151***	.339***	.212***	.107
	(.033)	(.033)	(.075)	(.075)	(.056)	(.078)	(.064)	(.079)
$Ration_r(\gamma_r)$	-.227***	-.229***	-.227***	-.255***	-.194***	-.235***	-.071	-.208***
	(.027)	(.027)	(.047)	(.061)	(.039)	(.074)	(.058)	(.066)
Year Fixed Effects	✓	✓	✓	✓	✓	✓	✓	✓
Appliance Fixed Effects	.	✓	.	.	.	.	.	.
Robust S.E.	✓	✓	.	✓	✓	✓	✓	✓
Clustered S.E. (5 clusters)	.	.	✓	.	.	.	.	.
Weighted Regression	.	.	.	✓	.	.	.	.
Mean Dep. Variable	.790	.790	.790	.790	.808	.776	.840	.819
Observations	2053	2053	2053	2053	720	222	254	604
Products, k	671	671	671	671	267	83	73	174

Notes. This table displays the estimates of the logit regression capturing the post rationing effect on the composition of products being sold by electrical appliances retailers, β_P from equation (3). Each column corresponds to a different regression using the specifications indicated in the rows. Marginal effects are presented. The unit of observation is product, year and subsystems (South and Southeast/Midwest), ranging from 2001 to 2005. *Sample* in columns 1 to 4 comprises all electrical appliances (fridge, freezer, AC, and lamps), remaining columns restrict sample to the appliances indicated int he top row. Regressions are not weighted, except in column 4 where regression is weighted by the number of stores selling each product. *Standard errors* are estimated with Huber-White robust estimator, except in column 3 where standard errors are estimated using wild cluster bootstrap as Cameron, Gelbach and Miller (2008), clustered by appliance. *Controls.* All regressions with constant, year and region fixed effects. Regression in column 2 includes appliance fixed effects. *Source.* Microdata from the consumer price index (IPC) collected by IBRE/Getulio Vargas Foundation. *** p<.01, ** p<.05, * p<.1.

Table 1.A9: (Part 1) Statistics from Qualitative Variables (Percentage of Respondents)

	South (1)	Southeast/Midwest (2)
Change in life quality due to rationing?	(N=788)	(N=2668)
None	.48	.43
Less comfortable	.02	.21
Much less comfortable	.00	.08
Learnt to have comfort while saving money	.49	.28
Did you substitute incandescent light bulbs with fluorescent ones?	(N=1000)	(N=2819)
Yes, all.	.54	.32
Yes, more than half of them.	.00	.04
Yes, less than half of them.	.00	.07
No.	.45	.56
Do you still use fluorescent light bulbs?	(N=552)	(N=1160)
Yes, all of them.	.99	.69
No, I am back to incandescent ones.	.00	.22

Notes. This table displays the percentage of households in each region (column) who chose the stated response to each of the questions (rows). Data from the Appliances and Habits of Use Survey (PPH) 2004/2005.

Table 1.A9: (Part 2) How the Rationing Affected Appliances Utilization? (Percentage of respondents in the Southeast/Midwest)

		Use as before the rationing (1)	Use less than before the rationing (2)	Bought it after the rationing (3)
Refrigerator	(N=2716)	.88	.12	.00
Freezer	(N=542)	.60	.37	.02
Air conditioner	(N=219)	.28	.69	.03
Electric Shower	(N=2510)	.56	.43	.00
Lamps	(N=2730)	.46	.54	.00

Notes. This table displays the percentage of households in the Southeast/Midwest who chose the stated response (column) to the questions regarding each appliance (row). Data from the Appliances and Habits of Use Survey (PPH) 2004/2005.

Chapter 2

Winners and Losers in the Labour Market: Heterogeneous Effects of Brazil-China Trade[1]

2.1 Introduction

China's recent growth and emergence into the world economy is one of the largest economic events of recent times. Between 1990 and 2008, the Chinese economy grew at two-digit rates for years and became well integrated in the world's production chain. In this period, Chinese trade with the world grew at a stunning average of 19 percent per year. Triggered by internal market-oriented structural reforms, this growth was supported in part by the development of a strong export-oriented, labour-intensive manufacturing sector at the same time that the country became a major importer of raw materials and components for final assembly in Chinese factories. Naturally, a phenomenon of this magnitude should affect production and labour markets in the rest of the world. We examine the effects of China's growth on local labour markets in a single (large) developing country – Brazil.

Much of the reduced-form literature on the effects of this 'China shock' in other countries has seen China as a competitor, affecting, for example, manufacturing employment (Hsieh and Woo 2005, Autor et al. 2012, Pierce and Schott 2012), firm exit (Iacovone et al., 2013), and innovation (Bloom et al., 2011) mainly via import competition. However, China is also an increasingly large consumer of goods produced abroad. If China has been the source of a large import competition shock, it must also have been the source of a large export demand shock, which potentially affects different sectors and areas (Dauth et al. 2012, di Giovanni et al. 2012).

This paper investigates how the effects of increased Chinese import competition on

[1] This is joint work with Jason Garred and João Paulo Pessoa.

local Brazilian labour markets versus increased Chinese demand for Brazilian goods. Imports from China are almost entirely manufactured goods, while exports to China are increasingly in primary goods (products of agriculture and mining sectors). We exploit that Brazil is a geographically large country, and areas affected by import competition and/or export demand may be far apart, to perform a within-country, across-local-labour market analysis to identify any heterogeneity in the labour market effects of Chinese import competition and export demand growth. We do this by comparing trends in microregions with different exposure to these 'China shocks', similar to Bartik (1991), Topalova (2007) and Autor et al. (forthcoming). Using Brazilian census data, we analyze unemployment, employment structure (across sectors primary/manufacturing/services), informality, wages, participation in Brazilian main cash transfer program and migration. We find evidence of significant and heterogeneous effects on both sides of the 'China shock' across most of these dimensions.

Figure 2.1 shows that China's total exports are dominated by manufactures, while an increasing share of China's total import demand is for primary goods. It is also evident that the share of primary goods in China's imports from both developed and (especially) developing countries tripled in one decade. This suggests that China may be inducing a commodity boom by shifting out the demand, a set of products that developing countries tend to specialize in. Therefore, in order to understand the full effects of the demand-side 'China shock', we should incorporate primary sectors into our analysis – particularly if we are interested in effects on developing countries. Moreover, we might expect labour market variables to respond asymmetrically to parallel shocks in primary and manufacturing sectors. However, the literature on the consequences of the Chinese growth to the world currently focuses on the manufacturing sector. We extend the analysis to examine the effect of China on local labour markets within both manufacturing and non-manufacturing sectors.

In order to understand these heterogeneous effects from China on a developing country's local labour markets, we want to study a country with sizable trade with China where both the import and the export sides are important, and with a diverse manufacturing and primary sectors composition. Brazil satisfies these conditions at the same time that it has a large territory with segmented local labour markets (Kovak, 2011). As shown in Figure 2.2, both Brazilian imports from and exports to China rose from around 3 percent to 15 percent over the last 15 years.[2] We can see as well in this figure that imports from China constitute almost entirely of manufactured goods, while exports are increasingly in the primary sectors. That is, by looking at Figures 2.1 and 2.2, we can see that the recent evolution of Brazil-China trade is not specific to Brazil, it follows a wider

[2]Figure 2.A1 in the appendix provides evidence that this growth is mostly due to trade creation and not trade being diverted from other countries.

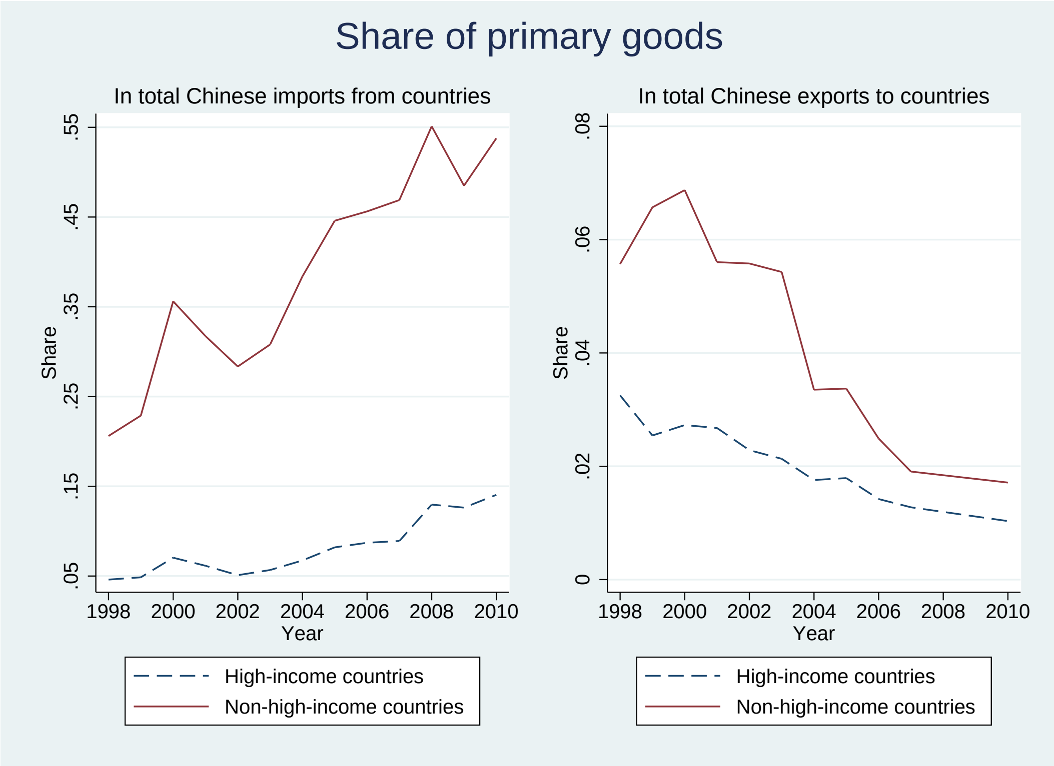


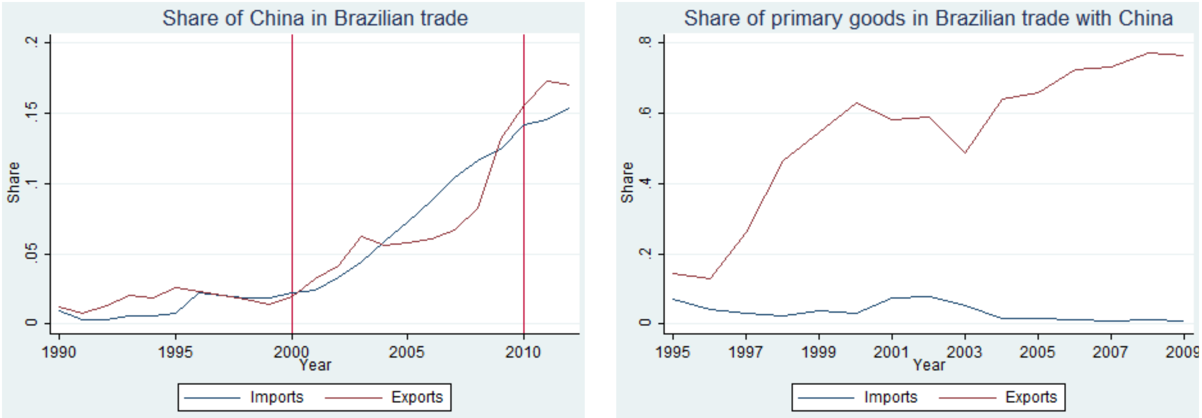
Figure 2.1: Evolution of the Share of Primary Goods in China's Imports and Exports

Notes. This graph presents the evolution of the share of primary goods in China's imports from and exports to high-income and non-high-income countries. *Source*: CEPII BACI, and definition of high-income countries from the World Bank.

change in trade pattern between China and the rest of the world.

Our identification strategy explores precisely the industrial and geographical variation on exposure to Chinese trade using a methodology closely related to Bartik (1991) and Topalova (2007). Our unit of local labour markets is a microregion: a geographical unit analogous to a commuting zone. Essentially, we allocate the 'China shocks' across these microregions according to the initial composition of their economies. Then we compare microregions with the same initial structure of employment (primary/manufacturing/services) that were exposed to China's growth to a different extent, with variation coming from the basket of goods within manufacturing and within primary. To account for correlated shocks simultaneously affecting Brazil-China trade and local labour markets, we instrument Brazilian imports from (exports to) China with Chinese exports to (imports from) all other non-high-income countries, close to Autor et al. (forthcoming). To account for international technological correlated shocks, we control for product-specific worldwide trends using a fixed effect regression methodology similar to Greenstone and Mas (2012).[3] We also make an argument regarding correlated Brazilian technological shocks.

[3]In Chapter 3 of this thesis we consider a counterfactual approach to separately identify the supply shocks and account for them in a Ricardian framework.



(a) (b)

Figure 2.2: Evolution of Brazil-China Trade

Notes. Graph (a) presents the evolution of the share of China on Brazilian total imports and exports. Graph (b) plots the share of primary goods in Brazil's import from and exports to China over time. *Source*: CEPII BACI.

One particular characteristic of labour markets in developing countries that cannot be neglected is that the informal sector[4] corresponds to a large share of these economies. In Brazil, for example, half the employed working age population fell under informal salary workers or self-employed workers according to the 2000 Demographic Census. Despite its relevance, there is a lack of empirical evidence of trade effects on the dynamics between formal and informal labour markets. In order to shed light on this point, we use data from the long form Brazilian Census 2000 and 2010, rather than data from the formal sector administrative records as most of the literature on trade and labour market in Brazil. The Census is a comprehensive dataset containing employment characteristics (industry activity and informality), as well as other relevant labor market variables such as wages and the participation in one of the largest cash transfer programs in the world, *Bolsa Família*.

Our results shows that import competition had no effect on the share of the working age population employed. However, it reduced in-migration to microregions exposed to competition from China. Evidence suggests deindustrialization in microregions affected by competition from China, characterized as reallocation of workers from manufacturing sector into services and primary sectors. Also, the share of workforce in formal manufacturing jobs seems to have shrank by 15 percent due to the 'China import shock'. However, this was more than compensated by an increase in the share of formalization in primary and services sectors. While we find no effects on wages overall, we find that manufacturing average hourly wages fell by 3 percent on average. Lastly, competition from China seems to have increased the share of the working age population receiving *Bolsa Família* by 0.3

[4]We follow the definition of informality from Schneider and Enste (2000): "all economic activities that contribute to the officially calculated (or observed) gross national product but are currently unregistered."

percentage points.

The effects of the 'export demand shock' are different, and seem to be consistent with quality-upgrading mechanism (Bernard and Jensen 1999; Verhoogen 2008). While we see no robust effect on the share of the working age population employed, we observe an increase in migration into microregions exposed to Chinese demand growth, as well as a large movement into formality. In particular, the primary sector benefited the most. This is a sector with traditionally high informality and low wages, and we find that the boom of exports to China caused a 40 percent increase in formalization in this sector, along with a 6.5 percent increase in average hourly wages. Reflecting these positive effects, we find that 'China export shock' led to an average reduction of 0.4 percentage points in the share of the workforce receiving *Bolsa Família*.

This paper contributes to the literature fourfold. First, we present evidence of the heterogeneous effects of China's growth on local labour markets in a large developing country. Second, we investigate the different impacts of both shocks from China, namely import competition and export demand. Third, we are the first to consider the effects of Chinese commodity demand growth on labour markets abroad. Fourth, we investigate trade effects on the dynamics between formality and informality, as well as participation on cash transfer programs, two important dimensions of labour markets in developing countries.

This paper closely relates to the literature on trade shocks and local labour markets, such as Topalova (2007) on India; Bustos (2011) on Argentina's industrial firms; Bernard and Jensen (1995) on the US exporters manufacturing sector; Autor et al. (forthcoming, and 2013) on China import competition on the US manufacture; and McLaren and Hakobyan (2012) on NAFTA's effect on the US. There is a growing literature investigating trade impact on Brazilian labour market (Chatterjee et al. 2013, Helpman et al. 2013), with particular attention given to the trade liberalization from early 1990s (Gonzaga et al. 2006, Dix-Carneiro 2011, Menezes-Filho and Muendler 2011, Kovak 2011). We believe we are the first to study the recent rise in Chinese commodities demand on labour markets abroad, as well as the first to investigate its consequences in Brazil.

Also relevant to this study is the literature on trade and informality, such as Goldberg and Pavcnik (2003), Nataraj (2011), McCaig and Pavcnik (2012), or Schneider and Enste (2000) for a survey on informal economies. We contribute to the understanding the heterogeneous effects of trade shock, specially the recent Chinese growth, on informality dynamics abroad.

The paper is organized as follows. We describe the data and background in Section 2. In Section 3 we present the empirical strategy. In Section 4, we present the results first looking at the effect of the 'China import competition shock' in employment and informality by industry, and subsequently at the effect of the 'export demand shock' on these same variables. Finally, we investigate the joint effect of both shocks on wages and on the participation in cash transfer programs in Section 4.3. Section 5 concludes, and the Appendix contains further empirical results and statistics.

2.2 Data and Background

This section describes the data used and provides basic summary statistics on evolution of Brazil-China trade and Brazilian labour market over the last 15 years.

2.2.1 Data

Labour market and socioeconomic data is from the long form Brazilian Demographic Census (*Censo Demográfico*) for 2000 and 2010 from the Brazilian Geography & Statistics Institute (IBGE). This is a comprehensive survey with individual level data. We are interested only in those individuals most likely to be participating in the labour market, therefore we consider only the working age population or the workforce which we define as every individual between 18 and 60 year old. We do not have data for the states Acre and Rondonia in 2000, so we exclude these states from the analysis (around 1.08% of the national workforce in 2000 and 1.16% in 2010). Data contains many labour market information including employment, wages, and average hours worked per week. Industry is classified according to *CNAE Domicílio* in 2000 and *CNAE Domicílio 2.0* in 2010, with an official concordance between the two. We calculate average hourly wages by dividing monthly wage by 4.3 times hours worked per week.

Our empirical strategy is at the local labour market level, so we aggregate the individual data by microregions using sampling weights. Microregion is a geographical unit defined by IBGE grouping municipalities according to their borders and integration of local economies. So our sample constitutes the 545 microregions in Brazil (excluding Acre and Rondonia), each containing an average of 10 municipalities. We cluster standard errors at a larger geographical area, mesoregions, which are constructed by IBGE analogously to the microregions. We have 136 mesoregions.

Trade data is from the world trade database developed by the CEPII (CEPII BACI). In contains the annual total value (in thousands of US dollars) of trade at industry-importing country-exporting country level from 1998 to 2010, containing more than 200 countries. This is a reconciled dataset originally from COMTRADE by the United Nations Statistical Division. Product disaggregation is at HS96 6-digit level. The HS96 6-digit level classification concordance with *CNAE Domicílio* leaves us a total of 20 primary industries and 36 manufacturing industries, presented in Table 2.A1.

2.2.2 Background

China's recent growth and emergence into the world economy has been extensively documented (Devlin et al., 2006), and I will be brief in this point. To our purposes it is important to highlight that Chinese development in the last decades was fast, large and it was heterogeneous across sectors. As shown in Figure 2.1 in the introduction, China's exports grew dominated by (labour-intensive) manufactures, while China's imports grew dominated by primary goods (products of agriculture and mining sectors).

The trade pattern between Brazil and China evolved in a similar way, as we can see in Figure 2.2. Brazilian imports from and exports to China rose from around 3 percent to 15 percent in a ten-year period, with imports being almost exclusively manufactured goods and exports being largely primary goods. What is important to our identification is that different products within manufacturing and primary goods contributed to this growth in different extents. Three products (iron and manganese ore, soybeans, and oil and gas) are responsible for 84% of the growth in Brazil's exports to China between 2000 and 2010. Although less concentrated, five products (general machinery and computers, other electronics, basic metals, special machinery, and communication equipment) represent 46% of the growth in Brazil's imports from China in the same period.

Table 2.1 presents summary statistics on the evolution of the Brazilian labour market between 2000 and 2010 using the two most recent national census. We can see in columns 1 and 2 that the national workforce grew by almost 20 million people, from a initial base of 94 millions people. At the same time, with the economies' expansion the share of workforce employed grew from 61.9 percent to 65.9 percent, what means the creation of more than 16 million jobs in ten years. We can see in the table as well the evolution of industry composition of Brazilian economy. While the share of workforce employed in primary sector shrank from around 10 percent to about 7 percent, the share of jobs in manufacturing sector remained virtually constant at 8.5 percent.

The sector that experienced the largest growth in the period was the non-trade sector, growing from around 43 percent to more than 50 percent of the workforce. One important event which needs to be considered is the massive expansion after 2002 of the main national cash transfer program, *Bolsa Família*. The share of working age population receiving *Bolsa Família* grew from 0.8 percent to 7.1% in ten years. By 2010, the share of workforce employed in the primary sector was smaller than the share of workforce receiving cash transfer from the national government. That is, this program reached such magnitude that it cannot be neglected in a labour market study.[5]

One particular characteristic of labour markets in developing countries is the size of their informal sector. Conceptually, we understand informality as Schneider and Enste (2000): "all economic activities that contribute to the officially calculated (or observed)

[5]Since cash transfer programs are present in several countries, this is not a Brazilian phenomenon.

Table 2.1: Brazilian Labour Market Summary Statistics

	Total Employment		Formal Jobs		Informal Jobs	
	2000	2010	2000	2010	2000	2010
	(1)	(2)	(3)	(4)	(5)	(6)
Workforce (thousands)	94,373.0	114,094.5				
Migrated in the last 5 years	.076	.115				
Employment share	.619	.659	.242	.327	.305	.286
Traded Sector share	.188	.152	.068	.078	.090	.072
Primary Goods share	.103	.068	.016	.018	.058	.048
Manufactured Goods share	.085	.084	.052	.060	.032	.024
Non-Traded Sector share	.431	.507	.174	.249	.215	.214
Government	.037	.038				
Not Work & Not Study	.323	.288				
Receives *Bolsa Família*	.008	.071				
Income per capita (R$)	198.28	548.63				

Notes. This table displays the descriptive statistics from Brazilian labour market in the years in columns. Workforce in the first row is the total number citizens between 18 and 60 years old. Income per capita is in nominal Real. All remaining variables are expressed as the share of workforce. Columns 1 and 2 present the figures referent to the total labour market. Columns 3 and 4 present figures referent to formal jobs, defined as employees regularly registred at the Brazilian Ministry of Labour and Employment (*com carteira assinada*), as described in Section 2. Columns 5 and 6 present figures referent to informal jobs, defined as employees not-regularly registred at the Brazilian Ministry of Labour and Employment (*sem carteira assinada*) and self-employed. *Source:* 2000 and 2010 Brazilian National Census, at individual level. Weighted data.

gross national product but are currently unregistered." Within our data, we define informal job as informal salary workers (paid with money or in kind) or self-employed workers.[6] Being part of the informal sector brings many disadvantages for the workers and firms since they are not granted their legal rights, such as property rights, and do not benefit from public services, such as social welfare. In 2000, more than 30 percent of the Brazilian workforce was employed in the informal sector, against only 24 percent in formal jobs, columns 3 and 5. The size of informality if very different across sectors. In 2000, while in primary industries the size of informality is more than threefold the size of formality, within manufacturing informal jobs represented about 37 percent of total jobs. Between 2000 and 2010 the share of informality felt in all sectors, although about 3.8 million informal jobs were created in the period.

[6]Although a self-employed worker could be registered with the local or federal governments, these cases are a really small fraction of self-employed workers. Administrative data from RAIS – the records of the Ministry of Labor and Employment (MTE) – show that only 0.9 percent and 0.8 percent of the workforce were registered as self-employed in 2000 and 2010, respectively. This data also corroborates the number of formal salary workers found in the census. We observe an overall under-report of formality of about 10 percent across all sectors, so our results on formality should be underestimated.

