Efficient Reallocation and Productivity during Commodity Price Cycles

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Abstract

This paper investigates how low-frequency commodity price fluctuations trigger a reallocation process that endogenously generates a decline in manufacturing productivity. I build a model in which firms with heterogeneous productivity decide between two technologies with different capital intensities and choose whether to become exporters. During a commodity boom, exporters lose market share due to exchange rate appreciation. Moreover, a commodity boom increases the relative cost of capital, which is used intensively in resource production, leading to additional reallocation within manufacturing from more capital intensive to less capital-intensive manufacturing firms. I calibrate the model to the Chilean economy and show that it can match the relevant micro and macro moments. When fed with a realistic commodity price cycle, the baseline model generates about half of the productivity decline observed in the data, a figure that is two times larger than in a counterfactual economy with no technology decision.

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1 Introduction

This paper revisits the link between commodity price cycles, sectoral allocations and measured productivity in resource-rich countries. Traditional narratives on the so-called Dutch disease emphasize how commodity price booms reallocate resources away from tradable sectors into both domestic services and the booming natural resource sector (see Corden and Neary 1982). This literature typically argues that such reallocation is inefficient and reduces long-run growth due to forgone productivity spillover externalities concentrated in the (non-commodity) tradable/manufacturing sector of the economy (e.g. Krugman 1987, Alberola and Benigno 2017, Alcott and Keniston 2018). In this paper, I propose an alternative framework with heterogeneous firms, that even in the absence of market failures, delivers an endogenous decline in measured productivity. The key intuition of the paper is that commodity price booms are associated with a firm composition effect in which relatively productive firms lose market share against relatively unproductive firms, thereby rationalizing the decline in productivity typically observed during these episodes.

Why relatively productive firms lose market share during a commodity price boom? Two market-based mechanisms are key to understand this behavior. On the one hand, as the commodity producing economy becomes richer during the boom, domestic absorption increases and the real exchange rate appreciates. Within manufacturing industries, exporter firms lose market share *vis à vis* nonexporters, as real exchange rate appreciation reduces their competitiveness abroad and hurts their revenues from export sales. Because in the data exporters are significantly more productive than nonexporters, this exchange rate channel induce a composition effect consistent with a decline in the average efficiency of operating firms.

On the other hand, resource booms in resource-rich economies are often associated with upward pressure on input prices, as they seek to scale up aggregate supply and demand. Because commodity production uses physical capital intensively, resource booms are associated with an increase in the relative cost of capital, thereby imposing a cost disadvantage to capital-intensive firms within manufacturing sectors. Because in the data capital-intensive firms are on average more productive than labor-intensive firms, the cost of capital channel interacts with the exchange rate channel to reinforce the overall decline in average productivity.

The extent of firm-level heterogeneity in capital intensities and export intensities determines the relative importance of each channel. If all plants produce with the same capital intensity, within-firm substitution between labor and capital plays no role as everyone faces the same increase in their unit costs. Likewise, if all firms were equally export-intensive, exchange rate dynamics would affect all plants symmetrically and there is no room for Dutch disease-like reallocation dynamics within sectors, in which exporters shrink relative to non-exporters. Using manufacturing firm-level data for Chile, the largest copper producer in the world, I document large within-sector variation of capital intensity in the cross-section of plants, suggesting that heterogeneous technologies with different exposures to changes in the cost of capital coexist even within narrowly-defined manufacturing industries. Moreover, only about 22% of manufacturing firms engage in exporting activities, thereby being exposed to the exchange rate channel.[1]

Motivated by this evidence, I study the differential effects of commodity price booms on the relative performance of exporters versus non-exporters and more capital-intensive versus less capital-intensive firms, within Chilean manufacturing industries during the period 1995-2013. The sample period analyzed includes the commodity price super-cycle that started around 2003, which provides a unique quasi-natural experiment to test the predictions of the theory proposed in this article. I find, first, that pre-boom exporters and capital-intensive firms exhibit shrinking profits relative to their non-exporting and labor-intensive counterparts during the boom period 2003-2013. Second, I document a "missing generation of exporters", as firms' probability of continuing to export declines significantly during the boom. Third, firms with relatively high capital-labor ratios in the pre-boom period downsize their capital intensities significantly during the boom. Overall, as relatively productive exporters and capital-intensive firms shrink, exit from exporting activities and downsize their reliance on capital, the weighted average productivity of the pool of operating firms decline.

To formalize my empirical findings and quantify the relevance of the proposed channels in determining allocations and average productivity, I build a two-sector

[1] Chilean copper mine production accounts for 27% of worldwide production in 2017 (Cochilco, 2018). The country's mining sector accounts for roughly 10% of GDP, 50% of total exports, 21% of the economy-wide stock of physical capital, and less than 5% of the labor force.

(commodity and exportable) model of a small and financially open commodity-exporting economy. The commodity sector is modeled as a representative firm that combines labor and capital to produce commodity output. The main actors in this economy are a continuum of firms with heterogeneous productivity aiming to represent the exportable/manufacturing sector. To deal with the differential effects that commodity shocks have on profits of exporters vs non-exporters (within manufacturing industries), I borrow the framework introduced by Melitz (2003), in which firms trade off a fixed exporting cost against the possibility of serving the foreign market. In turn, to deal with the significant cross-sectional heterogeneity and time variation observed in capital intensities across firms within manufacturing industries, I introduce a technology choice that allows firms to adjust their capital intensity in response to changes in relative input prices (along the lines of Bustos (2011), Arayavechkit, Saffie and Shin (2014), and Limão and Xu (2018)). When choosing their technology, firms trade off larger fixed costs against a reduction in their variable costs (or equivalently, a productivity boost).

As is well known, this type of framework leads to self-selection, in the sense that only the most productive firms find it profitable to pay the exporting and adoption fixed costs. Intuitively, the profitability of becoming an exporter and/or adopting the capital-intensive technology is increasing in the firm's productivity type, while the costs of those choices are fixed and type-independent. This ensures there are always threshold productivity levels above which exporting and upgrading technology are worthwhile for the most productive firms in the economy.

The model is calibrated to reproduce selected key macro and micro-level features of the Chilean economy, and is used to study the economy's dynamic response to a realistic commodity price cycle. In particular, to calibrate the parameters related to the exporting and capital intensity choices, I use the observed cross-sectional variation in export and capital intensities across firms within (3-digit) manufacturing industries.

When fed with an exogenously-given commodity price boom-bust cycle, the calibrated model generates reallocation dynamics reminiscent of traditional Dutch disease narratives, but in a context in which reallocation is efficient. First, the resource sector crowds out labor and especially capital from manufacturing, consistent with the fact that mining production in Chile is substantially more capital-intensive than the typical manufacturing industry. Second, within the manufacturing sector, reallocation is shaped by firms' initial export and capital intensities. More specifically, using a model-simulated panel of firms, I show that exporters contract significantly relative to non-exporters during the boom, while the profits of capital-intensive firms fall disproportionately, findings consistent with the microdata. Third, entry/exit and upgrade/downgrade dynamics induce a composition effect that explains about half of the decline in measured manufacturing productivity between the pre-boom period 1995-2002 and the so called super-cycle of 2003-2013. Fourth, the amplification effect generated by the cost of capital channel via the technology decision is quantitatively relevant. I find that the baseline model generates a productivity decline two times larger relative to a counterfactual economy with no capital intensity decision.

Related literature. There are two closely related articles studying Dutch disease-like reallocation dynamics using micro data to uncover the transmission channels from commodity booms to the macroeconomy. First, Benguria, Saffie, and Urzua (2018) exploit Brazilian regional variation in exposure to commodity price shocks and administrative firm-level data to disentangle similar channels as the ones studied here. While their emphasis is on labor market rigidities and the role of changes in the skill premium in shaping sectoral reallocation, I focus on substitution between labor and capital. These are natural choices as commodity production in Brazil (mainly agriculture) is unskilled labor-intensive, while mining production in Chile is capital-intensive. More importantly, by introducing a technology choice, I allow for an additional margin of adjustment that takes place within establishments, as I study how firms react to input price fluctuations by adjusting their optimal mix of labor and capital.

Second, Alcott and Keniston (2017) combine U.S. data on oil endowments at the county level with Census of Manufactures to estimate how oil booms affect local manufacturing firms. They find that manufacturing as a whole is not crowded out during oil booms, because negative effects on some tradables firms are offset by positive effects on upstream and locally-traded subsectors. By studying reallocation within the U.S. economy and focusing only on labor input, they abstract from the two key mechanisms emphasized in the present paper. On the one hand, they propose a "within-country" model of Dutch disease reallocation, thereby eliminating the differential effects of exchange rate fluctuations on the relative performance of exporters versus non-exporters. Interestingly, they do find that "tradable" manufacturing firms (those that sell outside the limits of their own county) do contract during resource booms. Their intuition for "tradable" U.S. firms has the same flavor as my results for exporters: they suffer from higher wages but do not benefit much from the oil boom and its associated increase in local demand. On the other hand, they abstract from changes in the relative price of capital, which I argue is a key element to consider given the high capital intensity of oil- and metal-related extraction and production processes.