2.3 Empirical Strategy

This section describes our identification strategy to estimate both the import competition shock and the export demand shock from China. Essentially, we compare microregions with the same initial structure of employment (primary/manufacturing/services) that were exposed to China's growth in different extent, with variation coming from the basket of goods within manufacturing and within primary in the beginning of the period. In order to do this, we first describe our measure of local labour market exposure to the 'China shocks' in Subsection 3.1. In Subsection 3.2, we describe our main regression model. Last, in Subsection 3.3, we propose an instrumental variable approach to deal with potential spurious correlation and discuss further concerns about our identification strategy. Chapter 3 of this thesis can be seen as a robustness exercise to our instrumental variable strategy.

2.3.1 Trade Exposure Measure

To identify to impact of import competition and export demand from China we exploit geographical variation in the exposure to both of these 'shocks' based on the initial production composition of local labour markets. Our unit of local labour market is a microregion: a geographical unit defined by the Brazilian Geography & Statistics Institute (IBGE) which groups municipalities according to their local economies' integration. The underlying assumption on this type of strategy is that these microregions are segmented labour markets, i.e., labour is not perfectly mobile across microregions. Under perfect labour mobility, wages and labour market conditions would be equalized and effects would unidentifiable (Topalova, 2007). Previous work on local formal labour markets in Brazil suggests that indeed these markets may be quite segmented (Kovak, 2011), and that even mobility between sectors within a local labour market is very costly in Brazil (Cosar 2010, Dix-Carneiro 2011).[7] This is corroborated by the observation that we will find no correlation between our trade exposure measures and the size of the workforce, as shown in Panel A of Table 2.A3.

We allocate the trade shocks across microregions as in Bartik (1991), Topalova (2007) and Autor et al. (forthcoming). We call an import shock in industry k the change in Brazilian imports from China of product k between 2000 and 2010, $\Delta I_k = I_{k,2010} - I_{k,2000}$. We first allocate this shock across microregions, m, according to the fraction of the workers in industry k employed in each microregion, $\frac{L_{km,2000}}{L_{k,2000}}\Delta I_k$, where $L_{km,2000}$ is the number of

[7]There are also plenty of evidence of slow labour mobility in the US both across cities (Topel 1986, Blanchard and Katz 1992) and sectors (Artuc, Chauduri and McLaren 2010). Furthermore, in the US labour mobility is particularly low for non-college graduate (Bound and Holzer 2000, Notowidigdo 2010), the vast majority of Brazilian workforce.

workers in industry k microregion m in year 2000, and $L_{k,2000} = \sum_m L_{km,2000}$.[8] Since microregions differ in size, which affects each industry's relevance for the local labour market, we normalize the trade shock per worker in each microregion, that is,

$$\frac{L_{km,2000}}{L_{k,2000}} \frac{\Delta I_k}{L_{m,2000}}$$

where $L_{m,2000} = \sum_k L_{km,2000}$. In order to find the total local exposure to each trade shock, we aggregate these measures by microregion across industries. Therefore, our import and export penetration measures are, respectively:

$$IPM_m = \sum_k \frac{L_{km,2000}}{L_{k,2000}} \frac{\Delta I_k}{L_{m,2000}}$$
$$XPM_m = \sum_k \frac{L_{km,2000}}{L_{k,2000}} \frac{\Delta X_k}{L_{m,2000}}$$

where ΔX_k is the export shock equal to $X_{k,2010} - X_{k,2000}$.[9]

Table 2.2 presents the summary statistics of IPM_m and XPM_m. Since data is in thousands of US dollars, we have that the average microregion received an import competition shock of US$1890 per worker, and an export demand shock of US$2050 per worker between 2000 and 2010. We can see as well a large variation of this shocks across microregions, with large standard deviation in particular for the export shock. This variation reflects the heterogeneity in the composition of local labour markets that is key for our identification. If all Brazilian microregions had the same production mix we would observe no variation in trade shock exposure.

One important observation for our empirical strategy is that these two shocks are almost orthogonal, with correlation between IPM_m and XPM_m equal to -0.018. This can also be seen when we plot IPM_m against XPM_m in Figure 2.3. In 2000, areas producing the products that experienced a large growth in imports from China were different from those areas producing the products that experienced a growth in exports to China. Figures 2.A2 presents maps of how these shocks are spread over Brazilian territory. It is important to note as well that this variation is not exclusively due to manufacture-intensive against non-manufacture-intensive microregions. Our industry classification contains 20 primary industries and 36 manufacturing industries, it is this within-variation that we exploit.

[8] The underlying assumption here is that the trade shock is distributed uniformly across workers in each industry.

[9] Outliers values of IPM_m and XPM_m (the 1st and 99th percentiles) were assigned the values of the 1st and 95th percentiles.

Table 2.2: Import and Export Penetration Measures Summary Statistics

	IPM_m		XPM_m	
Mean, (s.d.)	1.905	(1.693)	1.646	(2.714)
10 and 90 percentiles	.181	4.761	.128	3.180
Correlation = -.018				

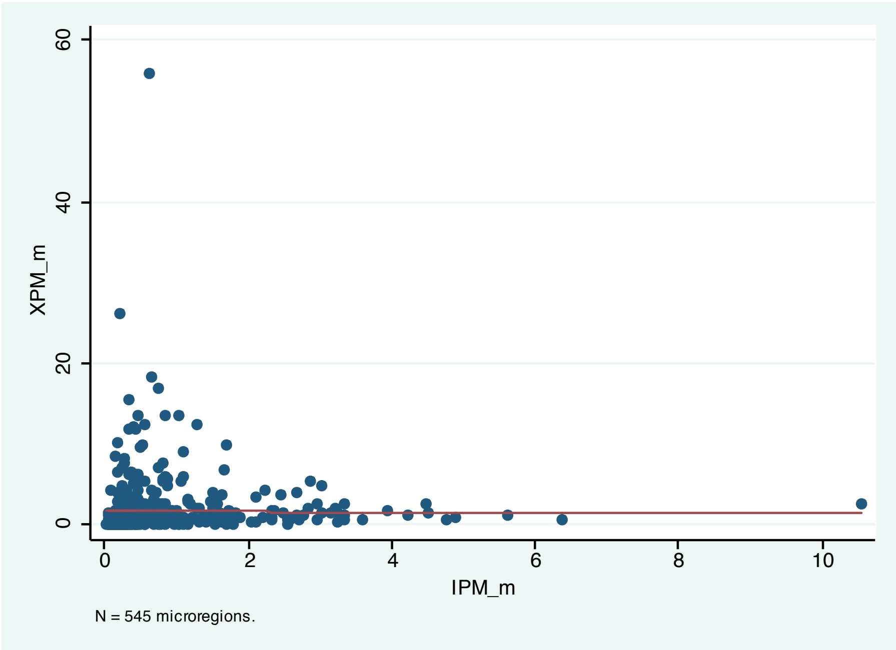


Figure 2.3: China Import versus Export Penetration Shock (2000-2010)

Notes. This graph presents the scatter plot of microregions' export penetration measure (XPM_m) against their import penetration measure (IPM_m), as described in section 3.1. The red line depicts a linear regression of XPM_m on IPM_m (correlation -0.18). *Source*: 2000 Brazilian Census, and CEPII BACI.

2.3.2 Reduced Form

We want to compare trends in labour market outcomes in microregions with different exposure to the 'China competition shock' and the 'China demand shock'. Our first-cut regressions are

$$\Delta y_m = \beta_I IPM_m + \beta_X XPM_m + W_m^{'} \gamma + \epsilon_m \tag{2.1}$$

where Δy_m is the change in labour market outcome between 2000 and 2010 in microregion m, IPM_m and XPM_m are the import and export penetration measures described previously, and W_m is a set of controls. Since we are interested in exploiting within-manufacture and within-primary industries variation, we need to compare areas with similar initial structure of employment (primary/manufacturing/services). Therefore, our set of controls include beginning of period workforce size, share of workers in primary sector in total workforce, share of workers in manufacturing sector in total workforce, share of workers in informal jobs in total workforce, and a cubic polynomial of income per capita.[10] In some specifications we will add further controls to deal with identification issues which will be discussed accordingly. To allow for spatial correlation of errors between microregions, we cluster standard errors at mesoregion level (a more aggregate geographical level). All regressions are weighted by the share of national workforce in the microregion.

The coefficients of interest, β_I and β_X, capture the average effect of extra US$1000 per worker import/export shock on the evolution of the dependent variable. We will investigate several labour market variables, such as employment (by sector and informality), average hourly wage, and the take-up of the largest social assistance program in Brazil, *Bolsa Família*. Two further variables can be used as a cross validation of our strategy that treats microregions as segmented labour markets as already discussed, which are: the size of workforce and in-migration.[11]

2.3.3 Instrumental Variables

Our goal is to identify what is the causal effect of the 'China shocks' on the local labour market dynamics in Brazil. However, regression equation (1) does not capture causality if there are correlated demand or supply shocks unrelated to China which are correlated with our exposure measures IPM_m and XPM_m. These unobserved shocks could be local technological or supply shocks in Brazil correlated with industries which experienced a change in Brazil-China trade or shocks correlated with the labour market variables used to construct the import and export penetration measures. Being more precise, if $corr\left(IPM_m, \epsilon_m | W_m\right) \neq 0$ or $corr\left(XPM_m, \epsilon_m | W_m\right) \neq 0$ our estimates from (1) are biased and we fail to identify causal relation. For example, if goods for which Chinese supply is increasing are also goods that had positive demand shocks (or negative supply shocks) in Brazil.

To deal with this issue we use an instrumental variables strategy. We instrument the import supply shock with a IPM-type measure using exports of China to all other non-high-income countries,[12] $ivIPM_m$. Analogously, we instrument the export demand

[10] It is important to control for a non-linear function of income to deal with the massive roll out of *Bolsa Família* in the period.

[11] In-migration is the share of the workforce who migrated to the current microregion in the previous five years.

[12] According to the Country and Lending Groups classification of the World Bank on July 18, 2013, high-income countries and territories are: Andorra, Antigua and Barbuda, Aruba, Australia, Austria, Bahamas, Bahrain, Barbados, Belgium, Bermuda, Brunei Darussalam, Canada, Cayman Islands, Channel Islands, Chile, Croatia, Curaçao, Cyprus, Czech Republic, Denmark, Equatorial Guinea, Estonia, Faeroe Islands, Finland, France, French Polynesia, Germany, Greece, Greenland, Guam, Hong Kong SAR, China, Iceland Ireland, Isle of Man, Israel, Italy, Japan, Rep. Korea, Kuwait, Latvia, Liechtenstein, Lithuania, Luxembourg, Macao SAR, China, Malta, Monaco, Netherlands, New Caledonia, New Zealand, Northern Mariana Islands, Norway, Oman, Poland, Portugal, Puerto Rico, Qatar, Russian Federation, San Marino,

shock with a XPM-type measure using imports of China from all other non-high-income countries, $ivXPM_m$.

Our strategy relies in four main assumptions for each of these instruments: the instruments are conditionally independent of Brazilian local labour market composition and evolution, $ivIPM_m \perp \Delta y_m | W_m$ *[Assumption 1]*; the instruments are uncorrelated with technological or labour supply shocks in Brazil, $corr\left(ivIPM_m, \epsilon_m | W_m\right) = 0$ *[Assumption 2]*; products that China exports to (or imports from) Brazil are sufficiently similar to the ones that China exports to (or imports from) other non-high-income countries, $corr\left(IPM_m, ivIPM_m | W_m\right) \neq 0$ *[Assumption 3]*; and every sector affected by the instrument is affected in the same direction (monotonicity) *[Assumption 4]*. Under these four assumptions our instrumental variable strategy estimates the conditional local average treatment effect (LATE) of China shock on local labour markets (Imbens and Angrist, 1994).

Assessing these assumptions, Chinese exports to non-high-income countries seem to be a plausible instrument for the import competition shock from China, IPM_m. Regarding *Assumptions 1 and 2, g*iven the small share of Brazil in international and Chinese trade,[13] paired with the much discussed idea that the recent enormous growth of China's trade with the world is driven by structural transformations within China,[14] China's exports to other countries is likely to be independent of labour market conditions in Brazil, and uncorrelated with Brazilian technological or labour shocks. The monotonicity *Assumption 4* says that every industry in Brazil which is affected by the growth of Chinese exports to other countries, is affected in the same way – i.e., or they are all negatively affected or they are all positively affected. International evidence suggest this is the case, increased competition from China negatively affects national labour markets in several industries and countries (Hsieh and Woo 2005, Iacovone et al. 2011, Dautch et al. 2012, Autor et al. forthcoming).

Figure 2.4 and Table 2.A2 provide direct evidence supporting *Assumption 3*. The figure plots the first stage of our instruments. We can see that Chinese exports to non-high-income countries has an enormous predictive power on Brazilian imports from China, the F-statistic is equal to 9120.07. That is, Chinese products are being sold everywhere, and the import competition shock from China on Brazilian firms is basically exogenous to Brazilian labour market evolution and shocks.

Saudi Arabia, Singapore, Sint Maarten (Dutch part), Slovak Republic, Slovenia, Spain, St. Kitts and Nevis, St. Martin (French part), Sweden, Switzerland, Trinidad and Tobago, Turks and Caicos Islands, United Arab Emirates, United Kingdom, United States, Uruguay, and Virgin Islands (U.S.).

[13] In 2010, Brazil represented less than 3% of total Chinese imports and 1.5% of total Chinese exports.

[14] China has been moving towards a market economy in the last decades, for example allowing multinational firms to enter in the country (Naughton, 2007), easing restrictions to national firms to access foreign markets (Hsieh and Klenow, 2009), market-oriented agricultural reforms (Huang and Rozelle 1996, Marden 2012), flexibilizing internal labour migration (Knight and Yueh, 2004), and most recently China gaining most-favored nation status in the WTO (Branstetter and Lardy 2006).

Our instrument for Brazilian exports to China has sound predictive power as well, but not as much high with F-statistic equal to 44.07. A similar set of arguments could be made to claim that Chinese imports from non-high-income countries is also a satisfactory instrument for the export demand shock from China. However, our **main concern** is that this instrument may not deal with correlated supply shocks as the instrument for the import competition shock. In a general equilibrium setting, as will be discussed in Chapter 3 of this thesis, the changes in Chinese comparative advantage are endogenous to a wider set of technology and demand shocks from all other countries, what could hamper the plausibility of assumption 2. That is, part of the Brazilian terms of trade may be a response to a wider change in comparative advantage worldwide not directly driven by China, for example soybeans. Chinese demand for soybeans increased in the recent decades, during the same period that genetic modified (GM) soybean seeds started to be adopted in large scale in the whole world, including Brazil (Bustos et al., 2013).

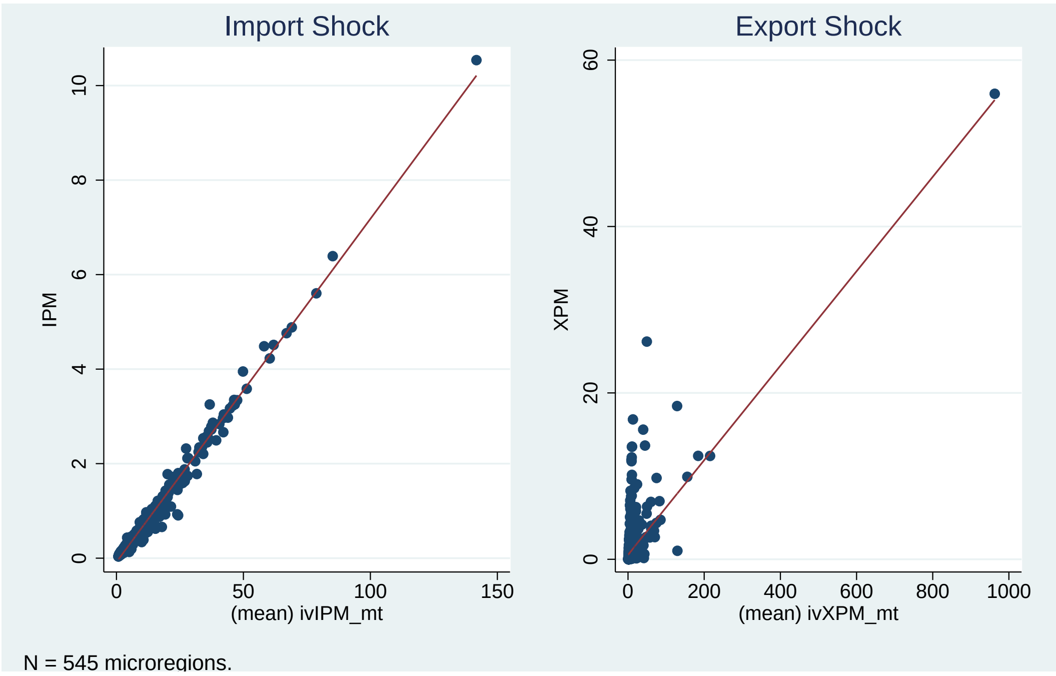


Figure 2.4: First Stage of Instrumental Variables Strategy

Notes. This graph presents the scatter plot of microregions' import and export shocks (IPM_m and XPM_m) against their instruments ($ivIPM_m$ and $ivXPM_m$), as described in the text. The red line depicts the first stage regression of IPM (coefficient 0.072 and s.e. 0.0004) and XPM individually (coefficient 0.059 and s.e. 0.008). F-statistic for import and export shocks are 30588.27 and 61.17, respectivelly. *Source*: 2000 Brazilian Census, and CEPII BACI.

GM *Roundup Ready* soybean seeds started to be commercialized in the US in 1996 and were legalized for cultivation in Brazil only in 2003.[15] Bustos et al. (2013) show that

[15]The main technological advantage of this variety of soybean seeds is that they are herbicide resistant. This reduces soil preparation costs as allows farmers to use herbicides *ex-post* to kill weeds after the crop was planted.

regions within Brazil more suitable to the use of this technology were more likely to adopt it. This is potentially a technological shock correlated to the China export demand shock. However, according to Franke et al. (2009) the adoption of Roundup Ready seeds in Brazil was slower than in other exporting countries and, until 2009, GM adoption was is still lower than the average country due to a market segregation (transportation, storage and processing). Furthermore, Bustos et al. (2013) also document another technological shock in a major crop in Brazil which is not as demanded by China. The Brazilian Agricultural Research Corporation (EMBRAPA) developed a technology that allows the cultivation of a second season of maize (*milho safrinha*). The authors show that the cultivation of maize spread over the lands more suitable to this new technology, similarly to GM soybeans. This is evidence that there was innovations in Brazilian primary sectors, but not necessarily targeted to international demand.

In sum, it is not clear that the adoption of GM soybean seeds in Brazil was a trade induced supply shock in Brazilian agriculture, adoption of GM soybean seed was spread over the world and Brazilian agriculture developed innovations in other crops not targeted to the external-Chinese market. In any case, even in the case that increasing demand from China was positively correlated with local supply shocks, this would bias our estimates of the export demand shock downward.[16] We interpret this soy technology shock as a worldwide correlated technology shock, which we deal in two ways. First, we use a fixed effect regression to estimate the sector-specific growth in the world, and use this as control in our regressions, as we describe in subsection 3.3.1. Second, in Chapter 3 of this thesis we consider a counterfactual approach to separately identify the supply shocks and account for them in a structural general equilibrium framework.

It is worthy to highlight that the export demand shock instrument may not accurately capture changes in Chinese final demand because of the prevalence of processing trade. Because of the existence of imports that are later re-exported after processing – e.g. imports of iron ore transformed into exports of machinery – time-series industry-level import data does not provide an accurate picture of the changing industry composition of a country's import demand for final consumption. In particular Chinese import demand deviates widely from final domestic import demand because of the prevalence of processing trade.[17] Although in the perspective of Brazilian labour markets an intermediary demand shock still constitutes an export demand shock in some sectors, one could be concerned that input trade dominates our instrument for export shocks. Since much of the Chinese imports for processing trade are from other countries in East and Southeast Asia (e.g., Hsieh and Woo (2005)), we deal with this issue by excluding East and Southeast Asia

[16] A second source of positive correlation between Chinese demand growth and technological shock in Brazil is oil discoveries. We perform a robustness check by dropping microregions with a large oil sector.

[17] This is a trade regime allowing inputs to be imported duty-free but requiring that these are re-exported once they are processed, which accounts for about 50% of Chinese trade.

from our instruments as a robustness check.[18] In Chapter 3 of the thesis we also consider a counterfactual to identify a demand (taste) shock in the structural general equilibrium framework.

One could have a similar concern when interpreting the LATE effects of our instrument for XPM_m. Soybeans corresponds to a small share of Chinese total imports, and recently more than 30 percent of Chinese soybeans imports comes from Brazil. So soybeans are underrepresented in our instrument. In order to deal with this, we check robustness of our results using as an alternative instrument: Chinese imports from Latin America excluding Brazil.[19] As we can see in Figure 2.A5 and in column 8 of Table 2.A2, although the predictive power of this instrument gets smaller (F-statistic 17.8) the scatter plot suggest that we have a smaller concentration of microregions for which the instrument fails to predict positive effects. This alternative instrument helps as a robustness check of the magnitude of the LATE effect captured by the main instruments.

One remaining concern about our identification is related to the measurement of the trade data, which is measured in value, current USD. Therefore, changes in relative prices could be underlying the figures observed and could be under- or over-estimating the effects in quantity produced. However, we do not see this as a problem: we are basically positing a terms-of-trade shock in which China changed the relative prices of goods. If the price of soya did not go up, then why would anyone in land-constrained soya-producing regions have gained from increases in soya demand? Wording in an Econ 101 terminology, if there was a demand shock in China that led to a shift out of the world's demand curve, this leads to a concomitant change in prices and quantities. The elasticities of demand and supply should determine how much price was affected and how much quantity was affected, and thus also the redistribution of gains from trade between China and Brazil in the affected sectors after the demand shock. If there are no price effects because of perfectly elastic supply, then neither Brazil, or any other country, would win from the soya demand shock.

2.3.3.1 Fixed Effects

To isolate product-specific worldwide technology or demand shock which could be correlated with the 'China shocks', we need a measure of sector growth net country-specific effects and uncorrelated with product-country specific shocks. We use use the trade data from all countries paired with a methodology similar to Greenstone and Mas (2012) to estimate this measure. Let x_{ij}^k be the total exports of product k from country i to country j. We consider trade between all 200 countries in the trade data to run the following

[18]For example, this considerably reduces the importance of electronic components in our instrument for export demand shock.

[19]Soybean production in some countries in this region grew really fast in the last decade, such as Argentina, Bolivia, Costa Rica and Paraguay.

regression equation

$$\Delta \ln x_{ij}^{k} = \delta_k + \xi_{ij} + e_{ij}^{k} \tag{2.2}$$

where $\Delta \ln z_{k,c}$ is the log-change in total exports of product-origin-destination countries between 2000 and 2010, δ_k and ξ_{ij} are product and exporter-importer countries fixed effects and e_{ij}^{k} is the error term. Therefore, the set of product fixed effects δ_k captures the worldwide product-specific trade growth net exporter-importer specific effects. Table 2.A1 column 7 shows the estimated values $\hat{\delta}_k$.

We allocate this worldwide sector growth across microregions using a IPM-type measure

$$WorldShock_m = 100000 * \sum_k \frac{L_{km,2000}}{L_{k,2000}} \frac{\hat{\delta}_k}{L_{m,2000}}.$$

We use this measure as a control in equation (1) in one specification. Therefore, the exclusion restriction – assumption 2 – of our instrument for the demand shock becomes $corr\left(ivXPM_m, \epsilon_m | W_m, WorldShock_m\right) = 0$. By construction, $WorldShock_m$ is uncorrelated with countries' bilateral trade shocks. That is, assumption 2 would still be an issue if, conditional on W_m and $WorldShock_m$, the instruments are correlated with Brazil-specific technological or demand shocks. Again, if this is still the case, Chinese demand and Brazilian supply shock would be positively correlated, and our instrument would have a positive correlation with the error term, meaning that the estimates would be biased towards zero. The counterfactual demand simulated in Chapter 3 will suggest that the increased Chinese demand for soya was mostly due to income growth in China leading to larger expenditure overall rather than a taste shock specifically to this product.[20]

2.3.3.2 Counterfactual Approach

As discussed previously, ideally we would like to control for local trends that are correlated with the 'China shock' variables and which affect labour market outcomes. In Chapter 3 we aim to get closer to this ideal using structural approaches from Dekle et al. (2007) and Costinot et al. (2012). We simulate counterfactual trends in production and trade, given counterfactual evolution of Chinese production costs relative to those of the rest of the world and/or trade balance. We compare these counterfactuals with the realized evolution of industries to assess the relevance of these correlated shocks to the evolution of Brazilian production across industries.