The technology choice introduced in this paper blends elements from Bustos (2011) and Arayavechkit *et al* (2014).[2] Bustos (2011) considers a single-input production function, in which firms can choose to reduce their marginal cost of production by paying a fixed cost. In my case, firms not only decide the amount of inputs to use in production, but also they optimally decide the capital share in a Cobb-Douglas production function that combines labor and capital, as in Arayavechkit *et al* (2014). I discipline the fixed cost of adoption using the empirically observed differences in productivity between capital-intensive versus labor-intensive manufacturing firms. In addition, I study the technology adoption margin in a quantitative dynamic model, and in the context of a small and open resource-dependent economy subject to persistent global cycles in commodity prices.

By studying the effects of resource booms on sectoral allocations and productivity, the paper is tightly linked to the long-standing literature about Dutch disease or the "Resource Curse" (see Corden and Neary, 1982; Krugman, 1987; Sach and Warner, 1997; van der Ploeg, 2011; Frankel, 2012; Rodrik, 2013). Alberola and Benigno (2017) propose a representative-firm three-sector commodity-exporter economy model to study the effects of commodity booms on long-run growth. They show theoretically that, when dynamic productivity spillovers are concentrated in the non-resource tradable sector, the commodity boom delays convergence to the world technology frontier and may even lead to a growth trap. While I do not consider spillover effects nor any form of endogenous growth, I extend the analysis in other important dimensions. First, I emphasize reallocation at the firm level within the manufacturing sector, which requires a framework with firm heterogeneity and an explicit distinction between exporters and non-exporters. Second, given the importance of relative in-

[2]Other articles with technology choice in the context of trade models includes Yeaple (2005) and Limão and Xu (2018).

put intensities in shaping reallocation, I allow for labor and capital in the production function, and discipline their shares directly using firm-level data. I am not aware of other articles studying the capital intensity dimension in shaping firm-level reallocation dynamics during a commodity boom episode. The paper also provides an alternative explanation for persistent downturns in productivity during commodity price booms without relying on inefficient reallocation due to reduced-form frictions and externalities.

Finally, the paper is also linked to the literature studying the effects of terms of trade shocks in the macroeconomy (see Mendoza, 1995; Kose, 2001; and Vegh, 2013, for a textbook discussion). Motivated by the recent commodity super-cycle, several articles have focused specifically on the effects of commodity price shocks in emerging economies (Schmitt-Grohe and Uribe, 2015; Shousha, 2016; Fernandez, Schmitt-Grohe and Uribe, 2017). Unlike these articles, which focus on the effects of global price fluctuations at business cycle frequencies, this paper seeks to understand the low-frequency dynamic effects that persistent commodity cycles have on resource allocation and productivity. This is a relevant distinction because, as emphasized by Erten and Ocampo (2013) and Reinhart et al (2016), commodity prices are characterized by much longer cycles (of around thirty years) than standard business cycle fluctuations, which puts significant pressure on sectoral allocations in commodity-dependent countries.

Layout. The remainder of the paper is organized as follows. Section 2 presents sector-level and firm-level empirical regularities observed before and after the commodity boom that started in 2003. Section 3 describes the quantitative model designed to disentangle the transmission channels from commodity cycles to manufacturing productivity. Section 4 tests the ability of the model to replicate the empirical facts, and studies whether the model's transitional dynamics can reproduce the most recent commodity super-cycle and its effects on factor allocations and measured productivity. Section 5 concludes.

2 Empirical Analysis

2.1 Commodity Cycles and the Macroeconomy

Figure 1 illustrates the relationship between the recent commodity price "super-cycle", sectoral allocations and measured productivity, using aggregate data for Chile. Panel (a) shows the time paths of the real price of copper -by far the country's main produced and exported commodity- and the country's manufacturing share in total output. The crowding-out effect of commodity prices on manufacturing is especially marked during the persistent boom that started in 2003.

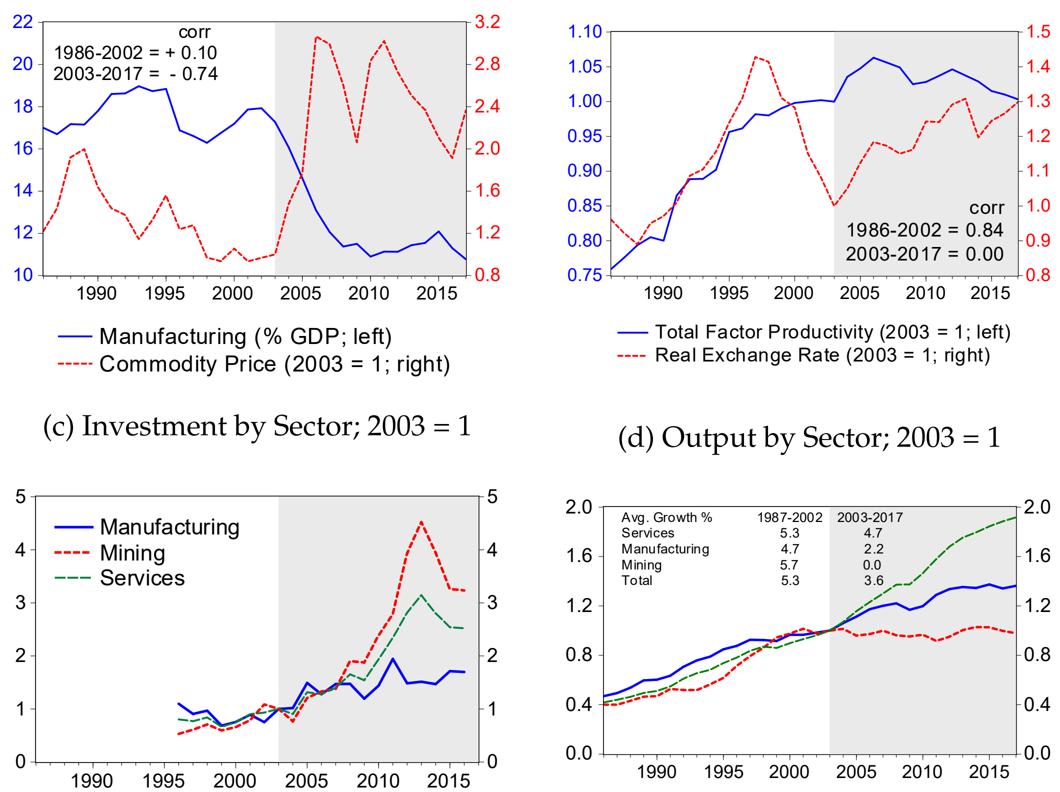
Figure (1) Commodity Price Boom and Sectoral Allocations

(a) Manufacturing Share in GDP

(b) Aggregate TFP and RER

(c) Investment by Sector; 2003 = 1

(d) Output by Sector; 2003 = 1



Notes: Author's calculations based on data from the Central Bank of Chile. The gray area indicates the commodity boom period 2003-2017. Panel (a) reports the nominal manufacturing share in total nominal output, while the real commodity price is PPI-deflated. Panel (b) reports economy-wide measured TFP and the real exchange rate (RER). Panels (c) and (d) report real investment and real output by sector.

Panel (b), in turn, illustrates the relationship between aggregate TFP and the real exchange rate. During the nineties, high productivity growth led to currency appreciation, as predicted by the Balassa-Samuelson hypothesis. However, the relationship breaks down during the commodity boom period (2003-2016), when protracted exchange rate appreciation (30% between 2003 and 2017) coexisted with a medium-run slowdown in aggregate productivity growth (0% between 2003 and 2017).

How can persistent commodity booms generate productivity slowdowns in resource-rich economies? Several channels may be at play. First, the positive wealth effect raises consumption of all types of goods, which all else equal benefits domestic sales relative to export sales. Second, larger local demand induces exchange rate appreciation, which disproportionately affects exporters relative to non-exporter firms. Overall, firms face a double incentive to switch productive resources towards the domestic market as well as the booming resource-based sector. Panel (c) of Figure 1 illustrates this pattern. New investment flows during the commodity boom were mostly directed to the resource sector and domestic services, at the expense of the prototypical (non-commodity) tradable sector, namely manufacturing. Panel (d) confirms that while domestic services boomed and led output growth during 2003-2017, the manufacturing sector tended to lag behind. It is also noteworthy that, despite the large mining investment boom, real commodity production stayed flat during this period, partly as a consequence of a significant decrease in the quality (ore grade) of the natural resource being mined. See Appendix A for a cross-country documentation of the fall in mining productivity in the period under analysis.

In this paper, I argue that the "between sector" reallocation dynamics illustrated in Figure 1 are just part of the story. There are also pervasive reallocation dynamics that take place *within* the manufacturing sector. On the one hand, currency appreciation shrinks exporters' revenue, while non-exporters or "purely-domestic" firms enjoy booming local demand. I use microdata on export sales versus total sales to directly measure the exposure to exchange rate risk at the firm-year level. I argue that distinguishing between exporters and non-exporters is quantitatively important for two reasons. First, only 22% of manufacturing firms, on average, actually sell their varieties abroad, thereby being vulnerable to exchange rate risk.[3] Second, ex-

[3] Due to a lack of suitable data, traditional studies have focused on "tradable sectors", relying on the strong assumption that all "tradable" producers operate in foreign markets.

porters overwhelmingly outperform non-exporters in several outcome variables such as value added, revenue productivity and capital intensity (Bernard and Jensen, 1999; Bernard et al, 2003; De Loecker and Warzynski, 2012). More importantly for the purpose of this paper, I show below (both in the data and in the model simulations) that it is precisely exporters who shrink more and eventually exit from export activities during the protracted commodity price cycle illustrated in Panel (a) Figure (1).

On the other hand, resource booms raise the marginal products (and hence the cost) of mobile productive resources, particularly for inputs used intensively in commodity extraction and production. As emphasized by Corden and Neary (1982), if the commodity sector uses relatively few resources that can be drawn from elsewhere in the economy, the crowding out or "resource movement" effect is negligible. However, commodity (mining) production in Chile uses physical capital disproportionately: while the mining sector represents about 10% of aggregate output, it uses 21% of the economy-wide capital and less than 5% of the labor force. The relative scarcity of capital induces a cost disadvantage to capital-intensive manufacturing firms. I exploit firm-level variation in capital-labor ratios within manufacturing industries in order to infer their exposure to the "cost of capital channel".

2.2 Data

The firm-level data used in the present paper comes from the Encuesta Nacional Industrial Anual (ENIA) (Annual National Industrial Survey) conducted by the Instituto Nacional de Estadistica (INE), the Chilean government statistical agency. The survey contains yearly information on establishments with more than ten employees in the period 1995-2013.[4] It includes 5,000 observations per year and provides information on firm industry, value added, domestic sales, export sales, employment, intermediate inputs spending, and the value of the capital stock.

Firm-level revenue total factor productivity is estimated using the method of Wooldridge (2011) and, under the assumption of constant returns to scale, using cost shares (of total costs) as in Foster, Haltiwanger, and Krizan (2001). Aggregating the micro-level data, ENIA accounts for 86% of aggregate manufacturing value added and 50% of total manufacturing labor as recorded by the country's statistical office.

[4]Most firms in Chile are single-establishment.

2.3 Firm characteristics and estimated productivity

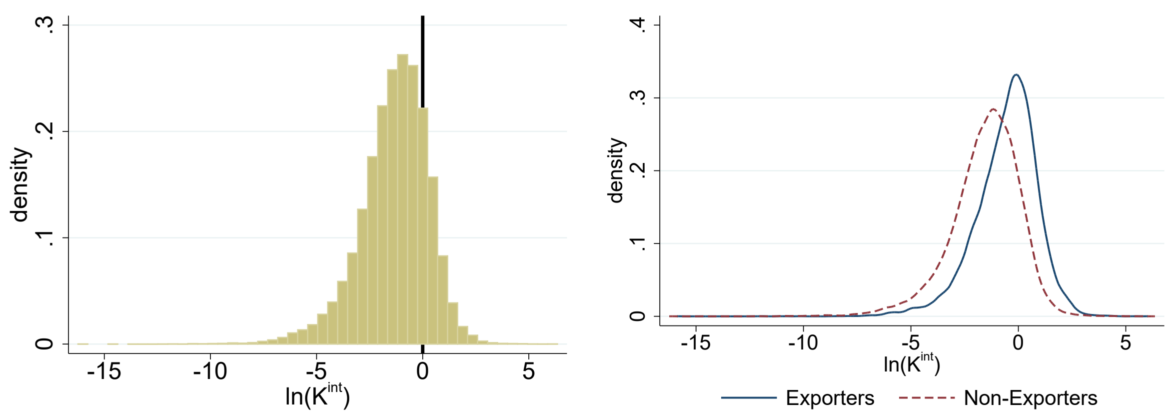
In this subsection, I document several empirical regularities that are relevant for the analysis. First, I show significant heterogeneity in capital intensity across firms within 3-digit manufacturing industries. Capital-intensive firms are bigger and more productive than their labor-intensive counterparts. Second, I show that exporters are bigger, more productive, and more capital-intensive than non-exporter firms, findings that are consistent with the literature (see Bernard and Jensen, 1999).

Fact 1: *There is substantial cross-sectional heterogeneity in capital intensities within manufacturing industries.*

Figure 2 panel (a) displays the distribution of capital intensities across manufacturing firms pooling all years in the sample. Each firm's capital intensity is computed as their capital-labor ratio relative to their own (3-digit) industry average. I define as "High-K" ("Low-K") the firms with a capital-labor ratio above (below) their industry-level average, that is, firms to the right (left) of the vertical line in Panel (a). Panel (b) shows that exporters are significantly more capital-intensive than non-exporters.

Figure (2) Capital Intensity Moments

(a) Relative to own (3-digit) sector (b) Capital intensity by export status

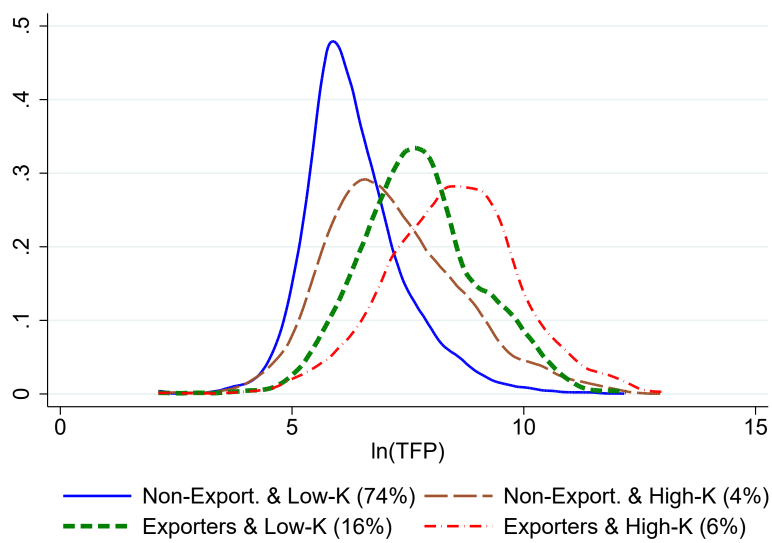


Notes: Capital intensity of firm f is computed as $K_f^{\text{int}} = \frac{K_f/L_f}{\sum_i K_i / \sum_i L_i}$, where the summation is done (3-digit) industry-wise. The figures pool all years in the sample 1995-2013.

Fact 2: *Exporters and capital-intensive firms outperform non-exporters and labor-intensive firms.*

Figure 3 documents the estimated productivity (revenue TFP) distribution across firm-year pairs grouped according to exporting and capital intensity status. On average, exporters outperform non-exporters, and High-K firms outperform Low-K firms. Naturally, the very selected group of High-K exporters (6% of the sample) is substantially more productive than the remaining groups, especially relative to the most numerous group of Low-K non-exporters (74% of the sample). A similar sorting pattern holds when estimating productivity using pre-boom years only. Appendix B presents panel regressions documenting systematically how exporters and capital-intensive firms display significantly higher revenue TFP relative to other groups in the economy, even after controlling by sector-year fixed-effects. The quantitative model developed in the next section is calibrated to approximately replicate the average productivity levels implied by the distributions in Figure 3.

Figure (3) Firm-level productivity distribution by groups.



Notes: Kernel density estimation. Capital intensity of firm f is computed as $K_f^{\text{int}} = \frac{K_f/L_f}{\sum_i K_i/\sum_i L_i}$, where the summation is done (3-digit) industry-wise. The figures pool all years in the sample 1995-2013. "High" ("Low-K") is defined as firms with $K_f^{\text{int}} > 1$ ($K_f^{\text{int}} \leq 1$). Firm-level revenue TFP is estimated using Wooldridge (2011). Figures in parenthesis in the legend are the average shares of each group.

2.4 Firm-Level Implications of a Commodity Boom

In this subsection, I present evidence that commodity booms disproportionately affect the profitability of export-oriented and capital-intensive firms.[5] Second, they induce a large decline in net entry rates into exporting, as well as a significant increase in the probability of exit from exporting during periods of high commodity prices. Similarly, the probability of using capital-intensive technologies also shrink during commodity price booms, suggesting that firms do react to changes in relative input prices and substitute towards labor.