[20] We intend to use the theoretical framework used in Chapter 3, which is based on Eaton and Kortum (2002) model, to give explicit microeconomic foundations to this fixed effects specification.

2.4 Results

In this section we provide empirical evidence of the ‘import competition shock’ and ‘export demand shock’ from China on a series of labour market variables. In order to present the results in a coherent way, and to simplify the comparison with previous literature, we separately discuss the import and export shocks, IPM_m and XPM_m, on local employment structure (primary/manufacturing/services and informality condition). In subsection 4.3, we consider the effects of both shocks on wages and participation on the largest cash transfer program in Brazil, *Bolsa Família*. As we show in the Appendix, results are not affected if we consider IPM_m and XPM_m jointly or on separate.

First of all, we assess to which extent microregions are a suitable definition for segmented local labour markets. Table 2.A3 in the appendix presents the joint effects of ‘China shock’ in the size of the workforce (Panel A), and in-migration (Panel B).[21] In Panel A, we find no effect of the ‘China import shock’ in the size of the workforce but we find evidence that the workforce of microregions exposed to the ‘China export shock’ experience a faster growth. However, as we can see in column 7, we find no effects when we drop microregions with a large oil sector, what suggests that the oil-rich microregions received some migratory inflow between 2000 and 2010. We find a decrease in migration into microregions affected by competition from China and an increase in migration into microregions exposed to Chinese demand between 2005 and 2010. It is encouraging, however, that the magnitudes are small: the average microregion would have received around 0.5% of the workforce due to Chinese demand growth between 2005 and 2010.[22] [23]

2.4.1 Import Competition

First, we analyze the effect of of China’s growth on local labour markets exposed to competition from China. Table 2.3 presents the results of regressing equation (1) using different specifications on three different LHS variables: the share of workforce employed (Panel A), the share of workforce employed in formal jobs (Panel B) and the share of workforce employed in informal jobs (Panel C). The first three columns display the reduced form results with and without set of controls and with state fixed effects. Since these are regressions in differences, the state fixed effects captures state-specific trends. That is, regressions with state fixed effects capture variations within state trends. All regressions are weighted by the share of national workforce, and standard errors are clustered by mesoregion (136 clusters) to allow for spatial correlation.

[21] In the census the migration variable means migration within the previous 5 years.

[22] Caselli and Michaels (2013) find no migratory flow into municipalities with offshore oil between 1970 and 2005. The different result we find may be due to a recent migration after 2005. If this is the case, this could suggest that labour market segmentation may have been affected endogenously by trade.

[23] We intend to use Dahl (2002) to correct for potential selection bias due to migration.

In Table 2.3 Panel A, we find that import competition had no effect on employment share. We see in columns 1 and 2 that the sign of the coefficients flip when the set of controls are added. This will be a recurrent observation since, as previously argued, we need to add the controls in order to compare microregions with similar structure of employment. We can observe that the estimates of the reduced form are very similar to the ones using the instruments, what is sensible given the strong predictive power of our instruments. We well return to the different IV specifications in time. We do observe in Panel B, however, that competition from China led to an increase in overall share of the formal sector by 0.7 percentage points on average in our prefered specification (column 5), from a base of 24.2 percent.

Table 2.3: Import Competition and Changes in Total Employment by Informality

Dependent Variable: Δ share of workforce

	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Total Employment									
IPM_m	.0210***	-.0005	-.0006	-.0007	-.0007	-.0006	.0007	-.0007	-.0002
	(.0034)	(.0013)	(.0015)	(.0013)	(.0015)	(.0015)	(.0014)	(.0015)	(.0015)
Panel B. Formal Jobs									
IPM_m	.0100***	.0042***	.0036**	.0041***	.0036***	.0036***	.0039***	.0035**	.0039***
	(.0012)	(.0011)	(.0014)	(.0011)	(.0014)	(.0013)	(.0015)	(.0014)	(.0013)
Panel C. Informal Jobs									
IPM_m	-.0024***	-.0015	.0002	-.0015	-.0001	-.0001	-.0001	.0000	-.0002
	(.0007)	(.0011)	(.0015)	(.0011)	(.0014)	(.0014)	(.0016)	(.0015)	(.0015)
Control Set		✓	✓	✓	✓	✓	✓	✓	✓
State FE			✓		✓	✓	✓	✓	✓
Worldwide Product Growth						✓			
Drop Oil Microregions							✓		
IV without Southeast Asia								✓	
IV Latin America only									✓

Notes. This table displays the estimates of Chinese import shock on the change of the share of workforce employed (Panel A), share of workforce employed in formal jobs (Panel B) and in informal jobs (Panel C), captured by β_I from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of observation is microregion and the number of observations is 545, except in Column 7 where the number of observations is 529. The unit of the coefficients is percentage points. All regressions with constant. *Control Set* contains beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 6 add control Worldwide Product Growth in the period net country fixed effects, as in section 3.3.1. The sample in column 7 drops the 16 microregions with the biggest share of oil industry. In columns 4 to 7 we *instrument* imports from China with Chinese export to all non-high-income countries excluding Brazil. Column 8 uses as instrument Chinese exports to other non-high-income countries except Southeast Asia, and column 9 uses as instrument Chinese exports to Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters (131 in Column 7). *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.4: Import Competition and Changes in Employment in Each Sector

Dependent Variable: Δ share of workforce

	Total Employment			Formal Jobs			Informal Jobs		
	OLS	IV	IV	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Primary Sector									
IPM_m	-.0011	-.0013	-.0013	.0020***	.0019***	.0019***	.0009	.0006	.0006
	(.0013)	(.0013)	(.0013)	(.0007)	(.0007)	(.0007)	(.0010)	(.0010)	(.0010)
Panel B. Manufacturing Sector									
IPM_m	-.0035	-.0035	-.0035	-.0040	-.0041	-.0041*	.0005	.0005	.0005
	(.0025)	(.0025)	(.0024)	(.0025)	(.0025)	(.0024)	(.0004)	(.0003)	(.0003)
Panel C. Non-Trade Sector									
IPM_m	.0038*	.0040*	.0040*	.0055***	.0057***	.0057***	-.0013	-.0013	-.0013
	(.0022)	(.0022)	(.0022)	(.0014)	(.0015)	(.0016)	(.0010)	(.0009)	(.0009)
Control Set and State FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Worldwide Product Growth			✓			✓			✓

Notes. This table displays the estimates of Chinese import shock on the change of the share of workforce employed in each sector by informality. Panel A presents labour market results in the primary sector, Panel B in the manufacturing sector, and Panel C in the non-tradable sectors, captured by β_I from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. Columns 1 to 3 presents the total change in the total share of workforce employed in each sector, columns 4 to 6 presents the change in the share of workforce employed in formal jobs, and columns 7 to 9 presents the change in share of workforce in informal jobs. The unit of observation is microregion (N=545). The unit of the coefficients is percentage points. All regressions with constant, State fixed effects and *Control Set* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in columns 3, 6 and 9 add control Worldwide Product Growth as in section 3.3.1. In the columns marked with IV, we *instrument* imports from China with Chinese export to all non-high-income countries excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.4 presents the effects of import competition on employment share, the share of formal and informal jobs by sector. Panel A presents results on the primary sector, Panel B on the manufacturing sector, and Panel C on the non-trade (services) sector. If we look at the estimates in each column comparing the different panels we can have an idea on the heterogeneous effects across sectors. If we look at the results in one panel comparing the different variables – employment, formal and informal jobs – we can have some idea on the dynamic between formality and informality. We can see that the competition shock reduced the share of employment in primary and manufacturing sectors (imprecisely estimated) but developed the non-trade sector. Menezes-Filho and Muendler (2011) also find evidence that Brazilian trade liberalization increased mobility into services using employer-employee data from formal firms in the manufacturing sector.

We can see in columns 4 to 6 of Table 2.4 that competition from China reduced the share of formal jobs within the manufacturing sector (Panel B), the most exposed sector. The share of workforce working in formal manufacturing jobs decreased 0.8 percentage points on average from a base level of 5.2 percent. This would represent a reduction of 15 percent in formal jobs in industries due to competition from China. At the same time, this was compensated by an increase of 1.1 percentage point on formal jobs in the services sector and of 0.3 percentage points in the primary sector, as presented in Panels A and C. This suggests that competition from China leads to local deindustrialization, with jobs from the traded sector migrating to services and primary sectors.

2.4.2 Export Demand

We, now, turn to the labour market effects of the growth of exports to China. Table 2.5 presents the results of regressing equation (1) on aggregate employment and formality in the microregions. In Panel A, we find no statistically significant effects of the 'China export shock' in employment share, except in the specifications in column 6. As we discussed in Section 3.3, one potential issue with the class of instruments used in this paper is the possibility of the existence of correlated technology or supply shocks that could threat the exclusion restriction. This type of positively correlated technology shock would bias our estimates towards zero. We deal with this issue in column 6 by controlling for worldwide product growth using the fitted values from a fixed effect regression following Greenstone and Mas (2012), as in section 3.3.1. This variable aims to capture international demand or supply shock which affected the international trade of products and which could be correlated both with Brazil production and Chinese trade with other non-high-income countries.[24]

[24] For example, genetic modified soybeans seeds. As we can observe in Table 2.A1, the fitted value fixed effect suggests that soybeans had an above average increase in international trade of 0.5 standard deviations of the average increase in trade of agriculture goods.

Table 2.5: Export Demand and Changes in Total Employment by Informality

Dependent Variable: Δ share of workforce

	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Total Employment									
XPM_m	.0060**	-.0001	-.0004	-.0019	-.0022	-.0061***	-.0000	-.0024	-.0009
	(.0027)	(.0007)	(.0007)	(.0012)	(.0015)	(.0017)	(.0015)	(.0014)	(.0010)
Panel B. Formal Jobs									
XPM_m	.0030***	.0016***	.0028***	.0016*	.0039***	.0038**	.0079***	.0033***	.0054***
	(.0011)	(.0006)	(.0005)	(.0009)	(.0011)	(.0015)	(.0019)	(.0009)	(.0013)
Panel C. Informal Jobs									
XPM_m	-.0008	-.0011	-.0019***	-.0029***	-.0039***	-.0037***	-.0039**	-.0037***	-.0034***
	(.0010)	(.0010)	(.0007)	(.0010)	(.0010)	(.0014)	(.0018)	(.0009)	(.0011)
Control Set		✓	✓	✓	✓	✓	✓	✓	✓
State FE			✓		✓	✓	✓	✓	✓
Worldwide Product Growth						✓			
Drop Oil Microregions							✓		
IV without Southeast Asia								✓	
IV Latin America only									✓

Notes. This table displays the estimates of Chinese export shock on the change of the share of workforce employed (Panel A), share of workforce employed in formal jobs (Panel B) and in informal jobs (Panel C), captured by β_X from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of observation is microregion and the number of observations is 545, except in Column 7 where the number of observations is 529. The unit of the coefficients is percentage points. All regressions with constant. *Control Set* contains beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 6 add control Worldwide Product Growth in the period net country fixed effects, as in section 3.3.1. The sample in column 7 drops the 16 microregions with the biggest share of oil industry. In columns 4 to 7 we *instrument* exports to China with Chinese imports from all non-high-income countries excluding Brazil. Column 8 uses as instrument Chinese imports from other non-high-income countries except Southeast Asia, and column 9 uses as instrument Chinese imports from Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters (131 in Column 7). *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.6: Export Demand and Changes in Employment in Each Sector

Dependent Variable: Δ share of workforce

	Total Employment			**Formal Jobs**			**Informal Jobs**		
	OLS	IV	IV	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Primary Sector									
XPM_m	-.0010*	-.0011	-.0026*	.0006***	.0020***	.0039***	-.0004	-.0013*	-.0009
	(.0005)	(.0011)	(.0015)	(.0002)	(.0006)	(.0008)	(.0004)	(.0008)	(.0011)
Panel B. Manufacturing Sector									
XPM_m	.0001	-.0005	-.0029*	.0004	-.0002	-.0026*	-.0003*	-.0002	-.0002
	(.0005)	(.0008)	(.0016)	(.0004)	(.0007)	(.0016)	(.0001)	(.0003)	(.0003)
Panel C. Non-Trade Sector									
XPM_m	.0005	-.0007	-.0006	.0019***	.0024***	.0029**	-.0013***	-.0025***	-.0027***
	(.0005)	(.0010)	(.0013)	(.0005)	(.0009)	(.0012)	(.0003)	(.0005)	(.0007)
Control Set and State FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Worldwide Product Growth			✓			✓			✓

Notes. This table displays the estimates of Chinese export shock on Panel A presents labourTrade data market results in the primary sectorthe change of the share of workforce employed in each sector by informality. Panel A presents labour market results in the primary sector, Panel B in the manufacturing sector, and Panel C in the non-tradable sectors, captured by β_X from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. Columns 1 to 3 presents the total change in the total share of workforce employed in each sector, columns 4 to 6 presents the change in the share of workforce employed in formal jobs, and columns 7 to 9 presents the change in share of workforce in informal jobs. The unit of observation is microregion (N=545). The unit of the coefficients is percentage points. All regressions with constant, State fixed effects and *Control Set* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in columns 3, 6 and 9 add control Worldwide Product Growth as in section 3.3.1. In the columns marked with IV, we *instrument* exports to China with Chinese imports from all non-high-income countries excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

That said, in Table 2.A3 this specification provides the largest estimates of growth in workforce in regions affected by the export shock. According to this specification, the workforce in the average microregion grew by 2.14 percent in the period, while employment share decreased almost 1 percentage point the equivalent to a 1.6 percent decrease. So, according to this specification, employment share decreased due to the faster growth of workforce from migration flow.[25] Note as well that overall employment effect is virtually zero when we drop oil-rich microregions in column 7, in the same way that in Table 2.A3 we find no effect on workforce size under this specification.

While we find small and non-robust effects on overall employment share, we find strong and robust evidence that the demand shock from China increased the share of formal jobs, at the same time that it reduced the share of informality in the local labour markets. Chinese demand for Brazilian products increased by 0.64 percentage points the share of formal jobs in the average microregion, from a base of 24.2 percent, at the same time it reduced the share of informality by the same magnitude. This represents a 2.65 percent increase in formality share.

As we can see in Table 2.6, while this dynamic can be observed in the primary and non-trade sectors, this effect is stronger in the primary sector (Panel A). In 2000, only 1.6 percent of the workforce was formally employed in the primary sector, while 5.8 percent was informal. The average increase of 0.64 percentage points in the share of formal jobs in the primary sector caused by 'China demand shock' represented a 40 percent increase in formalization in the primary sector. We find this result in all specifications, all with similar magnitudes. Curiously, the magnitudes of the formalization effects are even larger when we drop oil-rich microregions and when we use the instrument 'Chinese imports from Latin America'. As we discussed in the previous section, the LATE effect estimated with our main instrument underweights the relevance of soybeans in Brazilian trade, while the instrument using Latin America alleviates this issue.

These result are consistent with a known mechanism in the literature. In order to be sold in the international markets, products need to meet quality standards and a quality-upgrading mechanism would make the more productive firms to grow targeting the exporting market (Bernard and Jensen 1999; Verhoogen 2008). Since formal firms tend to be more productive, this mechanism would suggest that the Chinese demand shock would have a greater impact in the formal firms. Furthermore, it has been observed that the more productive firms enter in the exporting market and this induce the adoption of skill-intensive technologies (Bustos, 2011) what is consistent with our finding on overall employment. The results on wages we present next gives further support this quality-

[25]An alternative explanation could be similar to the one mechanism observed in Menezes-Filho and Muendler (2011). Studying formal labour reallocation, the authors observe Brazilian trade liberalization led to an increase in unemployment suggesting that productivity grew faster "than sales expansions so that output shifts to more productive firms while labour does not".

upgrading mechanism.[26] [27] [28]

2.4.3 Wages and Social Assistance

According to the trade and quality-upgrade mechanism, the more productive firms enter in the exporting market attracting higher-quality workers (Bernard and Jensen 1999, Verhoogen, 2008). Since wages reflects workers productivity, we would observe a positive impact on average hourly wages. Table 2.7, Panel A, presents the joint effects of China import and export shocks on average hourly wages. We observe no significant effect of 'China import competition shock' in wages. However, we find that 'China export shock' caused an increase of 1.5 percent in hourly wages on the average microregion, what corroborates this mechanism.

As shown in Table 2.8, the sector that experienced the largest increase on average hourly wage in response to 'demand shock' was again the primary sector, with an average wage growth of 6.5 percent caused by China demand growth for these products. We can observe as well a weak increase on wages in all sectors in microregions exposed to the demand shock. At the same time, we can observe heterogeneous effects on Panel B. Import competition from China seem to have reduced average hourly wages by 1.6 percent in the manufacturing sector, which could reflect an analogous quality-downgrading effect of trade competition. This dynamic resemble the on observed after the trade liberalization in Brazil, when employment shifted from skilled to unskilled intensive sectors, but within exporting sectors the share of skilled labour increased (Gonzaga et al., 2006).[29]

At last, we can see in Table 2.7, Panel B, the joint effects of China import and export shocks on the share of the workforce enrolled on *Bolsa Família*, the largest cash transfer program in Brazil. We find that the 'import competition shock' led to a statistically significant increase of 0.3 percentage points in the share of workforce receiving *Bolsa Família*. The (weakly) negative effect of import competition on employment share (Table 2.4, Panel B) and wages (Table 2.8, Panel B) in the manufacturing sector is coherent with this result. At the same time, 'China export shock' led to a reduction of 0.4 percentage points in the share of the workforce receiving cash transfer. The boosted primary sector may have contributed to this positive effects. Given that the share of the workforce

[26]Unfortunately, we cannot investigate with the census data whether this is a consequence of formal firms overgrowing informal firms, or whether informal firms become formal. We could do this analysis using administrative data from formal firms in future work.

[27]Furthermore, a more bureaucratic channel could be underliyng the observed increase in formalization. By the Brazilian legislations, only registered (formal) firms can export products. This can generate incentives to formalization both in the extensive and intensive margins, as via a VAT chain effect on formalization (De Paula and Scheinkman, 2010).

[28]This dynamics is also consistent with the literature on trade and informality, such as Goldberg and Pavcnik (2003), Ulyssea (2010), Krishna et al. (2011), and McCaig and Pavcnik (2012).

[29]There is a large literature on the effects of trade increasing inequality in developing countries, see Goldberg and Pavcnik (2007) for a survey.

receiving *Bolsa Família* increased from 0.8 to 7.1 percent in the ten-year period analyzed, the average microregion exposed to the Chinese demand growth experienced a 6% smaller expansion of cash transfers takeup. Since the extensive rollout of this program was one of the government's main campaign promises, this difference is likely to reflect a demand effects. That is, positive or negative trade shocks can have economically meaningful effects on the utilization of national social assistance and safety nets in developing countries.

Table 2.7: Import and Export Demand and Changes in Wages and Takeup of Cash Transfers

	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Average Hourly Wage (Dependent Variable: Δ Log average hourly wage)									
IPM_m	-.0615***	-.0072	.0042	-.0062	.0052	.0052	.0034	.0056	.0061
	(.0068)	(.0086)	(.0046)	(.0082)	(.0045)	(.0045)	(.0045)	(.0045)	(.0045)
XPM_m	.0000	.0108***	.0097***	.0153***	.0093**	.0096**	.0119**	.0094**	.0126***
	(.0036)	(.0020)	(.0018)	(.0034)	(.0038)	(.0039)	(.0061)	(.0037)	(.0036)
Panel B. Takeup of Cash Transfers (Dependent Variable: Δ share of workforce receiving Bolsa Família)									
IPM_m	-.0246***	.0002	.0019**	.0006	.0019**	.0018**	.0022***	.0020**	.0019**
	(.0028)	(.0014)	(.0008)	(.0015)	(.0008)	(.0008)	(.0008)	(.0008)	(.0008)
XPM_m	-.0069***	-.0015*	-.0012***	-.0016	-.0023***	-.0010	-.0027***	-.0022***	-.0019***
	(.0017)	(.0008)	(.0004)	(.0015)	(.0006)	(.0007)	(.0010)	(.0006)	(0.0006)
Control Set		✓	✓	✓	✓	✓	✓	✓	✓
State FE			✓		✓	✓	✓	✓	✓
Worldwide Product Growth						✓			
Drop Oil Microregions							✓		
IV without Southeast Asia								✓	
IV Latin America only									✓

Notes. This table displays the estimates of Chinese import and export shocks on the change of average hourly wages (Panel A), and on the share of workforce receiving social assistance from *Bolsa Família* (Panel B), captured by β_X and β_X from equation (1). Each column corresponds to a different regression using the specifications indicated. The unit of observation is microregion (N=545). All regressions with constant, State fixed effects and *Control Set* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 6 add control Worldwide Product Growth, as in section 3.3.1. The sample in column 7 drops the 16 oil-rich microregions. In columns 4 to 7 we *instrument* imports from (exports to) China with Chinese exports to (imports from) all non-high-income countries excluding Brazil. Column 8 uses as instrument Chinese exports to (imports from) other non-high-income countries except South and Southeast Asia, and column 9 uses as instrument Chinese exports to (imports from) Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.8: Import and Export Demand and Changes in Wages by Sector

Dependent Variable: Δ Log average hourly wage

	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Primary Sector									
IPM_m	.0321**	.0155	.0397**	.0195	.0407***	.0415**	.0403**	.0417***	.0425***
	(.0141)	(.0196)	(.0173)	(.0192)	(.0152)	(.0161)	(.0182)	(.0142)	(.0121)
XPM_m	.0247***	.0264***	.0211***	.0482***	.0405***	.0353***	.0369*	.0410***	.0308**
	(.0085)	(.0056)	(.0052)	(.0114)	(.0121)	(.0136)	(.0210)	(.0128)	(.0151)
Panel B. Manufacturing Sector									
IPM_m	-.0472***	-.0253***	-.0153*	-.0258***	-.0163**	-.0157*	-.0152*	-.0166**	-.0157*
	(.0054)	(.0077)	(.0080)	(.0072)	(.0079)	(.0081)	(.0086)	(.0080)	(.0083)
XPM_m	.0077**	.0132***	.0127***	.0190***	.0159***	.0104	.0180**	.0156***	.0146***
	(.0036)	(.0026)	(.0028)	(.0049)	(.0057)	(.0076)	(.0075)	(.0056)	(.0046)
Panel C. Non-Trade Sector									
IPM_m	-.0313***	-.0051	.0046	-.0043	.0051	.0056	.0042	.0050	.0051
	(.0058)	(.0097)	(.0043)	(.0095)	(.0040)	(.0037)	(.0038)	(.0039)	(.0042)
XPM_m	.0056	.0081***	.0072***	.0144***	.0078**	.0025	.0135**	.0074**	.0126***
	(.0038)	(.0024)	(.0021)	(.0034)	(.0037)	(.0044)	(.0062)	(.0037)	(.0039)
Control Set		✓	✓	✓	✓	✓	✓	✓	✓
State FE			✓		✓	✓	✓	✓	✓
Worldwide Product Growth						✓			
Drop Oil Microregions							✓		
IV without Southeast Asia								✓	
IV Latin America only									✓

Notes. This table displays the estimates of Chinese import and export shocks on the change of average hourly wages in each sector. Panel A presents labour market results in the primary sector, Panel B in the manufacturing sector, and Panel C in the non-tradable sectors, captured by β_I and β_X from equation (1). Each column corresponds to a different regression using the specifications indicated. The unit of observation is microregion (N=545). All regressions with constant, State fixed effects and *Control Set* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 6 add control Worldwide Product Growth, as in section 3.3.1. The sample in column 7 drops the 16 oil-rich microregions. In columns 4 to 7 we *instrument* imports from (exports to) China with Chinese exports to (imports from) all non-high-income countries excluding Brazil. Column 8 uses as instrument Chinese exports to (imports from) other non-high-income countries except South and Southeast Asia, and column 9 uses as instrument Chinese exports to (imports from) Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

2.5 Conclusion

This paper investigates the effects of China's recent ascension into the world's second largest economy on local labour markets in a single (large) developing country – Brazil. We perform a within-country, across-local-labour market analysis to identify heterogeneous labour market effects of growing 'China import competition' and 'China export demand'. Similar to Bartik (1991), Topalova (2007) and Autor et al. (forthcoming), we compare trends in local labour markets with similar initial structure of employment differently exposed to these 'China shocks', with variation coming from the basket of goods within manufacturing and within primary sectors (agriculture and mining) present in these areas at the beginning of the period.