***Fact 3:** Exporters and capital-intensive firms lose market share during a commodity boom (intensive margin).*

In order to document how firm characteristics shape the intensive margin of adjustment during commodity booms, I estimate the following specification:

$$\ln(Y_{ft}) = \alpha X_{f0} \cdot \tilde{P}^{Co}_{t-1} + \beta K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1} + \gamma X_{f0} \cdot K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1} + \delta' Z_{ft} + \varphi_f + \varphi_{st} + \varepsilon_{ft} \quad (2.1)$$

where Y_{ft} denotes an outcome variable (such as real value added or real profits) for firm f in year t, X_{f0} is a dummy variable that takes the value 1 if firm f exports in its first period $t = 0$ in the sample (conditional on $t = 0$ being in the pre-boom period 1995-2003), K^{int}_{f0} denotes the capital intensity of firm f in period $t = 0$, and $\tilde{P}^{Co}_t = P^{Co}_t - \overline{P}^{Co}$ is the demeaned real commodity price shock. Finally, the vector variable Z_{ft} collects firm-level controls, while φ_{st} and φ_f represent (3-digit) sector-year and firm fixed effects, respectively. The coefficient α in (2.1) measures the relative effect of commodity shocks on the subsample of exporting firms. Similarly, β is the relative effect of commodity price fluctuations on the subsample of capital-intensive firms. Finally, γ is the incremental relative effect of commodity price shocks on High-K exporters relative to Low-K non-exporter firms. [6]

Table 1 presents the results. Columns (1) and (2) report the results for the period 1995-2007, which avoid concerns about the Great Recession being a potential con-

[5] To ease exposition, I use High-K vs Low-K and capital-intensive vs labor intensive interchangeably.

[6] Note that the baseline impact of commodity price shocks on Low-K non-exporters is absorbed by the sector-year fixed effects.

founding factor. Columns (3) and (4) report the baseline results for the full sample 1995-2013. It is clear from the table that exporters and capital-intensive firms shrink significantly during periods of high commodity prices. The double interaction is also negative (and significant for the full sample 1995-2013), suggesting that High-K exporters, the most productive firms in the economy, suffer a double hit in the form of decreasing revenues due to currency appreciation and disproportionately larger variable costs through the cost of capital channel. Overall, they face a $13\% = 100 \cdot (0.079 + 0.023 + 0.031)$ larger *decrease* in their real profits relative to Low-K non-exporter firms. A potential concern is the possibility that financial frictions are partly driving these patterns. Appendix C presents robustness analysis which shows that my main results survive even after controlling by that channel using firm-level size measures interacted with the commodity price shock.

Table (1) Panel Regressions: Commodity Booms and Outcome Variables

	VA	Profits	VA	Profits
	Sample: 1995-2007		Sample: 1995-2013	
	(1)	(2)	(3)	(4)
$X_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.122***	-0.130***	-0.093***	-0.079***
	(0.0331)	(0.0347)	(0.0291)	(0.0292)
$K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.015*	-0.017**	-0.021***	-0.023***
	(0.0077)	(0.0077)	(0.0073)	(0.0074)
$X_{f0} \cdot K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.016	-0.032*	-0.032**	-0.031**
	(0.0180)	(0.0184)	(0.0157)	(0.0152)
Firm FE	yes	yes	yes	yes
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.139	0.127	0.176	0.169
N. obs.	49,178	48,634	59,945	59,281

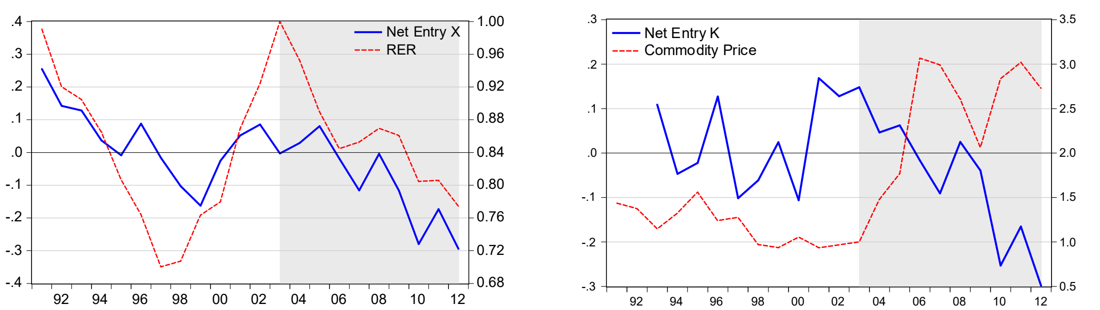
Notes: Results for regression (2.1). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. Columns (1) and (2) present results for the sample 1995-2007, while columns (3) and (4) for 1995-2013. Columns (1) and (3) use real value added as dependent variable, while columns (2) and (4) use real profits. All specifications include controls for firm size.

Fact 4: *Exporters and capital-intensive firms are more likely to exit from foreign markets and downsize their capital-labor ratios during a commodity boom (extensive margin).*

This subsection documents the extensive margin of adjustment. More specifically, when the commodity shock is persistent enough, the protracted real appreciation of the exchange rate induces some pre-boom exporters to exit from foreign markets. Similarly, some pre-boom capital-intensive firms are not able to bear the increase in the cost of capital and are forced to downsize to less capital-intensive technologies. Figure 4 illustrates these patterns. Panel (a) presents net entry rates into foreign markets, while Panel (b) displays analogous net entry rates into the capital-intensive technology as defined in Figure 2. Panel (a) shows a protracted decline in net entry into foreign markets that coincides with the commodity price super-cycle period. Overall, it is noteworthy the positive correlation between the exchange rate appreciation induced by the commodity boom and the plummeting of net entry rates, as predicted by the exchange rate channel. In turn, Panel (b) illustrates how manufacturing firms massively switch away from physical capital during the period in which the real commodity price skyrocketed.

Figure (4) Net Entry Rates

(a) Foreign Market (b) Capital-Intensive Technology



Notes: Net entry rates are defined as the difference between entry rates and exit rates. Panel (a): Entry into the foreign market is defined as the number of firms exporting in year t that did not export in year $t-1$ divided by the total number firms that export in year $t-1$. The exit rate is defined as the number of firms that export in year t but do not export in year $t+1$ relative to the number of firms exporting in year t. Panel (b): The entry rate into the capital-intensive technology is defined as the number of firms with $K^{int}_{ft} > 1$ and $K^{int}_{ft-1} < 1$ divided by the total number firms with $K^{int}_{ft-1} > 1$. The exit rate from the Capital-Intensive technology is defined as the number of firms with $K^{int}_{ft} > 1$ and $K^{int}_{ft+1} < 1$ relative to the number of firms with $K^{int}_{ft} > 1$.

To document systematically the effects of commodity booms on firms' decisions to exit from exporting and downsize their capital-labor ratios, I follow the literature and specify a dynamic linear probability model.

$$Y_{ft} = \alpha_1 Y_{ft-1} + \alpha_2 Y_{ft-2} + \beta_1 Y_{ft-1} \cdot Z_t + \beta_2 Y_{ft-2} \cdot Z_t + \varphi_{st} + \varphi_f + \varepsilon_{ft} \tag{2.2}$$

where Y_{ft} can take the form of an export dummy $Y_{ft} = X_{ft} = 1$ if firm f exports in year t or a capital intensity dummy $Y_{ft} = K_{ft} = 1$ if firm f classify as High-K in year t (according to the definition in Figure 2), Z_t is a commodity cycle measure, and φ_{st} and φ_f are sector-year and firm fixed effects. I use two alternative measures for the commodity cycle. First, I use a "boom" dummy variable that takes the value $Z_t = 1$ in years 2004-2013 and zero otherwise. Second, I use a continuous variable given by the demeaned real commodity price $Z_t \equiv \tilde{P}_t^{Co} = P_t^{Co} - \overline{P}^{Co}$. The regression also includes controls for firm-level size and productivity (not shown in equation (2.2)). The lagged dependent variable is included as fixed costs induce state-dependence in the exporting and capital-intensity decisions. I interact lags of the dependent variable with the commodity cycle measure in order to understand to what extent the probabilities of continuing to export and using the capital-intensive technology are affected by commodity price fluctuations. I introduce two lags in order to capture the idea that the negative effects of persistent commodity booms take some time to build up.

Table 2 reports the results. The coefficient on Y_{ft-j} is the marginal increase in the probability of exporting in period t if firm f exported in $t-j$. The interaction terms are interpreted as the incremental/detrimental effect of the commodity boom on the probability of continuing to export. For instance, from column (1) we have that an exporter in $t-1$ has a 30% higher probability of being an exporter in period t; if the firm also exported in $t-2$, the probability increases by about 5%. Regarding the interactions, for firms that exported last year, the commodity boom has a positive (sometimes not significant) effect on the probability of exporting today. But the negative effects are significant for firms that exported two years ago. Moreover, across specifications, the negative effect on $t-2$ dominates the positive effect on $t-1$ in absolute value and significance. Similar correlations hold in columns (3) and (4) for the probability of using capital-intensive technologies.