We employ an instrumental variables strategy akin to Autor et al. (forthcoming) to handle potential endogeneity from Brazil-China trade. Using detailed data from the Brazilian Demographic Censuses of 2000 and 2010, we analyze migration, unemployment, employment structure (primary/manufacturing/services), informality and participation in the major cash transfer program in areas affected by the 'China shocks'. We find evidence of significant and heterogeneous effects in both sides of the 'China shock' across most of these dimensions. The primary sector in the microregions exposed to Chinese demand experienced the largest gains, with a large increase in formalization in this sector along with an increase on average hourly wages, and lower participation in *Bolsa Família* program. On the other hand, the manufacturing sector in microregions exposed to competition from Chinese firms experienced the biggest losses: the share of workforce in formal manufacturing jobs shrank, average hourly wages deteriorated, and the share of the workforce receiving *Bolsa Família* increased.

Overall, considering jointly both import and export shocks, a back-of-the-envelope calculation suggests that the growth of Brazil-China trade led to a reduction of 0.4 percentage points in the share of working age population employed. We find, however, that trade with China increased by 1.1 percentage points the share of formal employment in Brazilian labour markets. This suggests that almost 13 percent of the growth of the formal sector in Brazil in the last decade – from 24.2 to 32.7 percent – was a consequence of the tightening of Brazil-China bilateral trade. On a more general note, this evidence suggest that one should be cautious when using formal sector data when studying labour markets in developing countries, since it is difficult to disentangle actual unemployment from labour reallocation between formal and informal markets.

These findings open a few avenues for future work. We intend to take advantage of occupation and other individual level data to understand who is being affected by trade, and its potential effects on labour sorting. We also would like to shed light on the mechanism underlying the dynamics between formal and informal jobs. Is it the case that trade created extra incentives to informal firms to become formal (Ulysseia, 2010), or did formal firms pherhaps take advantage of the international market and overgrow informal ones (Bernard and Jensen 1999, and Verhoogen 2008)? One last avenue is to investigate the effects of the fast expansion of cash transfer programs on labour market participation, and how this interact with the trade shocks.

2.6 Figures and Tables

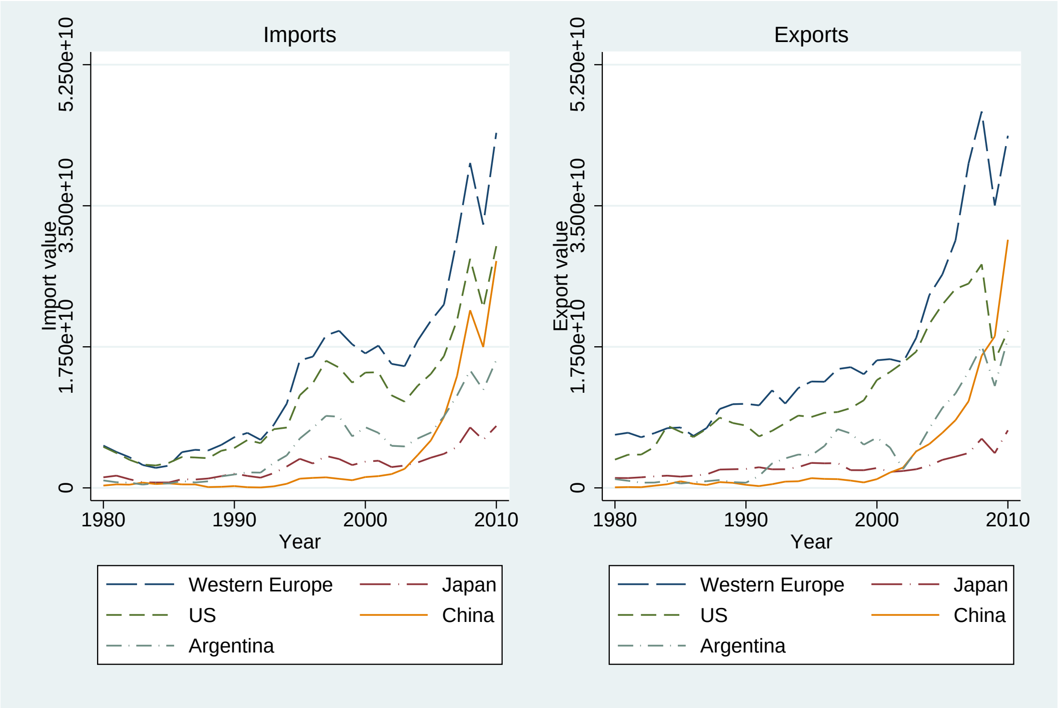


Figure 2.A1: Value of Brazil's trade to varios countries in Current USD

Notes. This graph shows the evolution of Brazilian imports and exports to different countries in current US Dollar. *Source*: CEPII BACI.

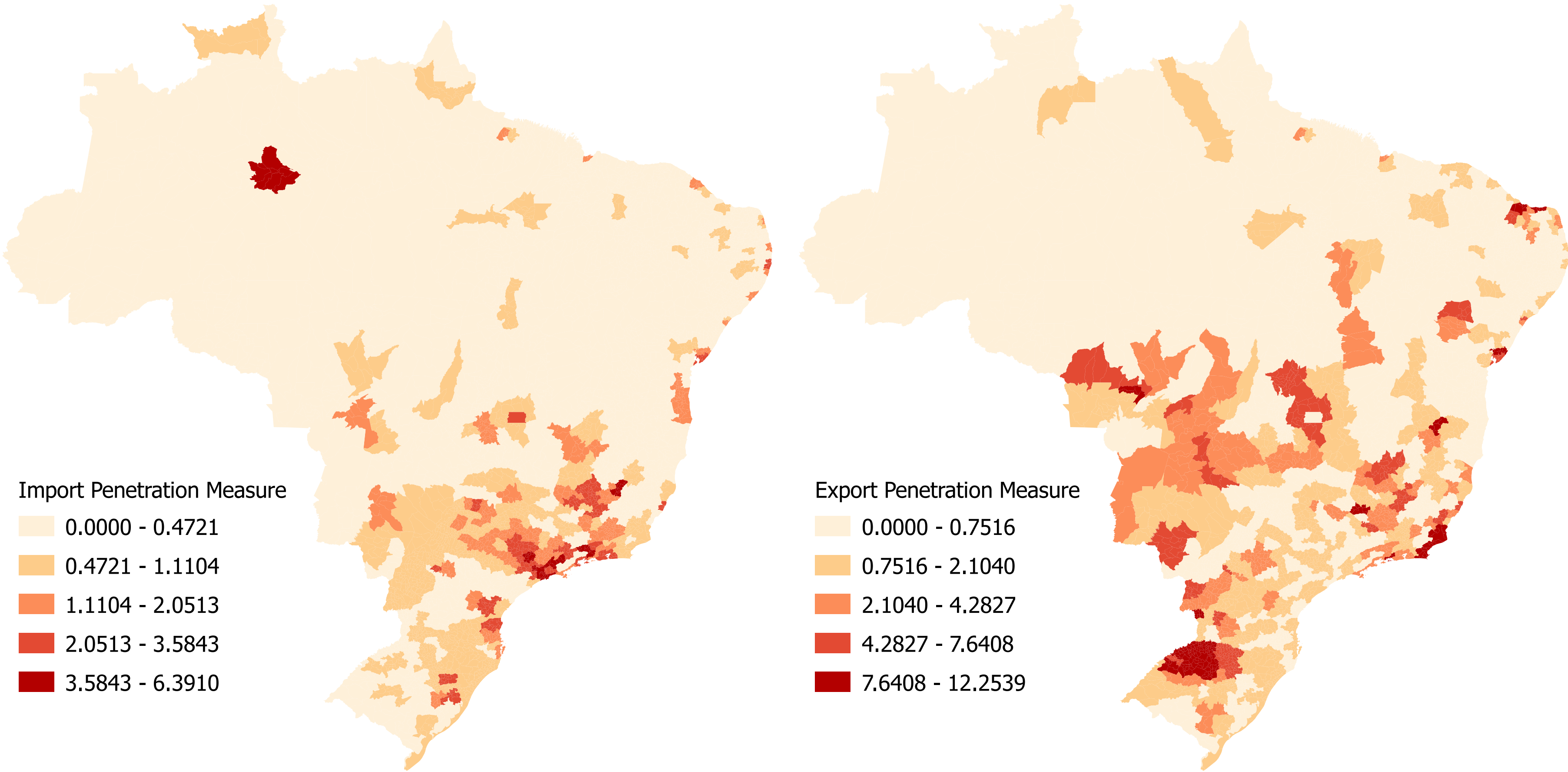


Figure 2.A2: Maps of China's Import and Export Penetration Measures

Notes. The maps show the China's import and export penetration measures (IPM_m and XPM_m) spread over Brazilian territory, described in section 3.1. The colour classifications are natural breaks (Jenks). *Source*: 2000 Brazilian Census, and CEPII BACI.

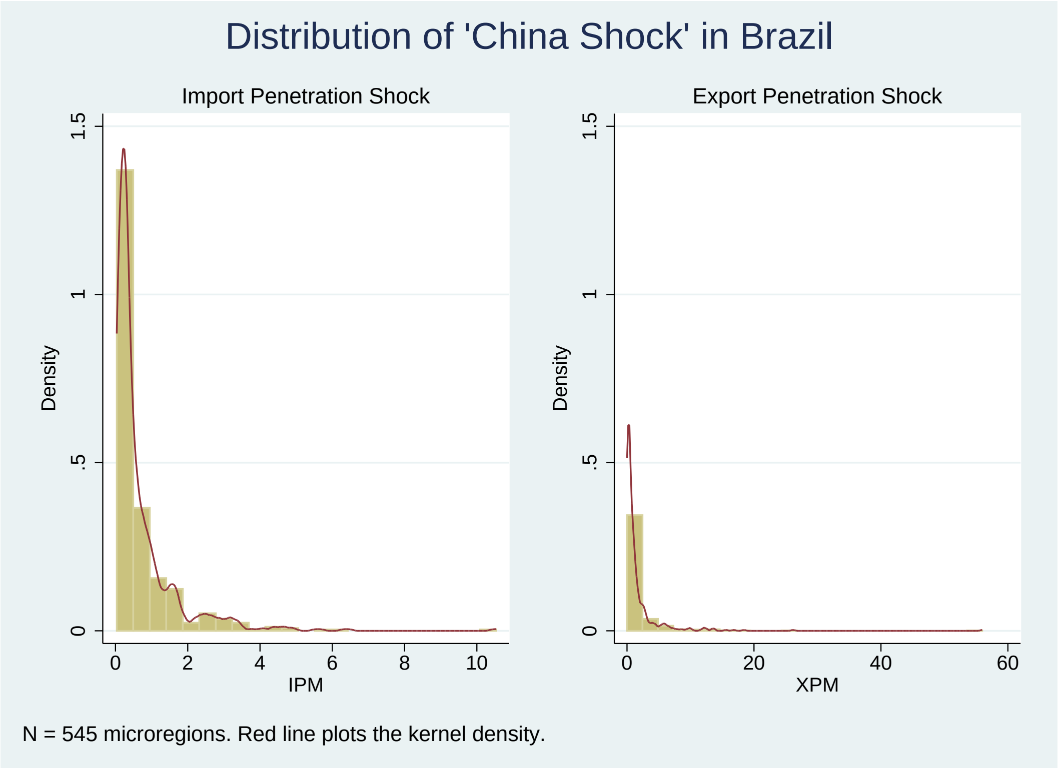


Figure 2.A3: Distribution of China's Import and Export Penetration Measures

Notes. This graph shows the distribution of China's import and export penetration measures (IPM_m and XPM_m), described in section 3.1. The solid line is a kernel density distribution. *Source*: 2000 Brazilian Census, and CEPII BACI.

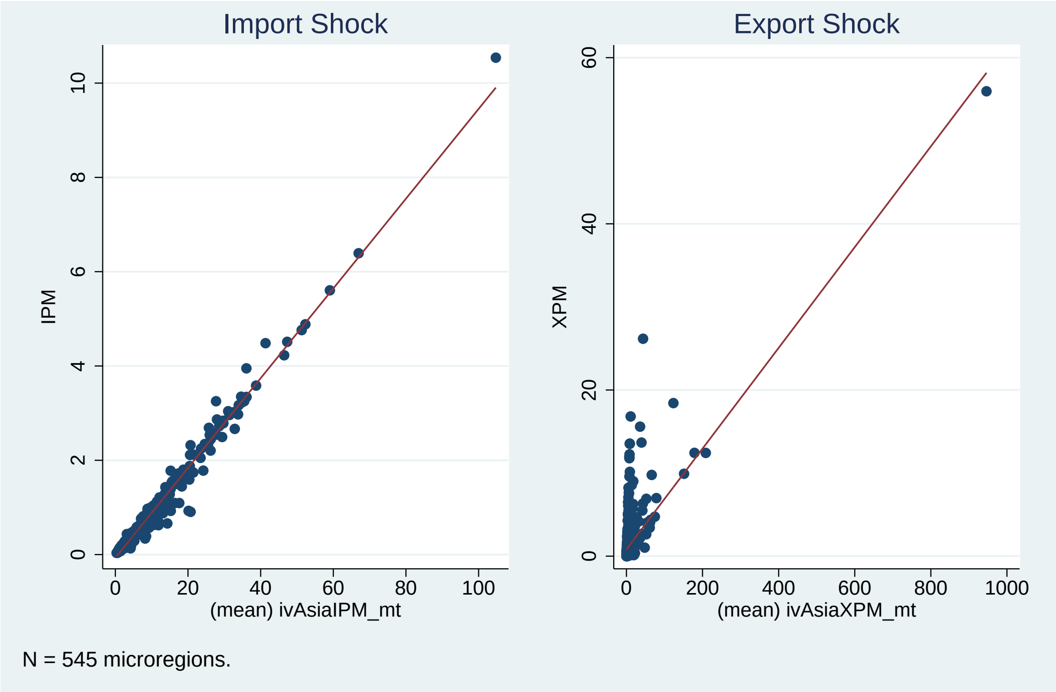


Figure 2.A4: First Stage (Instrument excluding South and Southeast Asia)

Notes. This graph presents the scatter plot of microregions' import and export shocks (IPM_m and XPM_m) against their instruments ($ivIPM_m$ and $ivXPM_m$), as described in section 3.3. The instruments of IPM_m (XPM_m) are Chinese exports to (imports from) other non-high-income countries except Southeast Asia. The red line depicts the first stage regression of IPM and XPM individually. F-statistic for import and export shocks are 7241.91 and 70.27, respectivelly. All regressions are weighted by the share of national workforce. *Source*: 2000 Brazilian Census, and CEPII BACI.

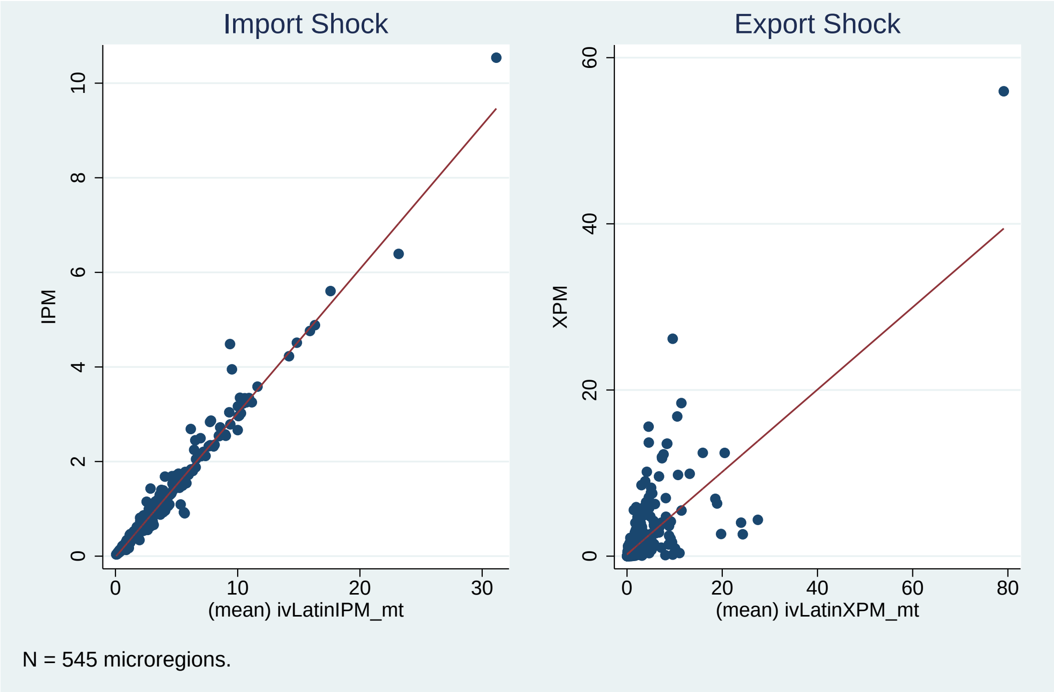


Figure 2.A5: First Stage (Instrument with Latin America only)

Notes. This graph presents the scatter plot of microregions' import and export shocks (IPM_m and XPM_m) against their instruments ($ivIPM_m$ and $ivXPM_m$), as described in section 3.3. The instrumet for IPM_m (XPM_m) is Chinese exports to (imports from) Latin America excluding Brazil. The red line depicts the first stage regression of IPM and XPM individually. F-statistic for import and export shocks are 837.17 and 17.82, respectivelly. *Source*: 2000 Brazilian Census, and CEPII BACI.

Table 2.A1: List of Sectors and Trade Statistics (Primary Goods)

	Import Penetration by Industry			Export Penetration by Industry			Worldwide Product Growth
	Mean	S.d.	N	Mean	S.d.	N	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Agriculture - cereals	.0001	.0001	526	.0006	.0007	526	1.087
Agriculture - oilseeds and fiber crops	-.0004	.0007	142	.0291	.0564	142	.381
Agriculture - sugar cane	0	0	407	0	0	407	2.258
Agriculture - tobacco	0	0	150	.0542	.1214	150	1.169
Agriculture - soya	0	0	269	1.0236	2.4327	269	1.311
Agriculture - oranges	0	0	311	0	0	311	.625
Agriculture - coffee	0	0	314	.0003	.0005	314	.414
Agriculture - cocoa	0	0	53	0	0	53	1.540
Agriculture - grapes	0	0	145	0	0	145	.816
Agriculture - other	.0128	.0090	545	.0001	.0001	545	.168
Agriculture - bovine and equine	0	0	542	0	0	542	.860
Agriculture - other animals	0	0	545	.0001	.0002	545	.089
Agriculture - pigs	0	0	494	0	0	494	1.95
Agriculture - birds	0	0	540	0	0	540	1.116
Forestry	.0003	.0004	543	.0006	.0008	543	-.024
Mining - coal	-.0018	.0111	147	0	0	147	1.483
Mining - oil and gas	0	0	336	.4259	3.1994	336	2.876
Mining - precious metals	0	0	133	0	0	133	2.640
Mining - iron, manganese, aluminum and tin	.0005	.0009	256	1.2623	2.4321	256	1.620
Mining - other Mining	.0006	.0019	536	.0100	.0298	536	.208

Notes. This table displays the summary statistics of import and export penetration measures (IPM_k and XPM_k), described in section 3.1, and our estimated worldwide product growth (δ_k), described in section 3.3.1. Number of microregions 545.

Table 2.A1: List of Sectors and Trade Statistics (Manufacturing Goods)

	Import Penetration by Industry			Export Penetration by Industry			Worldwide Product Growth
	Mean	S.d.	N	Mean	S.d.	N	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Manufacture - meat fish fruit and fats	.0093	.0158	531	.0632	.1074	531	.388
Manufacture - dairy products	0	0	506	0	0	506	.652
Manufacture - grain starch and feed	.0026	.0022	544	.0003	.0003	544	.488
Manufacture - other food	.0014	.0033	456	.0370	.0840	456	.498
Manufacture - beverages	0	.0001	467	0	0	467	.612
Manufacture - tobacco	0	0	167	0	0	167	.796
Manufacture - textile spinning etc	.0253	.0535	506	.0004	.0008	506	-.817
Manufacture - other textile	.0133	.0277	508	.0002	.0005	508	-.244
Manufacture - knitted goods and apparel	.0404	.0454	544	.0001	.0001	544	-.307
Manufacture - leather	.0136	.0231	381	.0152	.0259	381	-.217
Manufacture - footwear	.0030	.0107	437	.0002	.0006	437	-.109
Manufacture - wood and sawmills	.0016	.0029	543	.0019	.0036	543	-.103
Manufacture - paper	0..0065	.0129	315	.0732	.1462	315	.078
Manufacture - printing and publishing	.0018	.0026	507	0	0	507	-.290
Manufacture - coke	.0220	.0697	46	0	0	46	1.456
Manufacture - refined petroleum	.0042	.0076	379	0	.0001	379	1.214
Manufacture - other chemicals	.0171	.0300	477	.0017	.0030	477	.234
Manufacture - man-made fibers and basic chemicals	.0617	.1197	364	.0106	.0205	364	.331
Manufacture - rubber	.0104	.0205	351	.0004	.0007	351	.083
Manufacture - plastics	.0110	.0220	403	0	0	403	.111
Manufacture - glass	.0085	.0105	529	.0002	.0003	529	-.280
Manufacture - other mineral goods	.0142	.0243	520	.0001	.0001	520	-.091
Manufacture - basic metals	.0722	.2545	411	.0348	.1225	411	.526
Manufacture - metal products	.0213	.0279	543	.0014	.0018	543	.033
Manufacture - communications and electronics	.2264	.2518	532	.0016	.0018	532	.055
Manufacture - machinery and computers	.0873	.4044	478	.0026	.0123	478	.087
Manufacture - watches and clocks	.0008	.0070	532	0	0	532	-.157
Manufacture - domestic appliances	.0195	.0624	240	0	.0001	240	.072
Manufacture - motor vehicle parts	.0684	.1686	414	.0023	.0056	414	.071
Manufacture - motor vehicles	.0061	.0175	362	0	.0001	362	.635
Manufacture - shipbuilding	0	0	212	0	0	212	1.129
Manufacture - railway cars	0	0	68	0	0	68	.739
Manufacture - aircraft	0	0	74	0	0	74	.647
Manufacture - other transport	.0139	.0497	209	0	.0001	209	.118
Manufacture - furniture	0	0	543	0	0	543	-.055
Manufacture - other	.0309	.0540	540	.0008	.0013	540	0

Notes. This table displays the summary statistics of import and export penetration measures (IPM_k and XPM_k), described in section 3.1, and our estimated worldwide product growth (δ_k), described in section 3.3.1. Number of microregions 545.