Table (2) Panel Analysis: Dynamic Linear Probability Model

	$Y_{ft} = X_{ft} = \{0,1\}$		$Y_{ft} = K_{ft} = \{0,1\}$	
	$Z_t = \{0,1\}$	$Z_t = \tilde{P}_t^{C_o}$	$Z_t = \{0,1\}$	$Z_t = \tilde{P}_t^{C_o}$
	(1)	(2)	(3)	(4)
Y_{ft-1}	0.330***	0.343***	0.234***	0.258***
	(0.0148)	(0.0120)	(0.0124)	(0.0096)
Y_{ft-2}	0.077***	0.054***	0.1030***	0.0627***
	(0.0137)	(0.0104)	(0.0118)	(0.0085)
$Y_{ft-1} \cdot Z_t$	0.023	0.038**	0.0443***	0.0524***
	(0.0181)	(0.0184)	(0.0142)	(0.0141)
$Y_{ft-2} \cdot Z_t$	**-0.043****	**-0.046****	**-0.0757****	**-0.0805*****
	(0.0182)	(0.0184)	(0.0144)	(0.0138)
Firm FE	yes	yes	yes	yes
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.150	0.150	0.140	0.140
N. obs.	49,439	49,439	49,439	49,439

Notes: Results for regression (2.2). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. Sample: 1995-2013. Columns (1) and (2) present results for the exporting dummy, while columns (3) and (4) for the capital-intensive dummy. Columns (1) and (3) use a binary commodity price cycle variable, $Z_t = \{0,1\}$, that takes the value 1 in 2004-2013 and 0 in 1995-2003. Alternatively, columns (2) and (4) use the continuous real commodity price (demeaned). All specifications include controls for firm size and revenue TFP (not reported).

3 A Trade Model with Capital Intensity Choice

Consider a small and financially-open commodity-exporting economy with three goods: exportables (X), importables (M), and commodity (Co) goods. Households only consume exportables and importables. Commodity production is sold abroad at international price p^{Co}, the only exogenous driving force in the model. Exportable varieties are produced by a continuum of firms with heterogeneous productivity using labor and capital, while commodity goods are produced by a representative firm, using labor, capital, and a fixed natural resource. For simplicity, investment goods are fully imported. Capital accumulation is subject to quadratic adjustment costs.

3.1 Household

Time is discrete and indexed by t. There is an infinitely-lived representative household that maximizes lifetime utility given by:

$$U = \sum_{t=0}^{\infty} \beta^t \frac{\left[C_t - \varphi \frac{L_t^{\zeta}}{\zeta}\right]^{1-v}}{1-v},$$

where C and L are consumption and labor supply, while the parameters β, v, ζ, and φ govern time discounting, the intertemporal elasticity of substitution, the Frisch elasticity of labor supply, and the marginal rate of substitution between consumption and leisure. The consumption bundle C is defined as a CES aggregator of exportable C^X and importable C^M goods:

$$C_t = \left[\chi^{\frac{1}{\epsilon}} \left(C_t^X\right)^{\frac{\epsilon-1}{\epsilon}} + (1-\chi)^{\frac{1}{\epsilon}} \left(C_t^M\right)^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{3.1}$$

where χ and ϵ control the weights and the elasticity of substitution between goods. Exportable consumption is, in turn, a bundle over a continuum of manufacturing varieties indexed by ω:

$$C_t^X = \left[\int_{\omega} (q_{dt}(\omega))^{\rho} \, d\omega\right]^{\frac{1}{\rho}}, \tag{3.2}$$

where $\sigma = 1/(1-\rho) > 1$ is the elasticity of substitution among varieties.

The household supplies labor, accumulates capital, smooths consumption via foreign borrowing, and owns firms. The budget constraint can be written as:

$$p_t C_t + I_t + B_{t+1} = w_t L_t + r_t^k K_t + (1 + r^*) B_t + \Pi_t, \tag{3.3}$$

where p is the price of the consumption bundle, which is also a model-based proxy for the real exchange rate (RER); B is the country's net foreign asset position that pays exogenous interest rate r^*, w is the wage, I and K are investment and capital with rental rate r^k, and $\Pi = \Pi^X + \Pi^{Co}$ collects profits from the ownership of firms in both sectors. Investment goods are fully imported at price $p_t^M = 1$ (the numeraire). The aggregate stock of capital evolves according to:

$$K_{t+1} = (1 - \delta^k) K_t + I_t - \frac{\phi}{2} \Big(\frac{K_{t+1}}{K_t} - 1 \Big)^2 K_t.$$

where δ^k is the depreciation rate and ϕ governs the capital adjustment cost. The price of the exportable bundle *consumed domestically* is given by:

$$p_t^X = \left[\int_\omega (p_{dt}(\omega))^{1-\sigma} d\omega \right]^{\frac{1}{1-\sigma}}.$$

The household's cost minimization determines the following demands for each composite good:

$$C_t^X = \chi \left(\frac{p_t}{p_t^X} \right)^\epsilon C_t \tag{3.4}$$

$$C_t^M = (1 - \chi) \left(\frac{p_t}{p_t^M} \right)^\epsilon C_t \tag{3.5}$$

Note that plugging demands (3.4)-(3.5) in (3.1) yields an expression for the domestic basket price or real exchange rate (RER):

$$p_t = \left[\chi \left(p_t^X \right)^{1-\epsilon} + (1 - \chi) \right]^{\frac{1}{1-\epsilon}}.$$

The domestic demand for each variety in the exportable sector is given by:

$$q_{dt}(\omega) = \left[\frac{p_{dt}(\omega)}{p_t^X} \right]^{-\sigma} C_t^X. \tag{3.6}$$

Household's optimal behavior is characterized by demands (3.4)-(3.6), the flow budget constraint (3.3) (with Lagrange multiplier $\beta^t \lambda_t$), and the following optimality conditions:

$$\begin{aligned}
\frac{1}{(1+r^*)} &= \beta \frac{\lambda_{t+1}}{\lambda_t} = \beta \left[\frac{C_t - \varphi \frac{L_t^{\zeta}}{\zeta}}{C_{t+1} - \varphi \frac{L_{t+1}^{\zeta}}{\zeta}} \right]^{v} \left(\frac{p_t}{p_{t+1}} \right) \\
1 + \phi \left(\frac{K_{t+1}}{K_t} - 1 \right) &= \beta \frac{\lambda_{t+1}}{\lambda_t} \left[r_{t+1}^k + 1 - \delta^k + adj_{t+1} \right] \\
adj_t &\equiv \phi \left(\frac{K_{t+1}}{K_t} \right) \left(\frac{K_{t+1}}{K_t} - 1 \right) - \frac{\phi}{2} \left(\frac{K_{t+1}}{K_t} - 1 \right)^2 \\
\varphi L_t^{\zeta - 1} &= \frac{w_t}{p_t}.
\end{aligned}$$

3.2 Exportable Sector

This subsection augments the model of Melitz (2003) with physical capital and technology choice. There is an infinite pool of forward-looking potential entrants that consider making an initial investment, modeled as a one-time sunk entry cost f_e, in order to draw a permanent productivity type z from a distribution $g(z)$ with positive support over $(0, \infty)$ and continuous cumulative distribution $G(z)$. After observing z, firms with sufficiently low draws optimally decide to exit and never produce. In turn, successful entrants decide (i) between two constant-returns-to-scale technologies that combine labor and capital but differ in their capital share α, and (ii) whether to serve the foreign market and become an exporter. The market structure is monopolistic competition. To ease notation, I drop time subscripts in this subsection.

Technology choice. The basic technology with low capital intensity (α_l) entails a (per-period) fixed operational cost f_d, while adopting the capital-intensive technology $(\alpha_h > \alpha_l)$ requires a larger fixed cost $f_d + f_a$. Henceforth, I refer to these as "Low-K" and "High-K" technologies. For each $j = \{l, h\}$, the unit cost function is given by $c_j(z) = \frac{\phi_j}{z}$ where $\phi_j = \left(\frac{r^k}{\alpha_j}\right)^{\alpha_j} \left(\frac{w}{1-\alpha_j}\right)^{1-\alpha_j}$ is the weighted average price of the composite input. In essence, firms trade off lower variable cost (via the distance between α_h and α_l) with larger fixed operation cost (via f_a).

Exporting choice. Firms serving only the domestic market pays fixed (per-period) cost f_d and face residual demand given by (3.6). To serve the foreign market firms have to pay an additional fixed (per-period) exporting cost f_x. Foreign demand is given by $q_x(z) = \gamma\,(p_x(z))^{-\sigma}$, where γ controls the size of the foreign market. Firms trade off a larger market (via γ) with a larger fixed cost (via f_x).[7]

Pricing rule. Each firm charges a constant markup $(1/\rho)$ over unit cost. Then, for any $s = \{d, x\}$ and $j = \{l, h\}$, we have $p_{sj}(z) = \frac{\phi_j}{\rho z}$.

Profits. All fixed costs are valued in units of the numeraire. Depending on their productivity type, firms self-select into one of the following four groups: (a) purely domestic Low-K firms, (b) purely domestic High-K firms, (c) Low-K exporters, and (d) High-K exporters. After some manipulation, profits can be written as follows:

$$\pi_{sj}(z) = \begin{cases} \frac{1}{\sigma} p^{\sigma} C \left[\frac{\phi_l}{\rho z}\right]^{1-\sigma} - f_d & \text{if } s = d \text{ and } j = l \\ \frac{1}{\sigma} p^{\sigma} C \left[\frac{\phi_h}{\rho z}\right]^{1-\sigma} - f_d - f_a & \text{if } s = d \text{ and } j = h \\ \frac{1}{\sigma} \gamma \left[\frac{\phi_l}{\rho z}\right]^{1-\sigma} - f_x & \text{if } s = x \text{ and } j = l \\ \frac{1}{\sigma} \gamma \left[\frac{\phi_h}{\rho z}\right]^{1-\sigma} - f_a - f_x & \text{if } s = x \text{ and } j = h \end{cases}$$

where I use the convention that adoption fixed costs are assigned to domestic profits. Note that, for any $j = \{l, h\}$, the total profits of exporters are the sum of domestic and foreign profits ($\pi_{dj}(z) + \pi_{xj}(z)$).

Value functions. Regardless of their productivity type, all operating firms are subject to a constant probability δ of a bad shock that forces them to exit the market. Firms can also exit endogenously when their present discounted value becomes negative. Type-z firm chooses the technology and exporting decisions yielding the largest present dicounted value:

$$V(z) = \max\{V_{dl}(z), V_{dh}(z), V_{xl}(z), V_{xh}(z)\},$$

[7] I assume the same price elasticity for domestic and foreign demand.

$$
\begin{aligned}
V_{dj}(z) &= \max\left\{0, \pi_{dj}(z) + \frac{(1-\delta)}{(1+r^*)}V'(z)\right\}, \quad j = l, h \\
V_{xj}(z) &= \max\left\{0, \pi_{dj}(z) + \pi_{xj}(z) + \frac{(1-\delta)}{(1+r^*)}V'(z)\right\}, \quad j = l, h.
\end{aligned}
$$

Cutoffs. This environment gives rise to productivity cutoff rules that determine firms' entry/exit into domestic ($\bar{z}_d$) and foreign markets ($\bar{z}_x$) as well as adoption of the capital-intensive technology ($\bar{z}_a$). The least productive but successful entrants ($\bar{z}_d \leq z < \bar{z}_x$) serve the domestic market using the Low-K technology. Then, the marginal condition to pin down the domestic cutoff is given by:

$$
V_{dl}(\bar{z}_d) = 0.
$$

If $\bar{z}_a < \bar{z}_x$ (case 1), the marginal type that optimally chooses to upgrade technology is a purely domestic firm, while the marginal exporter uses the high-K technology. Conversely, if $\bar{z}_x < \bar{z}_a$ (case 2), the marginal exporter uses the low-K technology, while the marginal adopter is an exporter type. As in Bustos (2011) and Limão and Xu (2018), I calibrate the model to be consistent with case 2, because it is closer to the data. The cutoffs for the case $\bar{z}_x < \bar{z}_a$ are pinned down by:

$$
\begin{aligned}
V_{dl}(\bar{z}_x) &= V_{xl}(\bar{z}_x) \\
V_{xl}(\bar{z}_a) &= V_{xh}(\bar{z}_a).
\end{aligned}
$$

Distribution. Let $\mu(z)$, $\mathcal{M}$, and $\mathcal{M}_e$ denote the distribution of types, the mass of incumbent firms, and the mass of entrants firms in the current period. The firm productivity distribution evolves as follows:

$$
\mathcal{M}'\mu'(z) = \begin{cases} (1-\delta)\mathcal{M}\mu(z) + \mathcal{M}_e'g(z) & \text{if} \quad z \geq \bar{z}_d' \\ 0 & \text{otherwise} \end{cases}. \tag{3.7}
$$

Equation (3.7) tells us that the number of firms of each type tomorrow equals the number of firms that survive both exogenous exit (δ) and endogenous exit ($z \geq \bar{z}_d$) today plus the number of new entrants of each type. By the law of large numbers, the latter is simply given by the unconditional distribution $g(z)$. Note also that successful entrants are allowed to produce immediately upon entry. Finally, integrating over all active types, the law of motion for the mass of producers can be written as:

$$\mathcal{M}' = (1-\delta)\mathcal{M}\int_{\overline{z}'_d}^{\infty}\mu(z)dz + \mathcal{M}'_e\int_{\overline{z}'_d}^{\infty}g(z)dz.$$

Free entry. Sunk entry costs are valued in terms of the numeraire. They combine a fixed with a convex component that captures congestion effects in firm creation, help to match the empirical entry rate, and is computationally convenient. The assumed functional form is:

$$f_e\left(\mathcal{M}_e\right) = \overline{f_e} + \phi_e\left[\exp\left(\mathcal{M}_e - \overline{\mathcal{M}}_e\right) - 1\right]$$

where $\overline{f_e}$ is the fixed component, $\mathcal{M}_e$ is the mass of entrants (with steady state value $\overline{\mathcal{M}}_e$) and ϕ_e controls the degree of congestion effects. Because firms learn z after paying the sunk entry cost, prospective entrants consider the expected present value of entering net of entry cost:

$$\int_{\overline{z}_d}^{\infty}V(z)g(z)dz = f_e\left(\mathcal{M}_e\right).$$

Optimal input demands. With this production structure, we can derive the cost function that combines labor and capital spending used both directly in production and to cover the fixed operational costs:

$$TC_{sj}(z) = \frac{q_{sj}(z)}{z}\phi_j + \mathbb{F}, \quad s = d, x, \quad j = l, h$$

where $\mathbb{F} = \left[f_d + f_a\mathbf{1}\left(j = h\right)\right]\mathbf{1}\left(s = d\right) + f_x\mathbf{1}\left(s = x\right)$ collects fixed costs for any sj pair. By Sheppard's Lemma, demands for labor and capital by a type-z firm are:

$$l_{sj}(z) = \frac{\partial TC_{sj}(z)}{\partial w} = \begin{cases} \frac{(1-\alpha_j)\phi_j}{w}\cdot\left[\left(p^X\right)^{\sigma}C^X\left(\frac{\rho}{\phi_j}\right)^{\sigma}(z)^{\sigma-1}\right] & \text{if } s = d \\ \frac{(1-\alpha_j)\phi_j}{w}\cdot\left[\gamma\left(\frac{\rho}{\phi_j}\right)^{\sigma}z^{\sigma-1}\right] & \text{if } s = x \end{cases},$$

and

$$k_{sj}(z) = \frac{\partial TC_{sj}(z)}{\partial r^k} = \begin{cases} \frac{\alpha_j\phi_j}{r^k}\cdot\left[\left(p^X\right)^{\sigma}C^X\left(\frac{\rho}{\phi_j}\right)^{\sigma}(z)^{\sigma-1}\right] & \text{if } s = d \\ \frac{\alpha_j\phi_j}{r^k}\cdot\left[\gamma\left(\frac{\rho}{\phi_j}\right)^{\sigma}z^{\sigma-1}\right] & \text{if } s = x \end{cases}.$$

Aggregation. Aggregate labor and capital used in the exportable sector (both for domestic and foreign sales) can be computed as follows:

$$
\begin{aligned}
L^X &= \mathcal{M}\left[\int_{\bar{z}_d}^{\bar{z}_a} l_{dl}(z) + \int_{\bar{z}_a}^{\infty} l_{dh}(z) + \int_{\bar{z}_x}^{\bar{z}_a} l_{xl}(z) + \int_{\bar{z}_a}^{\infty} l_{xh}(z)\right]\mu(z)dz \\
K^X &= \mathcal{M}\left[\int_{\bar{z}_d}^{\infty} k_{dl}(z) + \int_{\bar{z}_a}^{\infty} k_{dh}(z) + \int_{\bar{z}_x}^{\bar{z}_a} k_{xl}(z) + \int_{\bar{z}_a}^{\infty} k_{xh}(z)\right]\mu(z)dz
\end{aligned}
$$

Aggregate *exportable* output sold in the *domestic* market is:

$$
Y^X = \left[\mathcal{M}\left(\int_{\bar{z}_d}^{\bar{z}_a} (q_{dl}(z))^{\rho}\,\mu(z)dz + \int_{\bar{z}_a}^{\infty} (q_{dh}(z))^{\rho}\,\mu(z)dz\right)\right]^{\frac{1}{\rho}}.
$$

Similarly, the total *value* of ***exported*** varieties is:

$$
X^X = \mathcal{M}\left[\int_{\bar{z}_x}^{\bar{z}_a} p_{xl}(z)q_{xl}(z)\mu(z)dz + \int_{\bar{z}_a}^{\infty} p_{xh}(z)q_{xh}(z)\mu(z)dz\right]. \qquad (3.8)
$$

Appendix D provides details about these aggregation terms.

3.3 Commodity Production

There is a representative firm in the commodity sector that hires labor and rents capital from the representative household in order to maximize profits. The technology is given by:

$$
Y_t^C = \overline{R}\left[\left(K_t^C\right)^{\alpha^C}\left(L_t^C\right)^{1-\alpha^C}\right]^{\eta}.
$$

where $\eta < 1$ induces decreasing returns to scale, and the constant $\overline{R}$ is set to target the empirical share of commodity output in total GDP.