Table 2.A2: First Stages Regressions

	IPM_m	IPM_m	IPM_m	IPM_m	XPM_m	XPM_m	XPM_m	XPM_m
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
CH Exports non-HIC	.0766***	.0764***				-.0253**		
	(.0008)	(.0009)				(.0074)		
CH Imports non-HIC		.0004			.0692***	.0737***		
		(.0006)			(.0104)	(.0106)		
CH Exports non-HIC & non-SE Asia			.0987***					
			(.0012)					
CH Exports Latin America				.2966***				
				(.0103)				
CH Imports non-HIC & non-SE Asia							.0864***	
							(.0103)	
CH Imports Latin America								.3773***
								(.0894)
F statistic (KP)	9120.07	7.2e+06	7241.91	837.17	44.07	7.2e+06	70.27	17.82

Notes. This table displays the estimates of the first stages used in the body of the text. Each column corresponds to a different regression using the specifications indicated in the rows. The unit of observation is microregion (N=545). All regressions with constant and *st of controls* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. CH Exports non-HIC (CH Imports non-HIC) stands for penetration measure calculated using Chinese export to (imports from) all non-high-income countries excluding Brazil. CH Exports non-HIC & non-SE Asia (CH Imports non-HIC & non-SE Asia) stands for penetration measure calculated using Chinese exports to (imports from) other non-high-income countries except Southeast Asia. CH Exports Latin America (CH Imports Latin America) is the penetration measure calculated using Chinese exports to (imports from) Latin America excluding Brazil. F statistic shown is KP Kleibergen-Paap Wald rk F statistic. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.A3: Import and Export Demand and Changes in Workforce and Migration

	OLS	OLS	OLS	IV	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Workforce (Dependent Variable: Δlog of total workforce)									
IPM_m	-.0052	.0041	-.0032	.0040	-.0025	-.0036	.0022	-.0027	-.0024
	(.0058)	(.0074)	(.0033)	(.0076)	(.0033)	(.0032)	(.0027)	(.0034)	(.0037)
XPM_m	.0008	.0032	.0084***	.0122***	.0128***	.0214***	-.0005	.0127***	.0072*
	(.0050)	(.0036)	(.0031)	(.0036)	(.0036)	(.0034)	(.0055)	(.0036)	(.0038)
Panel B. In-Migration (Dependent Variable: Δshare of workforce who migrated to current microregion in the previous 5 years)									
IPM_m	-.0027***	-.0040**	-.0038***	-.0041**	-.0038***	-.0037***	-.0031**	-.0039***	-.0038***
	(.0007)	(.0016)	(.0011)	(.0017)	(.0012)	(.0011)	(.0014)	(.0012)	(.0012)
XPM_m	.0016**	.0020***	.0021***	.0042***	.0037***	.0029***	.0033**	.0038***	.0043***
	(.0007)	(.0006)	(.0006)	(.0009)	(.0009)	(.0009)	(.0016)	(.0009)	(.0012)
Control Set		✓	✓	✓	✓	✓	✓	✓	✓
State FE			✓		✓	✓	✓	✓	✓
Worldwide Product Growth						✓			
Drop Oil Microregions							✓		
IV without Southeast Asia								✓	
IV Latin America only									✓

Notes. This table displays the estimates of Chinese import and export shocks on the evolution of workforce size (Panel A), and the share of workforce who in-migrated in the previous five years (Panel B), captured by β_I and β_X from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of observation is microregion and the number of observations is 545, except in Column 7 where the number of observations is 529. The unit of the coefficients is percentage points. All regressions with constant. *Control Set* contains beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 6 add control Worldwide Product Growth in the period net country fixed effects, both described in subsecton 4.1. The sample in column 7 drops the 16 microregions with the biggest share of oil industry. In columns 4 to 7 we *instrument* imports from (exports to) China with Chinese exports to (imports from) all non-high-income countries excluding Brazil. Column 9 uses as instrument Chinese exports to (imports from) other non-high-income countries except Southeast Asia, and column 10 uses as instrument Chinese exports to (imports from) Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters (131 in Column 7). *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.A4: Import and Export Demand and Changes in Total Employment by Informality

Dependent Variable: Δ share of workforce

	OLS	OLS	IV	IV	IV	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A. Total Employment							
IPM_m	.0210***	-.0005	-.0004	.0000	.0008	-.0005	-.0002
	(.0029)	(.0015)	(.0015)	(.0017)	(.0014)	(.0015)	(.0015)
XPM_m	.0061***	-.0004	-.0021	-.0061***	-.0006	-.0023	-.0008
	(.0018)	(.0007)	(.0015)	(.0015)	(.0013)	(.0014)	(.0010)
Panel B. Formal Jobs							
IPM_m	.0100***	.0032**	.0033**	.0033**	.0027*	.0033**	.0038**
	(.0011)	(.0015)	(.0015)	(.0015)	(.0015)	(.0015)	(.0015)
XPM_m	.0030***	.0027***	.0031***	.0025	.0061***	.0028***	.0044***
	(.0009)	(.0005)	(.0009)	(.0016)	(.0015)	(.0009)	(.0010)
Panel C. Informal Jobs							
IPM_m	-.0024***	.0005	.0004	.0003	.0008	.0004	-.0001
	(.0007)	(.0016)	(.0017)	(.0016)	(.0017)	(.0017)	(.0017)
XPM_m	-.0008	-.0019***	-.0040***	-.0038***	-.0044***	-.0038***	-.0033***
	(.0009)	(.0007)	(.0008)	(.0013)	(.0016)	(.0009)	(.0011)
Control Set and State FE		✓	✓	✓	✓	✓	✓
Worldwide Product Growth				✓			
Drop Oil Microregions					✓		
IV without Southeast Asia						✓	
IV Latin America only							✓

Notes. This table displays the estimates of Chinese import and export shocks on the change of the share of workforce employed (Panel A), share of workforce employed in formal jobs (Panel B) and in informal jobs (Panel C), captured by β_I and β_X from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. The unit of observation is microregion (N=545). The unit of the coefficients is percentage points. All regressions with constant. *Control Set* contains beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in Column 4 add control Worldwide Product Growth in the period net country fixed effects, as in section 3.3.1. The sample in column 5 drops the 16 microregions with the biggest share of oil industry. In columns 3 to 5 we *instrument* imports from (exports to) China with Chinese exports to (imports from) all non-high-income countries excluding Brazil. Column 6 uses as instrument Chinese exports to (imports from) other non-high-income countries except Southeast Asia, and column 7 uses as instrument Chinese exports to (imports from) Latin America excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters (131 in Column 5). *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** p<.05, * p<.1.

Table 2.A5: Import and Export Demand and Changes in Employment in Each Sector

Dependent Variable: Δ share of workforce

	Total Employment			**Formal Jobs**			**Informal Jobs**		
	OLS	IV	IV	OLS	IV	IV	OLS	IV	IV
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Panel A. Primary Sector									
IPM_m	-.0010	-.0012	-.0010	.0019***	.0017***	.0015**	.0010	.0008	.0007
	(.0013)	(.0013)	(.0014)	(.0007)	(.0006)	(.0006)	(.0010)	(.0010)	(.0010)
XPM_m	-.0009*	-.0008	-.0022	.0006**	.0015***	.0033***	-.0004	-.0015**	-.0012
	(.0005)	(.0011)	(.0015)	(.0002)	(.0006)	(.0007)	(.0004)	(.0007)	(.0010)
Panel B. Manufacturing Sector									
IPM_m	-.0035	-.0036	-.0034	-.0040	-.0042	-.0040	.0005	.0005	.0005
	(.0025)	(.0025)	(.0024)	(.0026)	(.0026)	(.0024)	(.0004)	(.0004)	(.0004)
XPM_m	.0002	.0004	-.0017	.0005	.0009	-.0011	-.0003**	-.0004	-.0004
	(.0005)	(.0010)	(.0014)	(.0005)	(.0009)	(.0013)	(.0001)	(.0003)	(.0003)
Panel C. Non-Trade Sector									
IPM_m	.0038*	.0043*	.0043*	.0052***	.0056***	.0056***	-.0011	-.0010	-.0010
	(.0022)	(.0024)	(.0024)	(.0014)	(.0016)	(.0016)	(.0010)	(.0010)	(.0010)
XPM_m	.0004	-.0018	-.0022*	.0017***	.0009	.0007	-.0013***	-.0023***	-.0023***
	(.0005)	(.0012)	(.0011)	(.0005)	(.0012)	(.0009)	(.0003)	(.0005)	(.0007)
Control Set and State FE	✓	✓	✓	✓	✓	✓	✓	✓	✓
Worldwide Product Growth			✓			✓			✓

Notes. This table displays the estimates of Chinese import and export shocks on Panel A presents labourTrade data market results in the primary sectorthe change of the share of workforce employed in each sector by informality. Panel A presents labour market results in the primary sector, Panel B in the manufacturing sector, and Panel C in the non-tradable sectors, captured by β_I and β_X from equation (1). Each column corresponds to a different regression using the specifications indicated in the rows. Columns 1 to 3 presents the total change in the total share of workforce employed in each sector, columns 4 to 6 presents the change in the share of workforce employed in formal jobs, and columns 7 to 9 presents the change in share of workforce in informal jobs. The unit of observation is microregion (N=545). The unit of the coefficients is percentage points. All regressions with constant, State fixed effects and *Control Set* containing beginning of period workforce number, share of workforce in primary sector, share of workforce in manufacture, share of workforce in informal jobs, and a cubic polynomial of income per capita. Regressions in columns 3, 6 and 9 add control Worldwide Product Growth as in section 3.3.1.. In the columns marked with IV, we *instrument* imports from (exports to) China with Chinese exports to (imports from) all non-high-income countries excluding Brazil. All regressions are weighted by the share of national workforce. *Standard errors* are clustered by mesoregion, 136 clusters. *Source:* 2000 and 2010 Brazilian Census, and CEPII BACI. *** p<.01, ** pI<.05, * p<.1.

Chapter 3

Winners and Losers in International Trade: a Structural Approach on Chinese Ascension[1]

3.1 Introduction

On the way to estimating an effect of the ascension of China in labour markets worldwide, we want to learn what China has meant for world's cross-sectoral production composition. In particular, in the light of Chapter 2, we want to learn about the interacting effects of changing Chinese supply and demand conditions on Brazil's sectoral structure. Our main motivation is that our Autor et al. (forthcoming) -inspired regressions in Chapter 2, using Brazil's imports from China and Brazil's exports to China as independent variables, have two main issues. First, growth in Chinese productivity may lead to Chinese imports replacing others' imports to Brazil as well as affecting Brazilian production itself (Gallagher et al., 2008), and this could affect our cross-sectoral interpretation of the effects of Chinese growth on Brazilian production. Second, growth in Brazilian productivity should not be assigned to demand from China, e.g. growth in Brazil's exports to China may be due to productivity growth within Brazil rather than Chinese demand (Bustos et al., 2013), and we want to consider only the latter.

In this paper we employ an unified theoretical framework to directly estimate the effect of changes within China on production in Brazil and in the rest of the world. In order to do so, we use the Ricardian model of trade of Costinot et al. (2012) which, building on Eaton and Kortum (2002), provides theoretically consistent foundations for estimating the relative production cost at a country-industry level. We use these estimates to develop counterfactuals in which China stays at its 'original' state, and then

[1]This is joint work with Jason Garred and João Paulo Pessoa.

compare Brazil's production composition in this world and the real world. We perform two main counterfactual exercises. First, we model productivity growth in China as the main lever by which Chinese supply and demand conditions evolve and affect Brazil. In other words, we investigate to what extent changes in global trade flows are affected just by scaling China up, without considering across-industries productivity changes within China. Second, we study how changes in composition of Chinese demand (taste) affects trade flows around the world, and Brazilian production.

The Ricardian model presented in section 2 is a full general equilibrium model, where factor prices and demand adjust endogenously. This creates feedback between the supply and demand components of the model in any counterfactual exercise. Incorporating these elements would require considerable additional structure, as in di Giovanni et al. (2012). This paper models China's effect on the rest of the world taking into account multiple factors, intermediate goods and trade imbalances.[2] To do this the authors need to develop a complex computable general equilibrium model – also based on Eaton and Kortum (2002). Other papers which adopt a full general equilibrium structural approach to investigate the effects if the recent China's growth are Dekle et al. (2007) and Hsieh and Ossa (2012). These papers intend to estimate the global welfare effects of China, while we want to understand to which extent changing Chinese supply and demand conditions affected Brazilian sectoral composition.

In order to perform a full general equilibrium exercise as in these papers, our counterfactuals would depend on some assumptions that deviate from the real world in ways that seem important for Brazil-China trade. Therefore, in favour of simplicity, and to illustrate the different mechanisms more clearly, we adopt a partial-equilibrium approach. We separately investigate the supply-side and demand-side aspects of China growth within the model, highlighting which general equilibrium mechanisms we switch off in each case. We understand that this partial equilibrium approach comes at the expense of having an unified theoretically consistent counterfactual, but we gain in clarity and in the plausibility of assumptions, such as trade imbalances and multiple factors of production.[3]

Our counterfactual results show that, within this Ricardian model of trade, it is true that 'China supply shock' hampered Brazilian manufacture and, in a much smaller extent, contributed to the expansion of iron ore production. We find no support for the idea of a demand (taste) shock in China that led to the increased production of soybeans and iron ore in Brazil. The two exercises – the supply and demand partial-equilibrium

[2]Notably, their industry-level data is at a very aggregate level, and agriculture and mining are not taken into account in some of its calculations.

[3]Costinot et al. (2012) model balanced trade, but imposing this in the counterfactuals means, for example, that China demands more and the US demands less than in reality partly because we have forced trade balances to move to zero. Also, much of the motivation for Chapter 2 is based on the fact that Brazil has access to land endowments that are highly in demand in China, but Costinot et al. (2012) model only a single factor economy (labour).

counterfactuals – together suggest that the boom of soybeans cultivation in Brazil is due to changes in Brazilian comparative advantage paired with a level increase in demand for this product within China. Our finding on iron and manganese ore are similar to the soybeans one, but in a smaller magnitude.

The main contribution of this chapter is to provide evidence based on a theoretical general equilibrium trade framework on the assumptions underlying the instruments used in Chapter 2, and in many papers in the literature which followed Autor et al. (forthcoming). The counterfactual worlds generated in this paper suggest that our concerns regarding the plausibility of these instruments seem to be mild. It does seem that within China supply shocks led to competition to manufacturing abroad, reducing the average trade share of developed countries. In particular, Chinese trade evolution seems more directed to labour-intesive products. At the same time, evidence suggest that changes in China's consumption pattern – i.e., spending a smaller share of their income in raw materials – actually weakened the international commodities boom.

The paper is organized as follows. We describe the theoretical framework n Section 2. Section 3 introduces the data and describes the estimation of the relative production costs. Section 4 presents the preliminary counterfactual exercises. Section 5 concludes.

3.2 Theoretical Framework

In this section we present the Ricardian model of trade of Costinot *et al.* (2012), which is based on Eaton & Kortum (2002). Suppose a world economy with $i = 1, ..., I$ countries and one factor of production, labour (we will consider a multi-factor environment in the next section). Let L_i and w_i be the number of workers and wages in country i. There are $k = 1, ..., K$ products (or industries). Labour is immobile across countries but free to move across industries. Each product exhibits constant returns to scale production function, but we allow for intra-industry heterogeneity.

Technology. Each product k has an infinite number of varieties $\omega \in \Omega \equiv \{1, ..., +\infty\}$. Let $z_i^k(\omega)$ be the productivity of variety ω of product k in country i, i.e., it is the amount of good produced with one unit of labour. As Eaton and Kortum (2002), assume $z_i^k(\omega)$ is a random variable independently distributed for each (i, k, ω) from a Fréchet distribution $F_i^k(.)$ such that

$$F_i^k(z) = \exp\left[-\left(z/z_i^k\right)^{-\theta}\right], \forall z \geq 0 \tag{3.1}$$

where $z_i^k > 0$ and $\theta > 1$.

That is, the production technology of each country-industry is defined by two parameters θ, which captures the intra-industry heterogeneity, and z_i^k, which captures the *fundamental productivity* of country i in industry k. As Costinot *et al.* (2012), we assume θ to be constant across countries and industries, so any comparative advantage will emerge from differences in the fundamental productivities (or in the cost of production, as we will see) as a standard Ricardian model.

Trade costs. We assume standard 'iceberg' costs. Formally, for each unit of product k going from country i to country j, only $1/d_{ij}^k$ units arrive, where $d_{ij}^k \geq 1$. Also, assume that there is no cost of internal trade, $d_{ii}^k = 1$, and no profitable triangulation, $d_{ij}^k \leq d_{ij}^k.d_{jl}^k$ for any other country l.

Market structure. We assume perfect competition, such that consumers in country j always pay the lowest price when buying variety ω of product k, that is

$$p_j^k(\omega) = \min_{1 \leq i \leq I} \left[c_{ij}^k(\omega) \right] \tag{3.2}$$

where $c_{ij}^k(\omega) = d_{ij}^k \omega / z_i^k(\omega)$ is the cost of producing variety ω of product k in country i delivered in country j.

Preferences. In order to allow for intra-industry trade, assume a two tier utility function with Cobb-Douglas upper tier and a constant elasticity of substitution in the lower tier. Therefore, the total expenditure in country j on variety ω of good k is

$$x_j^k(\omega) = \left[\frac{p_j^k(\omega)}{p_j^k} \right]^{1-\sigma_j^k} \alpha_j^k w_j L_j \tag{3.3}$$

where σ_j^k is the elasticity of substitution between varieties of a product, $\sigma_j^k < 1 + \theta$, and $p_j^k \equiv \left[\sum_{\omega' \in \Omega} p_j^k(\omega')^{1-\sigma_j^k} \right]^{1/\left(1-\sigma_j^k\right)}$ is the consumer price index. The parameter α_j^k, $0 \leq \alpha_j^k \leq 1$, will be at the core of our demand counterfactual, it measures the share of expenditure on product k in country j.

Trade balance. Assume that trade is balanced

$$\sum_{j=1}^{I} \sum_{k-1}^{K} \pi_{ij}^k \alpha_j^k \phi_j = \phi_i \tag{3.4}$$

$$\phi_i \equiv \frac{w_i L_i}{\sum_{i'}^{I} w_{i'} L_{i'}}$$

where ϕ_i is the share of country i in world income, and π_{ij}^k is the share of exports from country i in country j industry k. Formally, let $x_{ij}^k \equiv \sum_{\omega \in \Omega_{ij}^k} x_{ij}^k(\omega)$, where $\Omega_{ij}^k \equiv \left\{ \omega \in \Omega | c_{ij}^k(\omega) = \min_{1 \leq i' \leq I} \left[c_{i'j}^k(\omega) \right] \right\}$ is the set of all varieties of product k exported from country i to country j.

Trade flows and equation (4) solve countries relative wages $w_i/w_{i'}$.

3.3 Data and Estimation

In this section we introduce the data and present the estimation of the relevant parameters of the model.

3.3.1 Data

The trade data is from the world trade database developed by the CEPII (CEPII BACI). In contains the annual total value (in thousands of US dollars) of trade at industry-importing country-exporting country level from 1998 to 2010, containing more than 200 countries. This is a reconciled dataset originally from COMTRADE by the United Nations Statistical Division. Product disaggregation is at HS96 6-digit level.

For the counterfactual analysis, apart from the trade data we need gross output data for agriculture/forest, mining/energy and manufacturing industries. Data for agriculture and forestry is from FAOSTAT. Data is in current US dollars by country-industry-year. First, we use concordance HS96 to ISIC3 to figure out which goods where classified as agriculture rather than manufacturing by COMTRADE. Then, we drop all products associated with manufacturing from FAOSTAT. Concordance was made in two stages, first FAOCODE to HS (from FAO) and then concorded by hand to CNAE. We use only one one category for forest: roundwood.[4] The unit of production data is in quantities, but FAO trade data is in quantities and values. We use unit values to convert quantity produced to values. Outliers unit values (the 5th and 95th percentiles) were assigned the values of the 5th and 95th percentiles. Missing unit values assigned the median for the country across years.

Mining/energy data is from the BGS World Mineral Statistics, BP Statistical Review of World Energy, and World Input-Output Database. We concorded CNAE2.0 and HS96 by hand (CNAE was the limiting factor). Again, this data is in quantities, so we use unit values and prices (US Energy Information Administration and others) to convert to values.[5]

Last, data for manufacturing is from UNIDO INDSTAT4. This is all gross output data with ISIC3 classification, all in values of current US dollars. Data was cleaned to impute missing values. Data from China between 1999 and 2002, missing in the main dataset, comes from the summary statistics from the Annual Survey of Manufacturing from China, concorded to ISIC 3.[6] We hand concorded CNAE2.0 to 3-digit ISIC3 and used HS96 to ISC3 concordance. We restrict attention to 1999-2007, the years for which

[4]This is the best proxy for unprocessed logs according to FAO classification guide.

[5]'Other mining' category was derived from trade data.

[6]We applied the official exchange rate from China Statistical Yearbook 2003 to convert to current USD.

Brazilian 3-digit production data is available in UNIDO INDSTAT4.[7]

Overall, we end up with 35 countries between 1999 and 2007 (we use only 1999 and 2007 in this version of the project), and 73 sectors (17 agricultural/forestry, 7 mining/energy, 49 manufacturing). We also use bilateral trade information from the CEPII gravity database. It provides data on several trade cost dimensions for all pair of countries from 1948 to 2006.[8]

3.3.2 Estimation

Much of the motivation for Chapter 2 is based on the fact that Brazil has access to endowments (e.g., land) that are highly in demand in China, so we consider the Costinot *et al.* (2012) model presented in Section 2 but allowing for the possibility of multiple factors of production. This does not affect the mechanisms of the model, but it helps understanding the underlying assumptions in our counterfactuals. In particular, let the cost of production of variety ω of industry k in country i be:

$$c_i^k(\omega) = \frac{\prod_f (w_{fi})^{s_f^k}}{z_i^k(\omega)} \tag{3.5}$$

where $w_i^k \equiv \prod_f (w_{fi})^{s_f^k}$.

From (3) we have that:

$$x_{ij}^k = \frac{(w_i^k d_{ij}^k / z_i^k)^{-\theta}}{\sum_{i'=1}^{I} (w_{i'}^k d_{i'j}^k / z_{i'}^k)^{-\theta}} D_j^k \tag{3.6}$$

$$= \frac{(c_i^k d_{ij}^k)^{-\theta}}{\Phi_j^k} D_j^k \tag{3.7}$$

where D_j^k represents demand for the output of industry k in country j, which we will not model explicitly here in order to keep the focus on the estimation of the supply side. The last equality follows from equation (3.5). This gives us the following relationship in logs:

$$\ln x_{ij}^k = -\theta \ln c_i^k - \theta \ln d_{ij}^k - \ln \Phi_j^k + \ln D_j^k \tag{3.8}$$

Following Costinot *et al.* (2012), we estimation the cost parameters via exporter-industry fixed effects. By rewriting the expression above, and adding a time index t, we obtain:

$$\ln x_{ijt}^k = \delta_{it}^k - \theta \ln d_{ijt}^k + \delta_{jt}^k + \ln D_{jt}^k + \epsilon_{ijt}^k. \tag{3.9}$$

[7] We drop the following sectors: publishing (not in Chinese dataset, because it is considered service), recycling (not separate trade data for that), and refined petroleum and nuclear fuel (large number of missing data).

[8] Since data for 2007 is unavailable, in our estimation for the year 2007 we use 2006 trade costs instead.

Here, we intend for δ_{it}^k to identify $-\theta \ln c_{it}^k$, the cost of producing k in country i. This identification is industry-specific, so it does not give us across-industry information about costs, only within industry comparative costs in terms of a numeraire. That is, fixed effects identify the relative production costs in first differences relative to a base country. Note that this is a difference from Costinot *et al.* (2012). In their case, with a single-factor economy, the fixed effects regressions identify the fundamental productivity parameters in double-differences – i.e., relative to a base country *and* a base product. When we consider a multi-factor economy, the fixed effects regressions do not identify productivity anymore, but production costs which are a combination of factor costs *and* productivity as in equation (3.5).

Therefore, in each industry we define a base (omitted) country with industry-level unit cost 1, and the cost parameters for all other countries will be expressed as multiples of this country's unit cost.[9] In our main specification we use the United States as our baseline country. We estimate this equation separately for two years: 1999 and 2007.