3.4 Market Clearing

In equilibrium, the domestic market for exportable varieties clear:

$$
C_t^X = \left[\mathcal{M}_t\left(\int_{\bar{z}_{dt}}^{\infty} (q_{dt}(z))^{\rho}\,\mu_t(z)dz\right)\right]^{\frac{1}{\rho}} \equiv Y_t^X
$$

Labor and capital market clearing require:

$$\begin{aligned} L_t &= L_t^X + L_t^C \\ K_t &= K_t^X + K_t^C \end{aligned}$$

Finally, plugging several equilibrium conditions into the household's budget constraint, the balance of payments condition can be written as follows:

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

where the following definitions for the trade balance, total exports and total imports apply:

$$\begin{aligned} TB_t &\equiv X_t - M_t \\ X_t &\equiv p_t^{Co} Y_t^C + X_t^X \\ M_t &\equiv C_t^M + I_t + \Phi_t + \mathcal{F}_t \end{aligned}$$

where X_t^X denotes the value of manufacturing exports given by (3.8), and $\Phi_t = \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2 K_t$ and $\mathcal{F}_t = \mathcal{M}_t f_d + \mathcal{M}_t p_{xt} f_x + \mathcal{M}_t p_{at} f_a + \mathcal{M}_{et} f_e\left(\mathcal{M}_{et}\right)$ collect capital adjustment and fixed costs, respectively. Variables $p_{xt} = \left[\frac{1-G(\bar{z}_{xt})}{1-G(\bar{z}_{dt})}\right]$ and $p_{at} = \left[\frac{1-G(\bar{z}_{at})}{1-G(\bar{z}_{dt})}\right]$ denote the fraction of exporters and the fraction of capital-intensive firms, respectively. Appendices D, E and F contain details including the full set of dynamic and static equilibrium conditions as well as computational algorithms to solve the static model and compute transitional dynamics.

4 Quantitative Analysis

In this section, I present the calibration strategy designed to match certain key macro- and micro-level features of the Chilean economy. Next, I assess the model fit along both targeted and untargeted moments. Finally, I test the model's ability to reproduce the pattern of reallocation observed during the commodity super-cycle that started in 2003, and examine how the composition dynamics affect the average measured productivity in the manufacturing sector.

4.1 Calibration

Table 3 reports a set of parameters set a priori either using standard values in the literature or based on direct firm-level data. All data moments used in the calibration are averages over the pre-commodity boom period 1995-2003. The model period is one year. I set the time preference parameter $\beta = 0.96$ to target a long-run interest rate of 4%. I set the inverse of the intertemporal elasticity of substitution equal to $v = 1$ (log utility), and the Frisch elasticity equal to the baseline value documented by Rios-Rull et al (2011), which is 0.72 ($\zeta = 1 + 1/0.72 = 2.4$). The elasticities of substitution between C^X and C^M goods (ϵ) and among exportable varieties (σ) are set to standard values used in the literature. Capital depreciation is set at $\delta^k = 0.08$, while the exogenous exit shock probability is set to $\delta = 0.08$, so that the model's steady state reproduces the average between entry and exit rates observed in the data.

Table (3) Externally Calibrated Parameters

Symbol	Value	Description	Source/Target
β	0.96	discount	$r = 4\%$
v	1	Inverse IES	log utility
ζ	2.4	Frisch elasticity	literature
ϵ	0.75	subst. C^X - C^M	literature
σ	4	subst. varieties	literature
δ^k	0.08	depreciation	macrodata
δ	0.08	exit shock	microdata

The remaining parameters, listed in Table 4, are chosen to match several key data moments. Certain parameters are set to match selected macroeconomic targets. I normalize the initial state of the economy to have a zero net-foreign asset position, $\overline{B} = 0$. I set the fixed resource parameter $\overline{R}$ in the commodity sector to match the share of mining in total output in Chile, $p^{Co}Y^C/Y = 0.1$. The scale parameter of labor supply is chosen to normalize the initial steady state nominal output $Y = 1$.

The middle block of Table 4 composed by parameters $\{\chi, \mu^z, \sigma^z, \gamma, f_d, f_x, f_a, \alpha_l, \alpha_h, \alpha^C\}$ is jointly estimated by minimizing a loss function given by the sum of squared residuals associated with the following set of moments: (a) nontraded share in total output Y^X/Y, (b) the (log) value-added ratio between percentiles 50th and 25th, (c) 75th and

50th, (d) 90th and 10th, (e) 95th and 5th, (f) 99th and 1th, (g) fraction of exporters, (h) fraction of High-K firms, (i) capital cost share for High-K firms, (j) capital cost share for Low-K firms, (k) labor in commodity sector (% of total L), (l) capital in commodity sector (% of total K). Note that I estimate 10 parameters targeting 12 moments so the system is over-identified.

Finally, the last block of Table 4 composed by parameters $\{\eta, \phi, \phi_e\}$ is calibrated to match moments from the transition dynamic equilibrium. The level of decreasing returns in commodity production η is set to match the peak-to-through change in the share of commodity output during the commodity boom ($\Delta Y^C/Y$). The capital adjustment cost parameter ϕ is set to target the economy-wide investment boom in the data, measured as the ratio between average investment in the pre-boom 1995-2003 and the commodity boom 2004-2013. The congestion cost at entry parameter ϕ_e is set to match the observed entry rate volatility in the manufacturing sector.

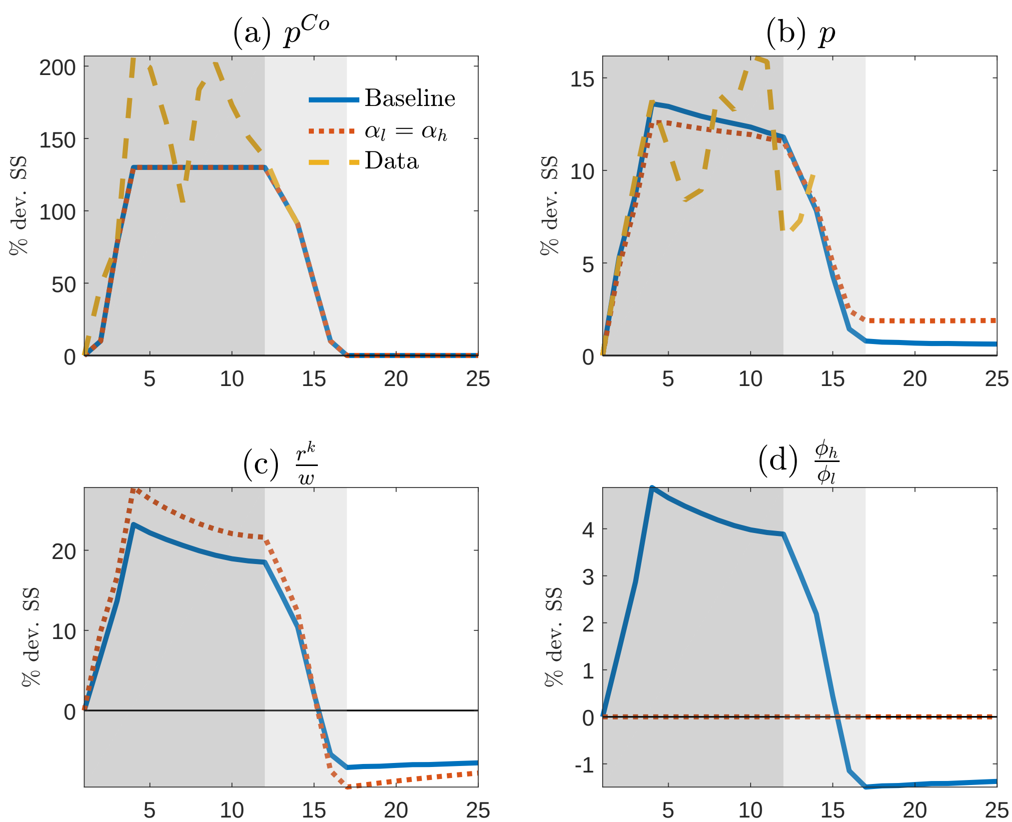
Table (4) Internally Calibrated Parameters

Symbol	Value	Description	Target	Data	Model
$\overline{B}$	0	SS NFA	TB/Y	0	0
$\overline{R}$	0.34	fixed resource	Y^C/Y	0.10	0.10
φ	69.3	labor supply	Y	1	1
χ	0.83	share C^X in C	Y^X/Y	0.55	0.56
μ^z	0.35	$\ln z \sim N(\mu^z, \sigma^z)$	ln(VA50/VA25)	0.93	0.93
σ^z	0.58	$\ln z \sim N(\mu^z, \sigma^z)$	ln(VA75/VA50)	1.23	1.05
γ	1.04	foreign size	ln(VA90/VA10)	4.26	4.12
			ln(VA95/VA05)	5.61	6.44
f_d	0.0023	operational cost	ln(VA99/VA01)	8.63	7.54
f_x	0.0452	exporting cost	fraction exporters	0.22	0.22
f_a	1.3842	adoption cost	fraction High-K	0.06	0.06
α_l	0.12	K share Low-K	cost share Low-K	0.12	0.12
α_h	0.33	K share High-K	cost share High-K	0.33	0.33
α^C	0.76	K share C sector	K^C/K	0.21	0.16
			L^C/L	0.04	0.02
η	0.49	DRS C sector	$\Delta\ Y^C/Y$	0.15	0.25
ϕ	20	K adjustment cost	$\Delta\ I$	1.23	1.22
ϕ_e	10	congestion cost	entry volatility	0.04	0.03

4.2 Transition Dynamics during Commodity Cycles

In this section, I solve for a perfect foresight transition equilibrium in which the commodity-producing economy is subject to an exogenously given global cycle in commodity prices. The economy is assumed to be in the steady state (with a zero initial net foreign asset position) up until period $t = 0$, assumed to be the year 2003 in the data. In period $t = 1$ (2004 in the data), the exogenous commodity price cycle illustrated in Panel (a) of Figure 5 is revealed once-and-for-all to all the agents. I feed the model with a commodity price boom-bust cycle similar to the one observed in the period 2003-2013.