We also control for trade costs in our estimates, allowing it to vary over time.[10] Controlling for trade costs is important for obtaining consistent estimates of the fixed effects of interest. Hence, we use several measures of bilateral trade costs to obtain a proxy for $-\theta \ln d_{ijt}^k$. More precisely, we have that:

$$\theta \ln d_{ij}^k = \beta' X_{ij}^k \tag{3.10}$$

where X_{ij}^k contains dummy variables for when countries i and j share a border, have the same official language, had a common colonizer post 1945, if they had a colonial relationship post 1945, if they have a regional trade agreement, and a variable containing the weighted distance between the two countries. We also include a variable that is equal to 1 for within country trade and zero otherwise, this controls for border effects in the same way as in Head & Mayer (2002).

Tables 3.1 and 3.2 report cost differences (adjusted for θ) around the world for 1999 and 2007 taking the US as our baseline country. That is, we consider $c_{USAt}^k = 1$ for all industries k and show the value of $(c_{it}^k)^\theta$ for the rest of the world. We have a total of 72 industries, but for the sake of simplicity we report the 10 among the 12 industries for which China observed the greatest reduction in costs[11] (or increase in productivity) between 1999 and 2007.

[9] The component $-\ln \Phi_{jt}^k$ is captured through the fixed effect δ_{jt}^k and summarizes how states of technology, input costs and barriers affect prices in the importer country – see Eaton & Kortum (2002) for a more detailed description.

[10] In our counterfactual analysis we will use end of period trade costs, such that estimates of the term $-\theta \ln d_{ijt}^k$ will not affect *directly* our counterfactual exercises in the next section.

[11] Even though manufacturing of beverages and batteries were among the top ten, we do not report them due to many missing values among the other countries.

Looking at the Motor Vehicles column in Table 3.1, we can see that China cost parameter relative to the US is equal to 23.02. Since this number is greater than 1, in 1999 it was more costly to produce motor vehicles in China than in the US. Using $\theta = 6.53$, as estimated in Costinot *et al.* (2012), we can have some idea on how does these numbers translate in cost/productivity terms. In this case, our estimates suggests that Motor Vehicles was $(23.02)^{1/6.53} = 1.6$ times mores costly to produce in China relative to the US in 1999. In 2007, the same Motor Vehicles column in Table 3.2 shows that China surpassed the US and became more productive in producing motors. By 2007, it was $(0.5)^{1/6.53} = 0.9$ times less costly to produce this type of product in China relative to the US, our baseline country.

In sum, the two tables can give us some idea of what is happening in terms of productivity (production costs) across industries around the world relative to our baseline country, the US. These and the other sector estimates will be the core of the first counterfactuals analyzed in the following section.

3.4 Counterfactual Exercises

Based on the estimates from section 3.2, in this section we perform counterfactuals exercises to analyze how countries and industries in Brazil would have performed in the absence of the recent Chinese ascension. The framework presented in section 2 is a full general equilibrium model, where factor prices and demand adjust endogenously. This creates feedback between the supply and demand components of the model in any counterfactual exercise. Incorporating these elements would require considerable additional structure, as in di Giovanni et al. (2012). In favour of simplicity, and to derive clearer intuition from the counterfactuals, we adopt a partial-equilibrium approach. Before presenting the counterfactuals, we describe the two main feedback channels within the model.

According to an Eaton-Kortum formula based on exporter-level cost of production c_i^k and iceberg trade costs d_{ij}^k, the model allocates the market share for each importer-industry jk across exporters i:

$$\frac{x_{ij}^k}{\sum_{i'} x_{i'j}^k} = \frac{(c_i^k d_{ij}^k)^{-\theta}}{\sum_{i'} (c_{i'}^k d_{i'j}^k)^{-\theta}}. \tag{3.11}$$

The denominator of the left-hand side above defines the expenditure of importer j on industry k. In the model, this is determined by the country's income from its own production across all industries and the Cobb-Douglas preference parameter α_j^k, which is idiosyncratic to that country:

$$\sum_{i'} x_{i'j}^k = \alpha_j^k \sum_{k'} \sum_{j'} x_{jj'}^{k'}. \tag{3.12}$$

Table 3.1: Cost/Productivity Differences in 1999

	Wiring	Watches	Aluminum	Wood	CPU/Machinery	Precious Metals	Plastics	Mineral Goods	Motor Vehicles	Soya
AUS	32.35	66.50	26.38	60.61	30.33	28.35	46.35	23.20	64.05	9.94
AUT	48.43	104.55	53.30	34.71	73.06	31.06	178.59	22.19	42.47	9.27
BGR	1698.49	2378.80	5100.80	11210.46	1149.56	165.63	30362.26	894.24	403.30	.
BRA	38.80	103.18	7.20	18.05	8.16	10.16	353.68	179.12	90.09	0.03
CAN	19.10	33.92	15.25	16.25	3.87	12.85	16.52	6.12	27.76	0.74
CHN	14.11	5.55	20.23	82.72	41.37	1.83	8.49	14.75	23.02	1.12
CYP	17459.09	13525.18	13708.22	2633.20	6783.87	1362.84	22606.10	1893.22	3818.53	0.78
CZE	138.52	472.90	74.73	61.91	185.09	55.38	3762.93	61.61	363.50	15.59
DEU	3.48	7.78	1.92	0.78	17.49	2.30	10.42	2.24	2.69	0.90
DNK	64.02	98.28	88.66	284.99	135.26	15.20	160.88	26.16	146.64	2.22
ESP	32.97	53.27	7.58	5.15	145.79	4.50	133.43	14.18	16.60	0.18
EST	6128.98	15835.96	2097.27	5246.16	144.75	236.81	4678.66	326.07	11984.48	4.16
FIN	37.97	81.70	111.35	74.31	19.12	48.41	12.23	18.26	125.43	4.21
FRA	13.68	18.34	5.05	2.70	53.34	5.31	11.17	5.57	15.49	2.92
GBR	11.71	13.20	7.08	3.61	228.69	6.31	10.91	7.48	9.03	2.08
HUN	836.33	260.46	193.77	83.15	341.18	155.72	7306.24	92.46	858.60	8.27
IDN	277.22	55.07	88.84	387.73	2.87	1.19	214.56	72.62	4.91	0.04
IND	163.05	257.20	71.70	85.90	419.45	40.89	1130.16	59.77	19.70	.
IRL	337.44	40.97	817.32	2009.03	2184.50	206.48	47.74	140.98	71.27	2.96
ITA	5.66	13.05	5.14	5.26	29.18	1.03	42.66	3.58	8.04	4.40
JPN	1.58	1.98	0.76	0.22	470.90	9.86	3.24	14.23	1.93	0.15
KOR	15.07	8.64	6.69	0.86	252.34	30.92	6.76	18.27	2.40	2.49
LTU	8779.22	28431.97	8478.47	5953.15	232.71	340.18	28403.47	1329.84	1001.69	1.92
LVA	12790.84	37055.71	12472.99	17436.35	101.87	435.30	37385.32	1951.76	347.91	49.06
MEX	139.06	45.39	44.89	23.96	507.87	16.94	62.40	133.41	28.11	0.18
MLT	24942.79	26021.65	31273.59	26113.75	12624.37	1165.53	20136.54	3377.77	2734.84	.
NLD	32.72	27.50	28.61	13.82	129.08	20.21	97.55	9.42	13.88	0.58
POL	256.71	517.42	148.31	96.43	160.80	15.63	1605.88	42.77	279.89	1.09
PRT	233.99	817.97	144.75	61.79	348.02	62.48	994.16	53.42	110.43	4.82
ROM	1300.01	2018.84	1452.12	1457.25	150.44	57.18	12881.01	201.49	195.83	0.08
SVK	847.61	2084.98	582.50	527.76	253.01	217.41	9270.06	338.44	175.83	1.22
SVN	1151.92	2414.81	1884.72	748.44	788.54	131.48	9908.23	237.07	274.90	2.65
SWE	21.96	54.55	20.46	7.63	15.86	12.48	6.33	15.32	303.83	6.00
TUR	328.98	916.67	73.61	170.95	678.42	62.49	1676.03	61.49	38.67	.
USA	1	1	1	1	1	1	1	1	1	1

Table 3.2: Cost/Productivity Differences in 2007

	Wiring	Watches	Aluminum	Wood	CPU/Machinery	Precious Metals	Plastics	Mineral Goods	Motor Vehicles	Soya
AUS	19.56	39.54	18.84	75.09	32.77	20.60	37.69	15.82	138.77	0.24
AUT	28.74	56.08	41.56	19.06	16.74	12.36	267.65	10.35	25.15	20.58
BGR	758.23	761.36	1904.44	7024.47	829.30	69.74	6917.14	264.44	471.42	0.33
BRA	13.55	20.76	3.86	23.30	1.15	7.42	52.48	47.10	23.88	0.01
CAN	12.43	15.81	16.56	32.55	2.05	11.04	6.00	7.47	27.61	0.54
CHN	1.11	0.43	1.34	5.29	1.93	0.08	0.23	0.32	0.50	0.00
CYP	5722.47	5231.10	16688.77	2818.82	792.03	1300.11	4943.89	3977.97	20494.22	6.12
CZE	72.99	50.15	23.41	35.62	70.74	22.62	119.34	14.81	215.31	7.20
DEU	3.11	3.95	1.21	0.80	5.21	1.34	6.73	1.40	2.14	1.19
DNK	66.75	53.80	62.09	373.86	115.24	7.82	131.99	15.00	67.20	0.96
ESP	30.59	22.71	5.26	4.42	89.13	4.16	103.56	6.16	11.53	0.26
EST	2293.35	2816.10	1953.46	1309.55	48.80	134.67	528.24	119.27	3796.46	3.57
FIN	28.48	56.48	72.14	96.04	9.08	60.92	6.86	12.21	204.50	4.90
FRA	12.78	12.17	3.49	3.14	36.30	4.03	17.73	5.46	13.39	1.24
GBR	11.96	13.26	6.83	3.83	266.75	6.70	15.95	8.83	8.22	3.20
HUN	331.11	67.79	43.07	24.31	262.27	60.10	17.20	67.60	528.65	2.89
IDN	40.34	28.84	21.20	352.49	2.45	0.64	95.61	20.81	1.88	0.01
IND	50.36	31.73	9.42	28.13	92.71	7.41	91.45	14.41	5.59	.
IRL	128.64	24.85	758.16	1610.75	1509.70	352.46	54.38	128.40	109.27	1.99
ITA	5.55	7.00	3.52	5.93	21.22	0.86	20.60	2.46	4.47	2.41
JPN	0.91	1.60	0.44	0.25	937.39	7.22	3.24	8.17	1.35	2.89
KOR	4.05	3.67	2.12	0.76	868.42	11.59	0.70	3.54	1.08	0.74
LTU	3357.67	2483.71	2070.50	1501.75	132.72	34.23	4431.35	255.84	767.61	2.50
LVA	6012.05	3971.97	7579.58	1935.68	45.17	171.02	6874.09	566.16	461.26	1.94
MEX	54.01	19.27	11.48	8.70	486.65	22.54	10.25	121.41	26.43	0.24
MLT	8019.25	7095.13	11951.47	9037.41	9413.43	7894.05	12990.95	9290.72	35667.63	.
NLD	14.78	14.06	18.36	16.01	72.75	15.32	14.20	6.67	8.93	0.28
POL	111.25	94.71	19.49	38.83	75.00	3.33	165.14	9.85	132.90	1.46
PRT	240.82	299.38	68.08	43.81	198.63	27.73	449.12	43.08	37.55	0.62
ROM	606.96	292.67	102.17	597.40	66.29	16.92	793.45	152.22	263.22	7.77
SVK	309.59	213.10	136.34	22.27	205.97	42.95	970.12	68.89	112.21	3.76
SVN	610.29	488.91	535.27	233.18	390.29	52.22	2442.70	84.02	193.12	18.35
SWE	20.93	27.06	14.32	7.40	11.79	9.40	9.09	10.14	847.46	2.65
TUR	90.32	154.65	16.01	17.02	682.79	10.82	1193.00	12.68	10.46	.
USA	1	1	1	1	1	1	1	1	1	1

The feedback between these supply and demand components of the model occurs on a few levels. To clarify these, keep the model fixed at only these two equations and imagine that there is a shock to the cost of production of industry 1 in country 1. If c_i^k decreases, then the share of exports from country 1 will rise for all importers j in industry 1 only, and remain the same in all other industries. So, for industry 1, the left-hand side of the equation (3.11) rises for country 1 and falls for everyone else. For all other industries, equation 3.11 remains unchanged.

However, whether a particular country gains or loses in levels (rather than shares) in any industry – i.e. whether x_{ij}^k rises or falls in each industry – depends on the behaviour of the denominator in equation (3.11). This is the first feedback effect between demand and supply, which we call the '*expenditure feedback*'. The change in country 1's income resulting from its cost decrease in industry 1 will result in a change in expenditure, but this will be spread over several industries according to equation (3.12). At the same time, all other countries' incomes will change both because of their changing shares in industry 1, and because of additional expenditure from country 1 in other industries, and this will result in changes in expenditure for them too, and so on.

The second feedback mechanism is what we might call the '*cost feedback*', and requires production costs to be driven in part by an endogenous variable – factor prices – and for income from production to be paid to factors. In Costinot *et al.* (2012), there is a single factor – labour – that serves this role. Consider again the above shock to production costs in industry 1 in country 1, and assume that they are driven by a rise in productivity. Then, for given wages, productivity rises mean that each unit of labour in country 1 can produce more units of industry 1 goods. The income from this additional production is paid in wages to labour, which raises the equilibrium wage, and thus the cost of production, in every industry in country 1. The net effect of productivity growth in industry 1 is thus that production costs in country 1 fall in industry 1 (although by less than the rise in productivity), and rise in all other industries in the country via this feedback mechanism.

Still on this point, note that we do not need data on wages – or factor prices – in order to calculate the counterfactuals. Restating the equations of the model to take this into account simply involves rewriting c_i^k in equation (3.11) as w_i^k/z_i^k, and adding a new factor market-clearing equation:

$$w_i L_i = \sum_k \sum_j x_{ij}^k. \tag{3.13}$$

This equation makes clear that wages can be written as a function of the x_{ij}^k terms and the labour endowment, so that one could simply write $c_i^k = (\sum_k \sum_j x_{ij}^k)/z_i^k L_i$ and keep wages out of the model altogether. That is what we do.

One last note on the model. Starting from an existing equilibrium, the changes in income and expenditure caused by the cost shock, say in country 1, presumably lead to a new equilibrium trade pattern. However, the equations above do not determine the level of income and expenditure in the initial equilibrium (unsurprisingly, given that this is a model of comparative advantage). We can see this by rewriting equation (3.11) and moving expenditure to the right-hand side:

$$x_{ij}^k = \frac{(c_i^k d_{ij}^k)^{-\theta}}{\sum_{i'} (c_{i'}^k d_{i'j}^k)^{-\theta}} \sum_{i'} x_{i'j}^k \tag{3.14}$$

Now, note that equations (3.12) and (3.14) are ambiguous with respect to the overall size of the world economy. Everybody could be very rich, so that the left-hand side and right-hand side of both equations are very large; or everybody could be very poor, so that the left-hand side and right-hand side of both equations are very small. Presumably this accounts for multiple-equilibria problem if we try to determine counterfactual levels of world income.

3.4.1 Supply Side Counterfactuals

Assume that Chinese cost of production evolved (in relative terms to the US) from 1999 up to 2007 in the same fashion as the world average. That is, from the cost of production estimates (δ_{it}^k) we calculate the average world growth in each sector, and substitute for ($\delta_{China,07}^k$) by using ($\delta_{China,99}^k$) multiplied by this average industry growth. The intuition for this counterfactual is that China's comparative advantage evolved from 1999 to 2007 as the world average in each industry.[12]

Referring to Chapter 2. Regarding our discussion on worldwide correlated technology shocks which potentially harms our instruments, we consider in this counterfactual that worldwide technology shocks do affect China as it affects all other countries. That is, we intend to isolate China-driven changes in comparative advantage worldwide.

We run two separate exercises for this type of shock. The first, named '*unrestricted'*, considers supply and demand interactions given the counterfactual evolution of Chinese production costs. The second exercise, named '*restricted'*, restricts total world consumption to its 2007 level – i.e., we switch off the '*expenditure feedback*' discussed previously.

In both cases we switch off the '*cost feedback*'. We do not incorporate factors as a full-fledged part of the model, assuming that the determination of the country-industry cost parameters (i.e. the parameters encompassing both productivities and factor prices) occurs outside the model. We simply posit that China's position in the world with respect to cost (productivities *and* factor prices) evolved exogenously, without allowing factor prices to adjust further in response to the resulting shifts in trade flows. Essentially, we

[12]For example, if producing electronics became less costly (relative to the US) everywhere in the world, electronics became less costly to produce (relative to the US) in China as well.

are assuming that factor prices are determined in a large outside sector in each country and we are not allowing these prices to adjust endogenously with trade flows.

3.4.1.1 Unrestricted

We know from Costinot *et al.* (2012) that we can write a counterfactual in terms of shares of the importer's industry-level demand as follows:

$$\frac{\tilde{x}^k_{ijt}/\tilde{D}^k_{jt}}{x^k_{ijt}/D^k_{jt}} = \frac{\tilde{\pi}^k_{ijt}}{\pi^k_{ijt}} = \frac{(\tilde{c}^k_{it}/c^k_{it})^{-\theta^k}}{\sum_{i'=1}^{I} \pi^k_{i'jt}(\tilde{c}^k_{i't}/c^k_{i't})^{-\theta^k}} \tag{3.15}$$

$$= \frac{e^{(\tilde{\delta}^k_{it}-\delta^k_{it})}}{\sum_{i'=1}^{I} \pi^k_{i'jt} e^{(\tilde{\delta}^k_{i't}-\delta^k_{i't})}} \tag{3.16}$$

where the tilde identifies the counterfactual variables. We then assign the updated 1999 values of comparative advantage to China in 2007, and recalculate trade shares. So, in 2007 the counterfactual 2007 trade shares of China, c, and all other countries, i, are, respectively:

$$\tilde{\pi}^k_{cj07} = \frac{e^{(\tilde{\delta}^k_{c07}-\delta^k_{c07})}}{\pi^k_{cjt} e^{(\tilde{\delta}^k_{c07}-\delta^k_{c07})} + \sum_{i' \neq c} \pi^k_{i'j07}} \pi^k_{cj07} \tag{3.17}$$

$$\tilde{\pi}^k_{ij07} = \frac{1}{\pi^k_{ij07} e^{(\tilde{\delta}^k_{c07}-\delta^k_{c07})} + \sum_{i' \neq c} \pi^k_{i'j07}} \pi^k_{ij07}. \tag{3.18}$$

Remember that we are interested in calculating new trade flows, $\tilde{x}^k_{ij07}$. With $\tilde{\pi}^k_{ij07}$ in hands, from equation (3.7) above, we obtain each country's expenditure given that a constant fraction of their income is spent in a given sector, α^k_{jt} (the Cobb-Douglas preferences parameters). Therefore, in each country the following equation must hold:

$$D_{it} = \sum_{j'} \sum_{k} x^k_{ij't} + \gamma_{jt} \tag{3.19}$$

$$= \sum_{j'} \sum_{k} (\pi^k_{ij't} \alpha^k_{j't} D_{j't}) + \gamma_{jt} \tag{3.20}$$

where γ_{jt} is a measure of trade imbalance for country j. We impose a world trade balance condition in every period of time t: $\sum_j \gamma_{jt} = 0$. This assumption is less strict than the country-by-country trade balance condition in Costinot *et al.* (2012). Rewriting the above equation in terms of the counterfactuals, we obtain the following:

$$\tilde{D}_{i07} = \sum_{j'} \sum_{k} (\tilde{\pi}^k_{ij'07} \alpha^k_{j'07} \tilde{D}_{j'07}) + \tilde{\gamma}_{j07}. \tag{3.21}$$

This is a linear system that can be easily solved numerically, but two observations should be made. First, the system possesses 35 unknowns and 35 equations, but not independent ones.[13] Remember that we have multiple equilibria with respect to the overall size of the world economy, so we must impose a condition on the demand (or the supply) to find a solution. We assume that world total demand is given by:

$$\sum_{j'} \tilde{D}_{j'07} = \sum_{j' \neq c} D_{j'07} + \frac{D_{c99}}{D_{us99}} D_{us07}. \tag{3.22}$$

That is, we are assuming that the size of world demand equals the sum of all countries apart from China plus a component saying that China would have grown at the same rate as the US in the period. Note that we are *not* fixing China's demand, we are simply fixing the total world demand.

The second condition we need to add is related to trade imbalances. We will assume that China's new trade imbalance will be fixed at:

$$\tilde{\gamma}_{c07} = \frac{\gamma_{c99}}{\gamma_{us99}} \gamma_{us07}. \tag{3.23}$$

This implies that China's surplus relative to the US is constant over time. Since the imbalances must sum up to zero, we proportionally cut $\tilde{\gamma}_{i07}$ for all countries with deficits such that $\sum_j \tilde{\gamma}_{j07} = 0$ is satisfied.

In all the following figures, we move the counterfactual in a smooth way towards our target $\tilde{\delta}^k_{c07}$. So, the horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the actual 2007 values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our final counterfactual $\tilde{\delta}^k_{c07}$.

Figures 3.1 - 3.3 show trade shares for China, developing countries (Brazil and India) and developed ones (USA and Germany).[14] As we can see in 3.1, Chinese average trade share would be almost 30 percent smaller if its comparative advantage relative to the US in 2007 was similar to its 1999 levels. While developing countries trade share would be virtually equal to their actual level, developed countries would have a larger share of the world trade. That is, according to this Ricardian model, Chinese structural productivity change shifted China's comparative advantage towards product otherwise produced by developed countries, without crowding out developing countries trade with the rest of the world.

Figures 3.4 - 3.6 show the counterfactual Brazilian supply for some industries in agriculture, mining and manufacturing sectors. As we can see in 3.4, Chinese technological growth had almost no impact on soybean production in Brazil. However, we see that

[13]It is easy to verify this by summing up all the equations in the system.

[14]Figures 3.A1 - 3.A3 presents the trade levels for these countries.

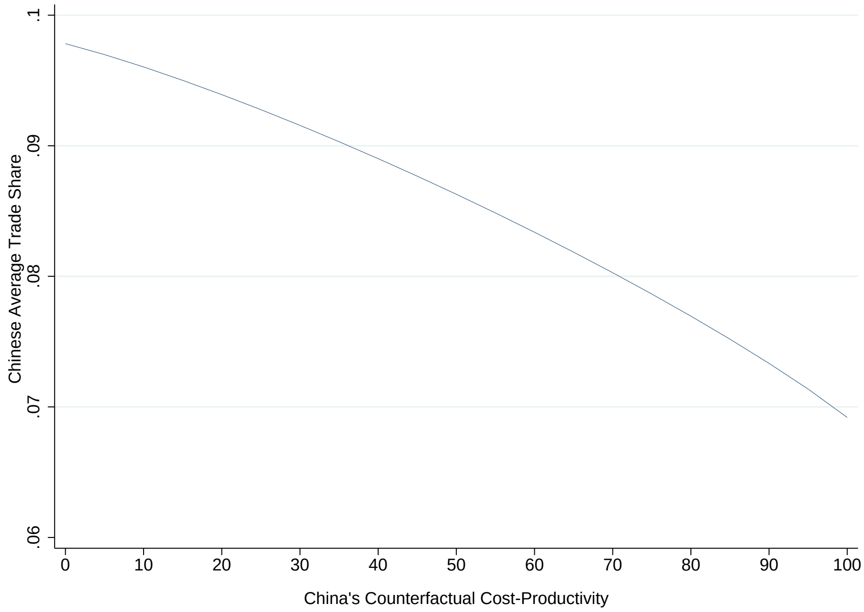


Figure 3.1: Unrestricted Supply Counterfactuals: Chinese Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

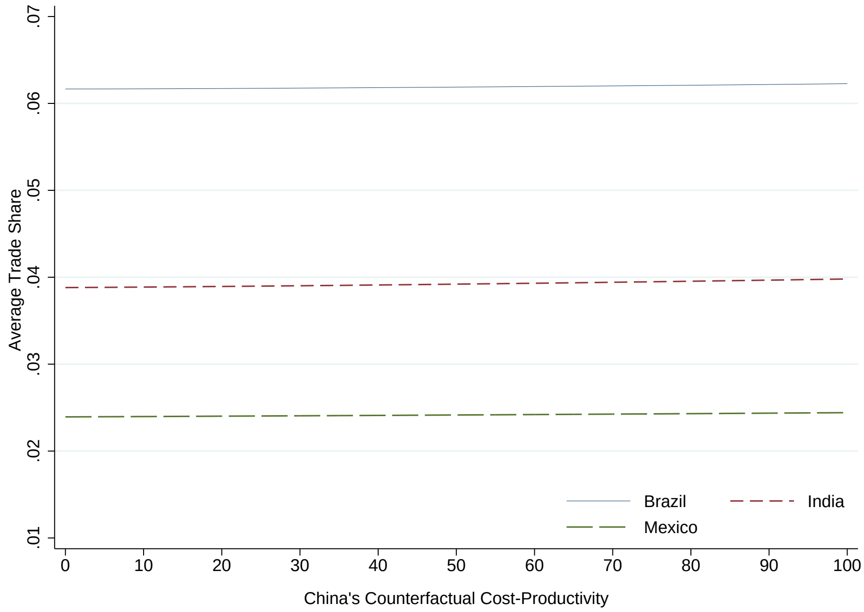


Figure 3.2: Unrestricted Supply Counterfactuals: Developing Countries' Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

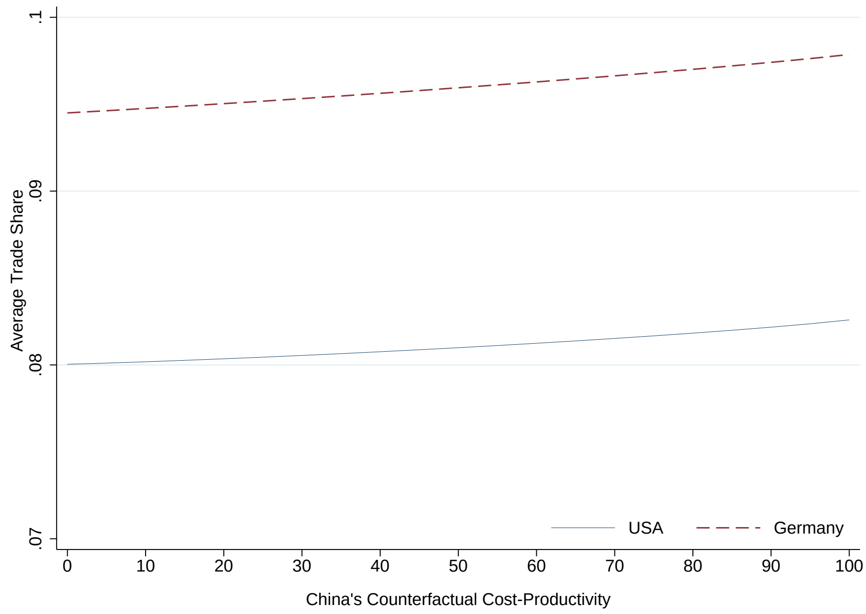


Figure 3.3: Unrestricted Supply Counterfactuals: Developed Countries' Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\bar{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\bar{\delta}^k_{c07}$.

Brazilian production of cereals and sugar cane would be larger if China's comparative advantage relative to the US had followed the world trend. In 3.5, we see a modest reduction on the share of iron and manganese ore in this counterfactual world, compensated by a larger production of other mining. This suggest that, within this Ricardian model of trade, Chinese development across-industries held back the expansion of Brazilian primary sector overall, and it was not crucial to the development of soya and iron ore production in Brazil.

In Figure 3.6, we can see that recent Chinese technological transformation indeed represented competition to the Brazilian manufacturing sector. We can observe that mostly all industries within the manufacturing sector would have been producing more if China's production cost had evolved as the world average. In particular, we see that labour-intensive products, such as plastics and textiles, would have experienced the larger changes. This is in line with the 'import competition shock' studied in Chapter 2.

3.4.1.2 Supply Restricted

We now perform a simpler exercise where demand for each country is restricted, switching off the '*expenditure feedback*'. In this way we can have an idea to which extent across-industries technological changes within China affected international trade and production

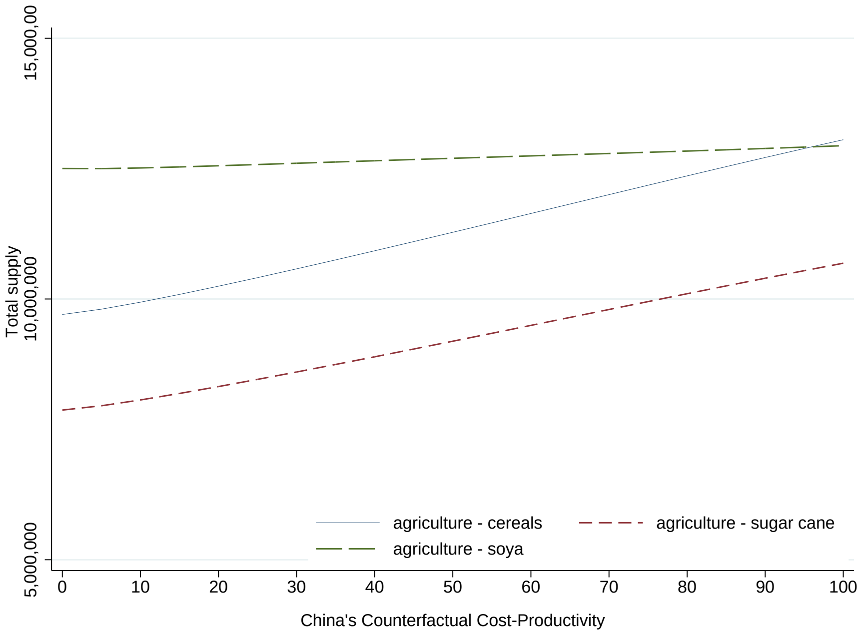


Figure 3.4: Unrestricted Supply Counterfactuals: Brazilian Supply: Agriculture

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

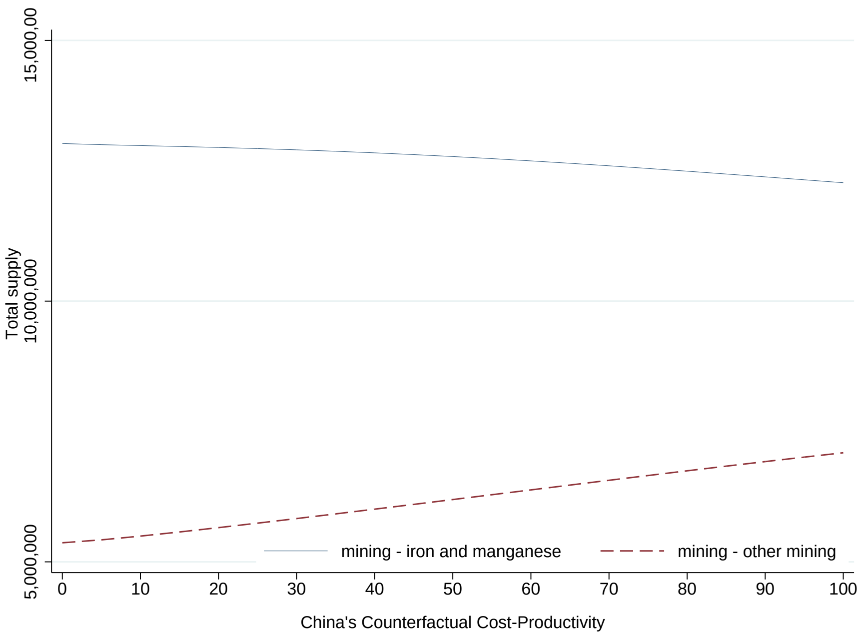


Figure 3.5: Unrestricted Supply Counterfactuals: Brazilian Supply: Mining

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

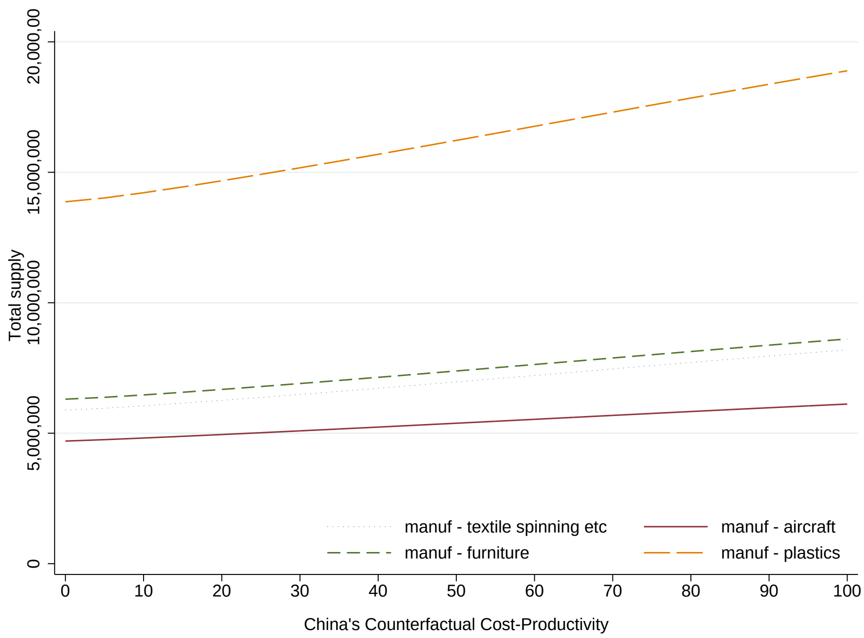


Figure 3.6: Unrestricted Supply Counterfactuals: Brazilian Supply (Manufacturing)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

net general equilibrium effects on countries' expenditures. In this scenario, we simply impose the realized demand, $D^k_{jt} = \tilde{D}^k_{jt}$, and apply equations (3.17) to back out trade flows $\tilde{x}^k_{ijt}$. Note that we do not need to solve any system of equations or make assumptions about countries' surplus or world demand, such that conditions (3.22) and (3.23) are put aside. As discussed in the beginning of this section, trade shares are not affected by the level of world demand, so these results are identical to the 'unrestricted' counterfactual.[15]

Figures 3.7 - 3.9 show the 'restricted' counterfactual Brazilian supply for some industries in agriculture, mining and manufacturing sectors. We see in Figures 3.7 and 3.8 that soybeans and mining production in Brazil follows a similar evolution to the 'unrestricted' counterfactual. However, without considering the effects of production costs on international expenditure, we observe that the counterfactual production of other agricultural products and other mining are equal to the realized ones. We also find no effects on production of manufacturing products, as in Figure 3.9. Again, within this model, it is not the case that across-industries Chinese productivity growth directly stimulated Brazilian soybean and iron ore production, but it did depreciate Brazilian manufacture by affecting world's expenditure across industries.

[15]Figures 3.A4 - 3.A6 show trade shares for China, developing countries (Brazil and India) and developed ones (USA and Germany). Figures 3.A7 - 3.A9 presents the trade levels for these countries.

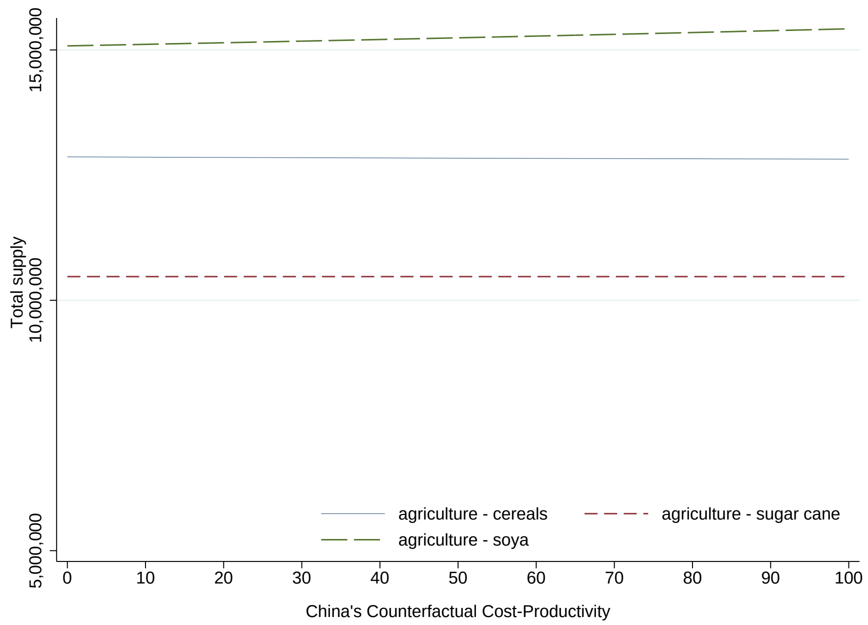


Figure 3.7: Restricted Supply Counterfactuals: Brazilian Supply (Agriculture)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

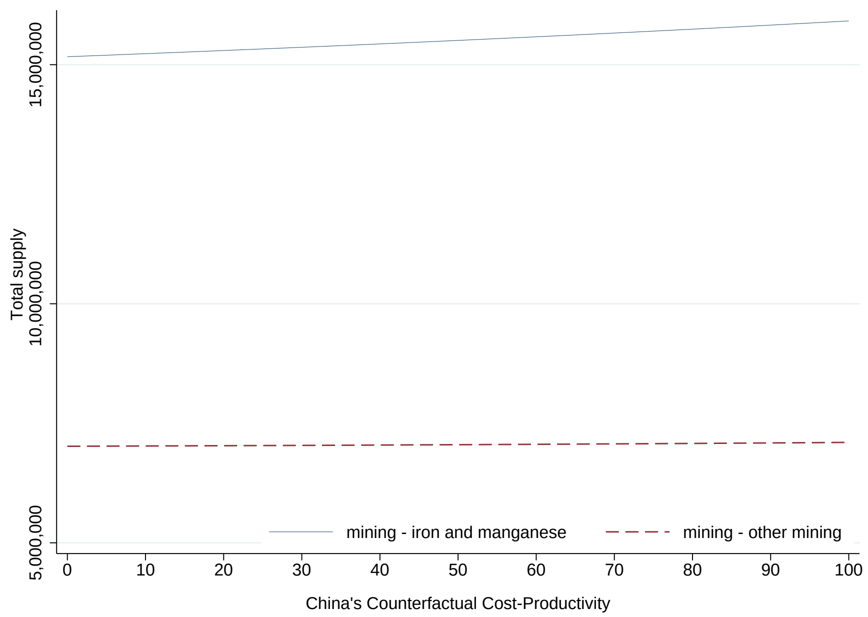


Figure 3.8: Restricted Supply Counterfactuals: Brazilian Supply (Mining)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

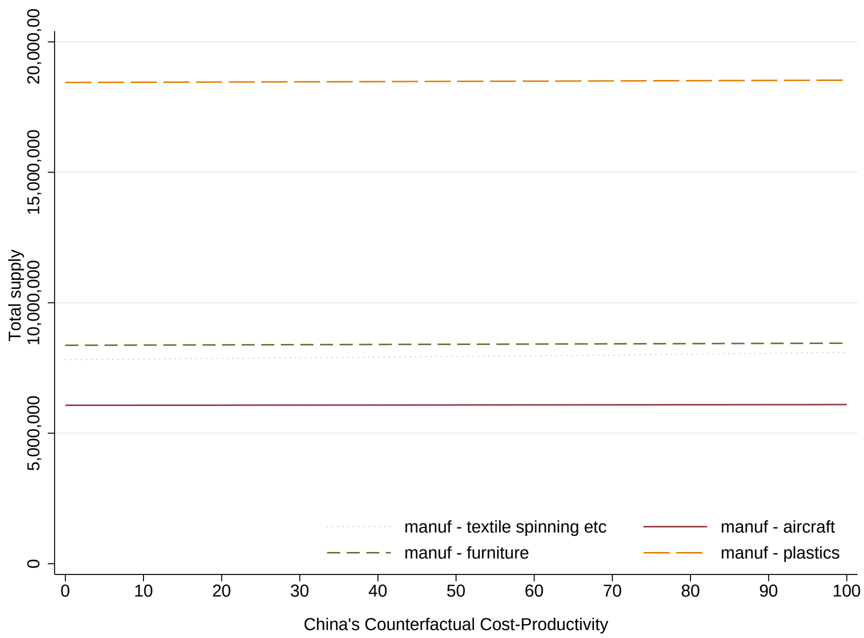


Figure 3.9: Restricted Supply Counterfactuals: Brazilian Supply (Manufacturing)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

3.4.2 Demand Restriction

In our last counterfactual we study how a demand (taste) shock in China affects trade flows around the world. In this exercise we focus on a change in the Cobb-Douglas parameters, α^k_{c07}, maintaining the supply parameters δ^k_{c07} equal to the real ones. We assume that China's consumption shares over industries in 2007 were the same as in 1999, $\tilde{\alpha}^k_{c07} = \alpha^k_{c99}$. We proceed in the same fashion as in our unrestricted counterfactual to find the new demand values $\tilde{D}_{j'07}$ applying a slightly modified version of equation (3.21):

$$\tilde{D}_{i07} = \sum_{j'} \sum_{k} (\pi^k_{ij'07} \tilde{\alpha}^k_{j'07} \tilde{D}_{j'07}) + \tilde{\gamma}_{j07}. \tag{3.24}$$

Note that conditions on total world demand (3.22) and trade imbalances (3.23) need to be imposed once more.

Referring to Chapter 2. Regarding our discussion on Chinese demand shock driving a commodity boom, we are generating a world in which China's tastes over products did not change over time.

Since trade shares are unchanged by hypothesis, it is trivial to find the counterfactual trade flows after the new demand is calculated. Figures 3.10 - 3.12 show the aggregate supply for China, developing countries (Brazil and India) and developed ones (USA and Germany). We observe Chinese supply higher in a world where Chinese tastes did not

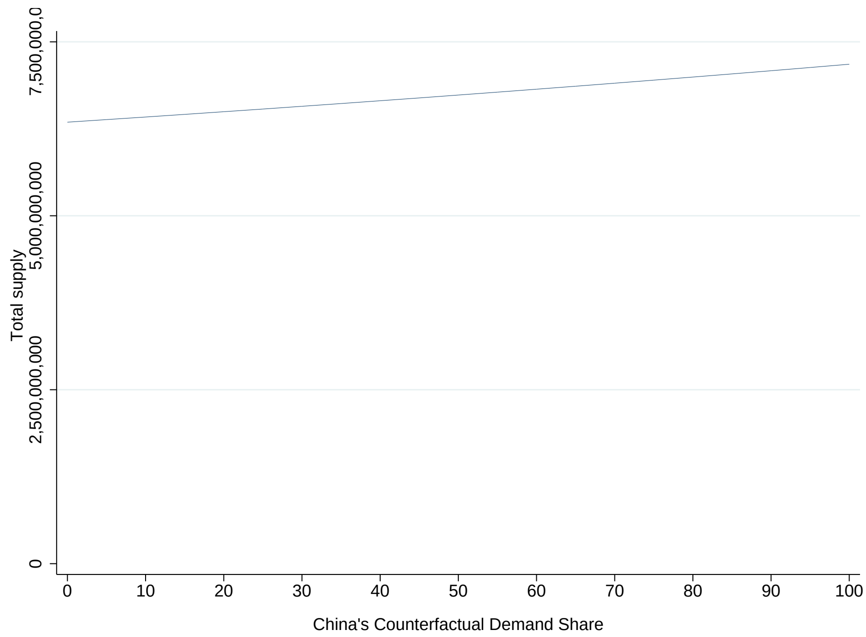


Figure 3.10: Demand Counterfactuals: Chinese Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

change in the last decade. Potentially, this is due to smaller consumption of technology intensive products.

In Figures 3.13 - 3.15 we can see the counterfactual Brazilian supply in products in agriculture, mining and manufacturing sectors. We observe virtually no effects in all products in these three sectors, except soybeans and iron and manganese ore – the two main exports from Brazil to China. If China's preferences in 2007 was the same as its preferences in 1999, Brazilian production of these products would have been even larger than the observed ones. China spends a smaller share of its income in raw material today than in 1999, particularly soybeans and iron and manganese ore, and a larger share in technology-intensive goods. In other words, if China triggered a commodity boom in the world, or at least in Brazil, this was driven mostly by a level effect of increased income in China, and any changes in China's tastes over products contributed to moderate such boom. This goes against the idea of a positive China demand (taste) shock towards soybeans and iron and manganese ore.

3.5 Conclusion

In this paper we performed counterfactuals exercises to analyze how countries and Brazilian sectoral production would have performed in the absence of the massive Chinese

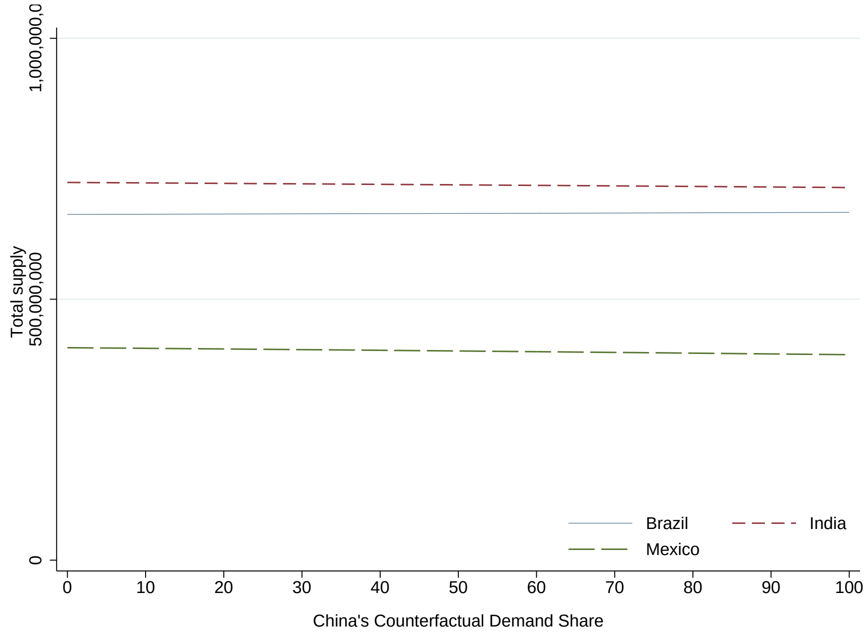


Figure 3.11: Demand Counterfactuals: Developed Countries' Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

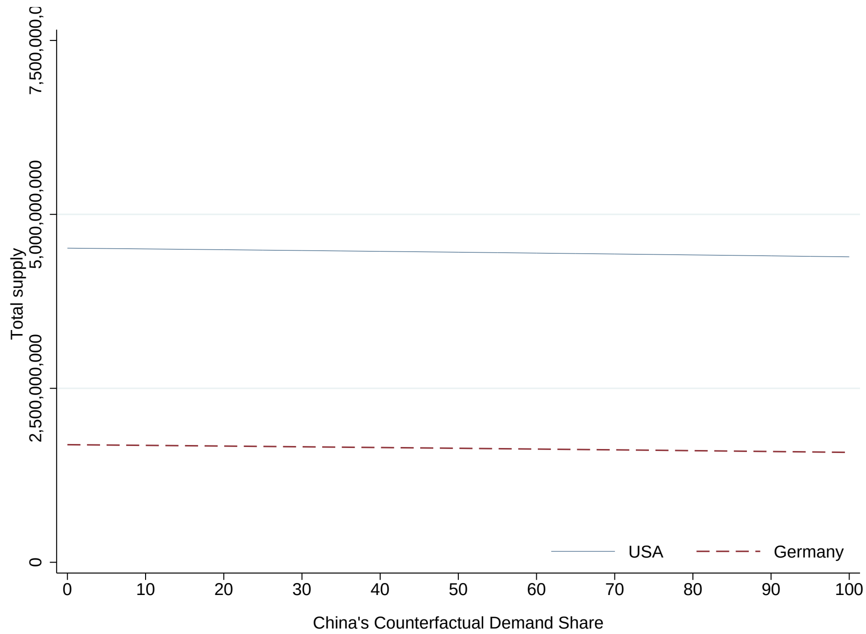


Figure 3.12: Demand Counterfactuals: Developed Countries' Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

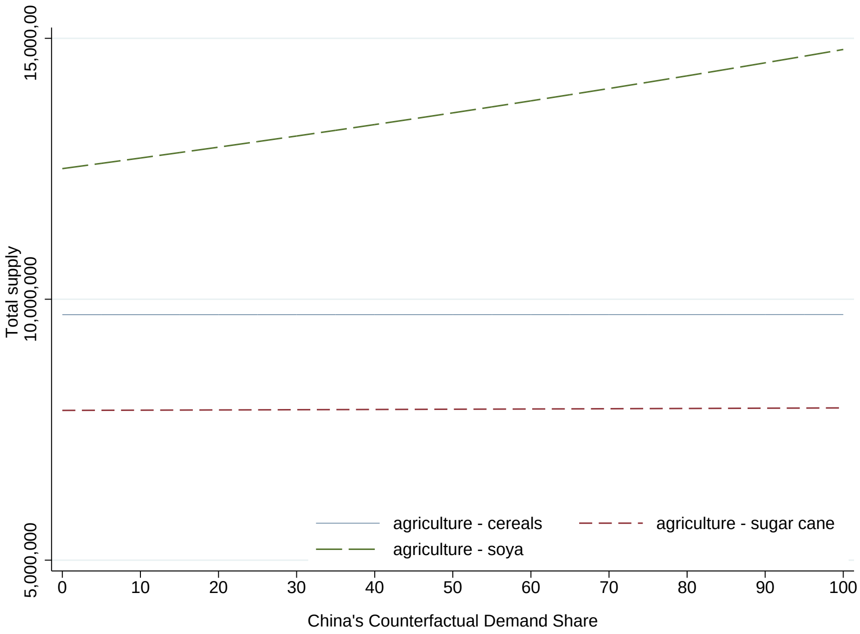


Figure 3.13: Demand Counterfactuals: Brazilian Supply (Agriculture)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

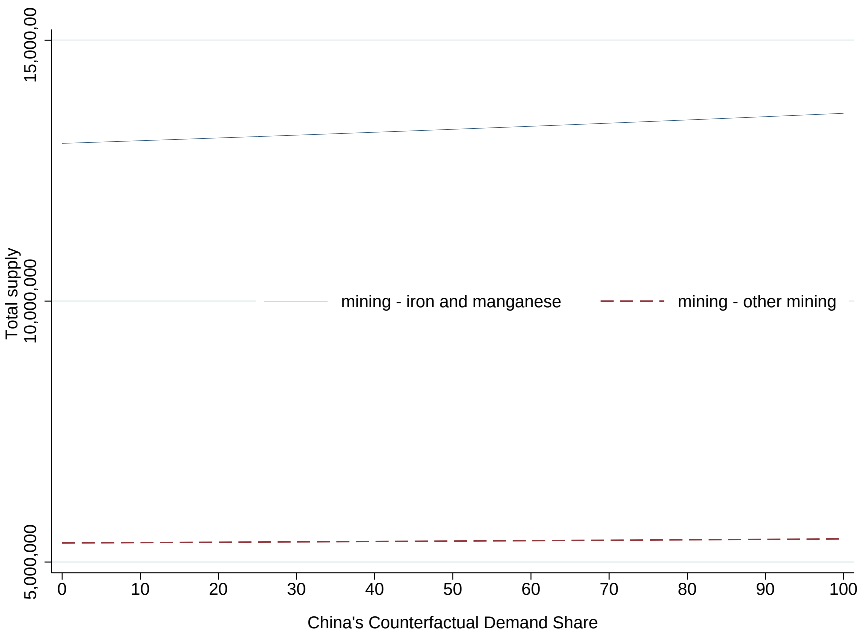


Figure 3.14: Demand Counterfactuals: Brazilian Supply (Mining)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

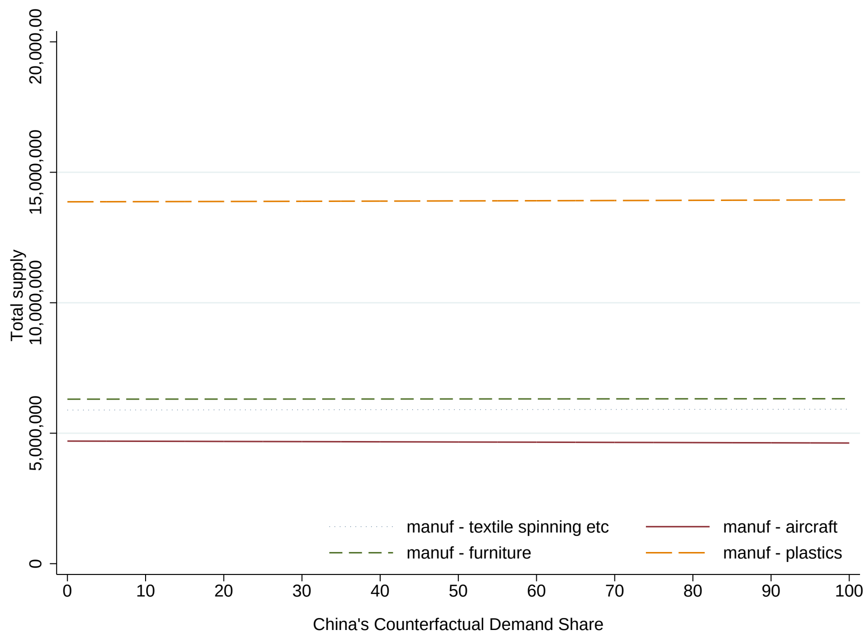


Figure 3.15: Demand Counterfactuals: Brazilian Supply (Manufacturing)

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, α^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\alpha}^k_{c07} - \alpha^k_{c07})(50/100) + \alpha^k_{c07}$, and 100 implies that we reached our target $\tilde{\alpha}^k_{c07}$.

growth. With this objective, we employ the Ricardian model of trade of Costinot et al. (2012) which, building on Eaton and Kortum (2002), provides theoretically consistent foundations for estimating the relative production cost at a country-industry level. We use these estimates to develop counterfactuals in which China stays at its 'original' state, and then compare Brazil's production composition in this world and the real world. We perform two main counterfactual exercises. First, we model productivity growth in China as the main lever by which Chinese supply and demand conditions evolve and affect Brazil. Second, we study how changes in composition of Chinese demand (taste) affects trade flows around the world and Brazilian production.

These exercises help us understanding the plausibility of the assumptions underlying the instruments used in Chapter 2, and in many papers in the literature inspired by Autor et al. (forthcoming). For example, Brazil increasingly imports manufactured products from China, at the same time that Brazil is a great producer of soybeans and one of its main supplier to China. Within the counterfactuals we can address questions, such as: how would the manufacturing production in Brazil have performed in the absence of the Chinese technological changes between 1999 and 2007?; or how would the soybean production in Brazil have performed in the absence of the Chinese demand changes between 1999 and 2007? We find that Brazilian manufacture would have grown more due to a softer competition if Chinese production costs had evolved as the world average. We also see that changes in China's preferences over consumption actually reduced the growth of soybean production in Brazil, due to an increasing preferences for technology-intensive manufactured goods.

In sum, we understand the preliminary results presented here suggest that these supply and demand partial-equilibrium counterfactuals support the instrumental variables strategy from Autor et al. (forthcoming), which inspired the instruments used in Chapter 2. To be frank, we are still considering how to move forward with this project, if we should be more ambitious in this paper, or if we should bring it even closer to Chapter 2.

3.A Appendix

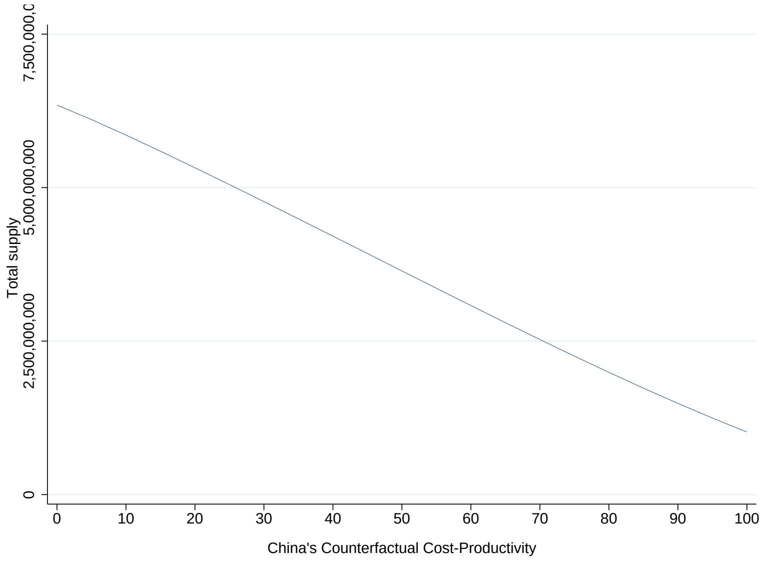


Figure 3.A1: Unrestricted Supply Counterfactuals: Chinese Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\bar{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\bar{\delta}^k_{c07}$.

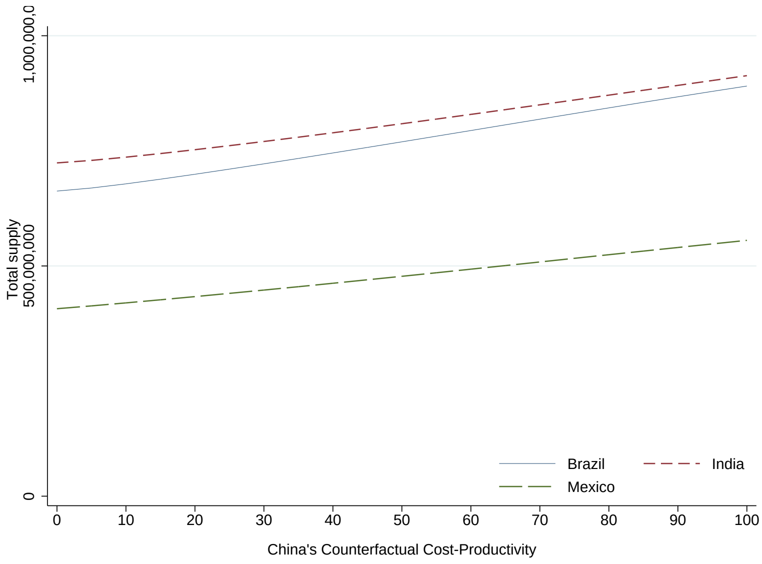


Figure 3.A2: Unrestricted Supply Counterfactuals: Developing Countries' Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\bar{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\bar{\delta}^k_{c07}$.

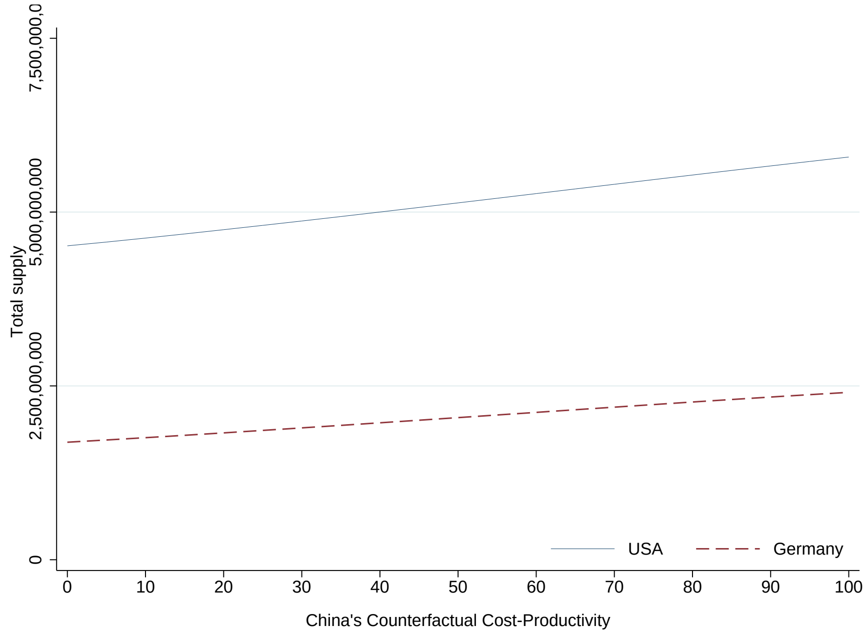


Figure 3.A3: Unrestricted Supply Counterfactuals: Developed Countries' Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

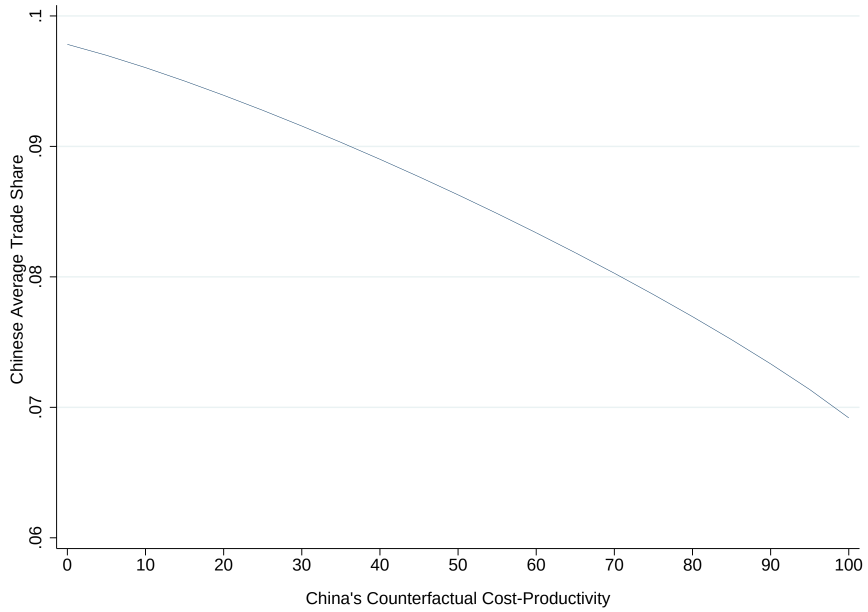


Figure 3.A4: Restricted Supply Counterfactuals: Chinese Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

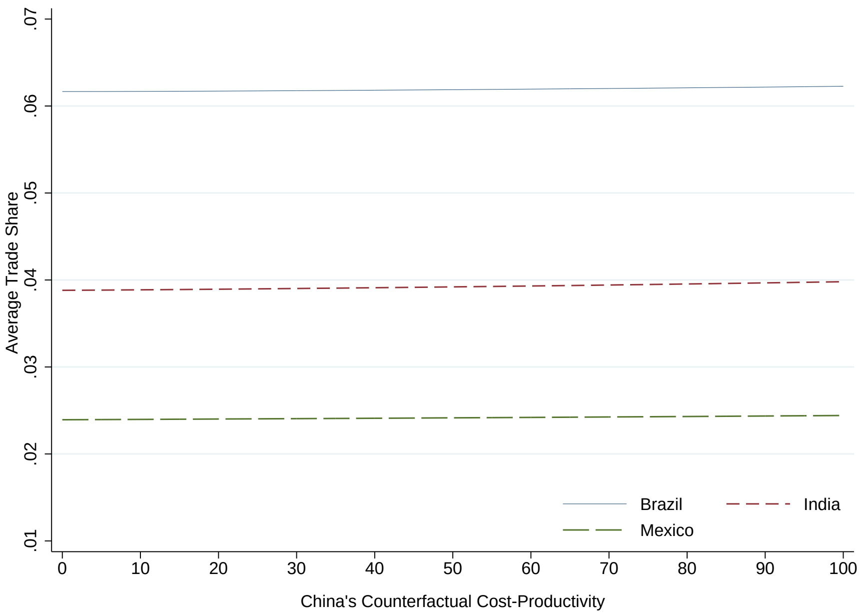


Figure 3.A5: Restricted Supply Counterfactuals: Developing Countries' Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

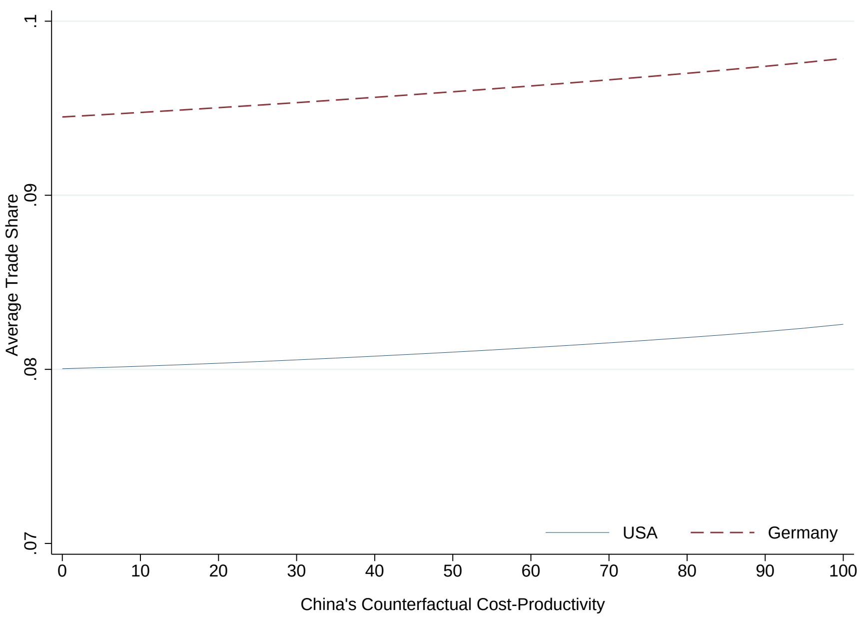


Figure 3.A6: Restricted Supply Counterfactuals: Developed Countries' Average Trade Share

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

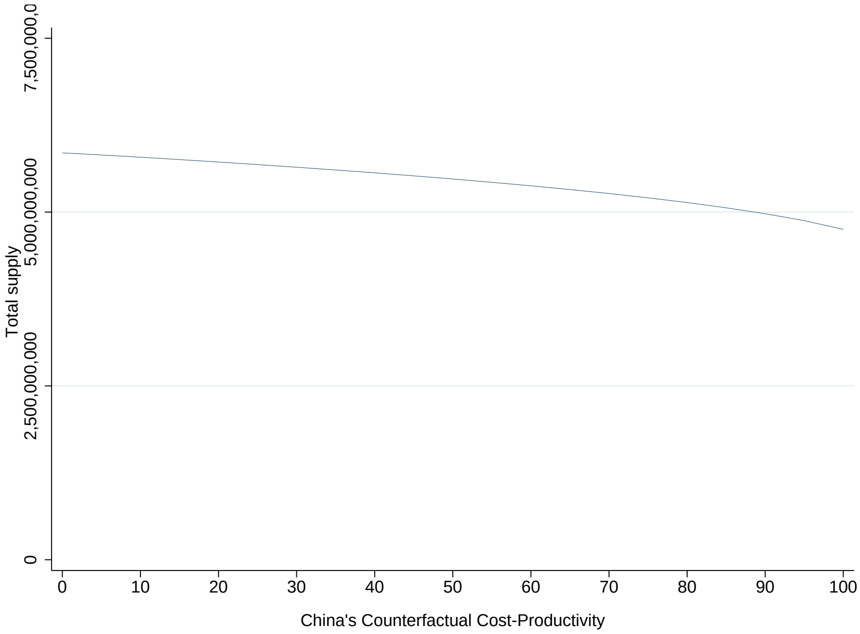


Figure 3.A7: Restricted Supply Counterfactuals: Chinese Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

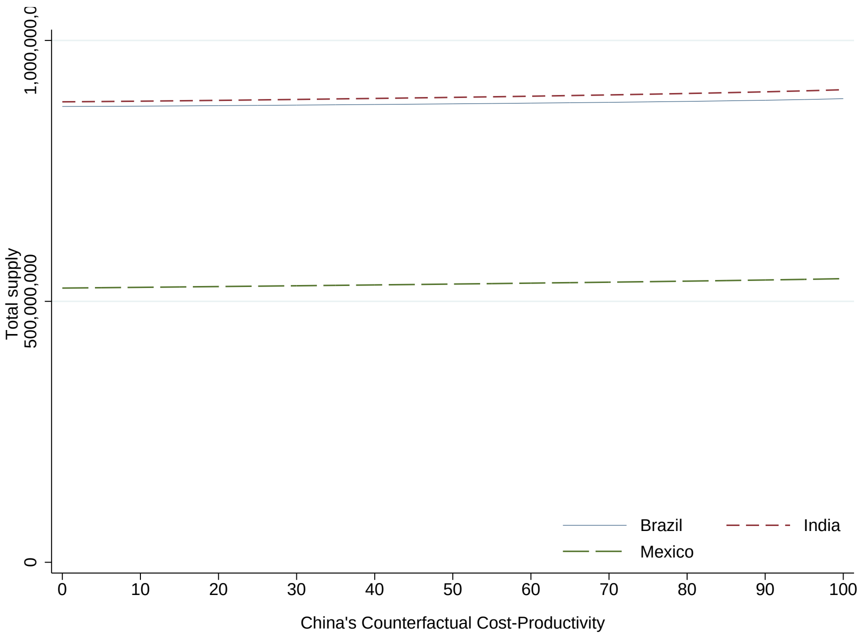


Figure 3.A8: Restricted Supply Counterfactuals: Developing Countries' Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

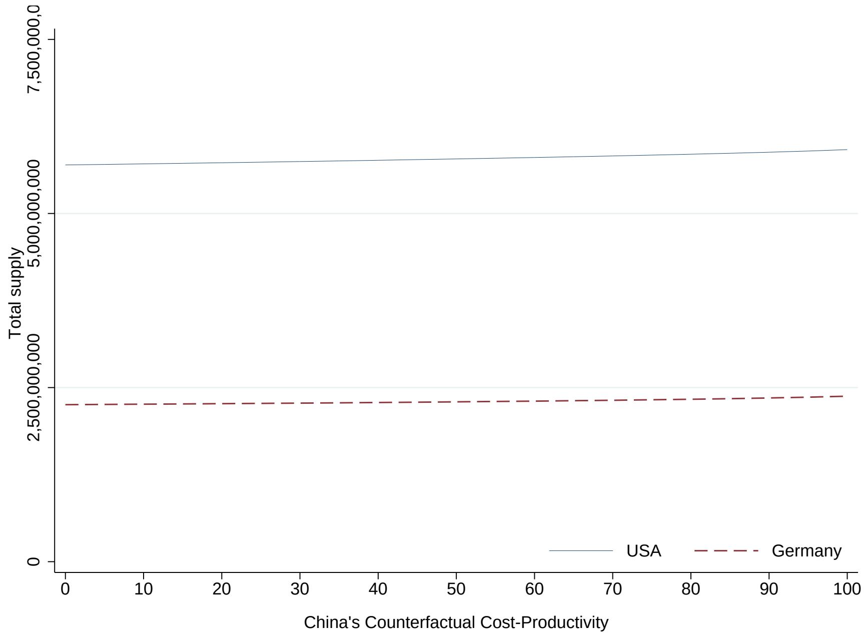


Figure 3.A9: Restricted Supply Counterfactuals: Developed Countries' Total Supply

NOTES: The horizontal axis represents the proximity to our counterfactual target. For example, 0 means that we are using the 2007 China values, δ^k_{c07}. A value of 50 means that we are half way to our objective, $(\tilde{\delta}^k_{c07} - \delta^k_{c07})(50/100) + \delta^k_{c07}$, and 100 implies that we reached our target $\tilde{\delta}^k_{c07}$.

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