Figure (5) Prices: Exogenous trigger and endogenous response



Notes: The solid lines depict the time series in the baseline model, while the dotted lines correspond to a counterfactual without technology decision. The dark and light gray shades represent the exogenous boom and bust cycle path fed to the model, illustrated in panel (a). Panels (b)-(d) are endogenous prices responses.

Panels (b)-(d) of Figure 5 report the dynamic response of the endogenous prices directly related with the two key channels emphasized in this paper. Each panel display the time paths for the baseline model (solid lines), a counterfactual simulation without technology choice, and data counterparts when available. Panel (b) shows that the real exchange rate p appreciates by about 15% from through to peak (panel (b)), thereby hurting exporters' revenues relative to non-exporters. Similarly, the cost of capital relative to the cost of labor r^k/w increases (panel (c)), inducing a cost disadvantage to the High-K types in the sense that their variable costs increase relatively more than for Low-K types during the boom phase (ϕ_h/ϕ_l increases in panel (d)).

4.2.1 Firm-Level Implications of Commodity Booms

To validate the model's ability to reproduce the micro-level empirical regularities, I simulate a panel of artificial firms based on the transition equilibrium, and then I re-estimate the panel regressions reported in Section 2. Table 5 shows that the model does a good job in reproducing the untargeted correlations between export status and capital intensity with firm-level performance measures during the commodity boom.

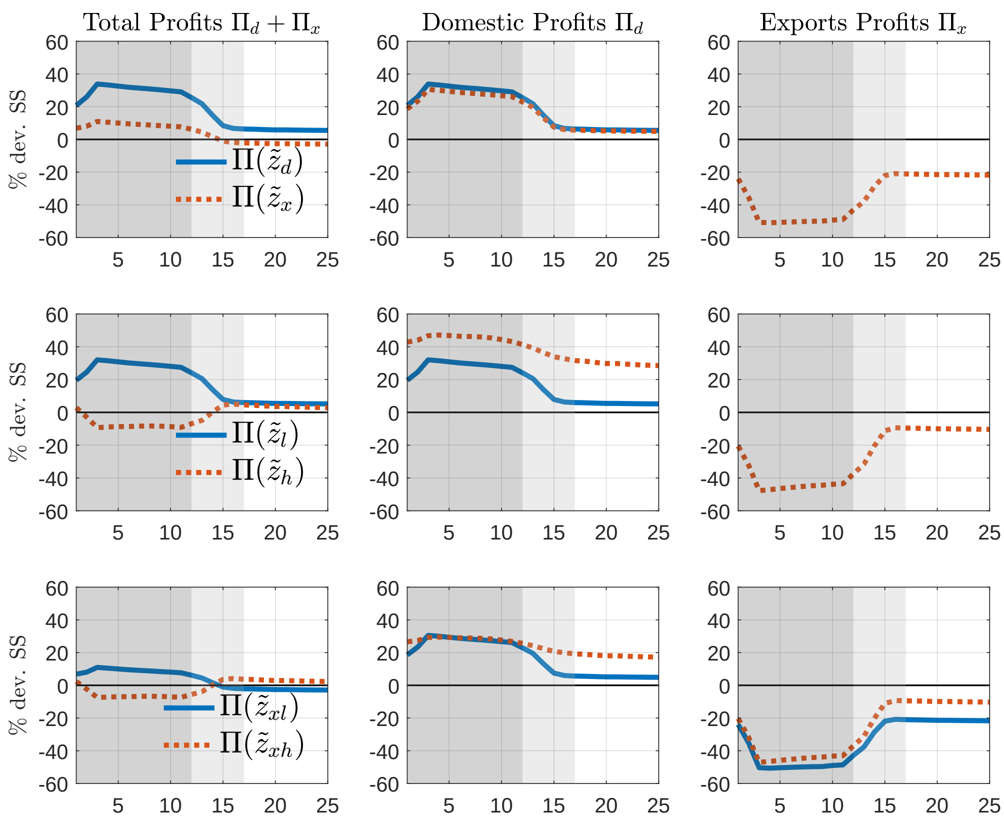
Table (5) Panel Regressions on Model-Simulated Firms

	Dependent Variable: ln(Real VA or Real Profits)			
	Value Added		Profits	
	Data	Model	Data	Model
$X_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.0699***	-0.0947***	-0.0548**	-0.0200***
	(0.0266)	(0.0018)	(0.0251)	(0.0036)
$K_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.0715**	-0.156***	-0.0912***	-0.0966***
	(0.0350)	(0.0065)	(0.0341)	(0.0092)
Firm FE	yes	yes	yes	yes
Adj. R^2	0.171	0.761	0.165	0.270
N. obs.	63,297	62,916	62,592	62,916

Notes: Results for regression (2.1). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. For comparability with the model, I replace the continuous capital-intensity variable from the data with a dummy equal to one when the firm classifies as "High-K" as defined in Figure 2. Moreover, because in the model-based panel all High-K firms are exporters, the triple interaction in (2.1) is removed from the specification.

Figure 6 illustrates how the main channels of the model operate at the firm level. Column (a) in the figure displays the evolution of total profits for different key productivity types in the economy. Columns (b) and (c) break down total profits among domestic and foreign components. In turn, the first row in the figure compares profits for the average exporter ($\tilde{z}_x$) versus the average purely-domestic type ($\tilde{z}_d$). The second row compares the average Low-K firm ($\tilde{z}_l$) with the average High-K type ($\tilde{z}_h$), while the third row compares the average exporter with Low-K ($\tilde{z}_{xl}$) against the average exporter with High-K technology ($\tilde{z}_{xh}$).

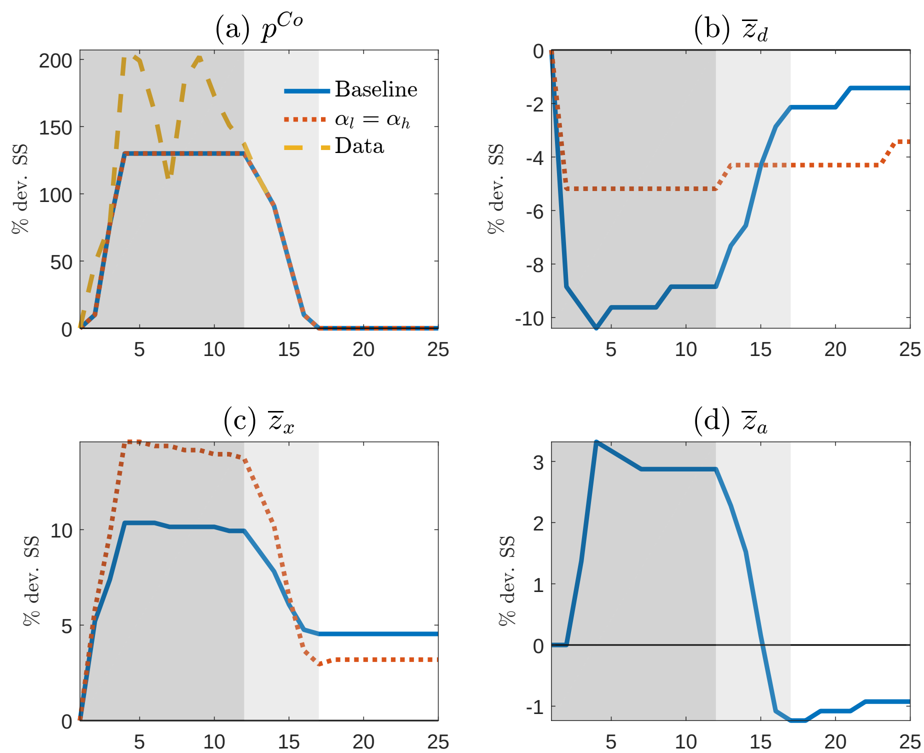
Figure (6) Profit Responses for average group types



Notes: The columns report total profits and its break down. The first row compares profits for the average exporter ($\tilde{z}_x$) versus the average purely-domestic type ($\tilde{z}_d$). The second row compares the average Low-K firm ($\tilde{z}_l$) with the average High-K firm ($\tilde{z}_h$). The third row compares the average exporter with Low-K ($\tilde{z}_{xl}$) against the average exporter with High-K technology ($\tilde{z}_{xh}$). The dark and light gray shades represent the boom and bust cycle path fed to the model. All series are in percent deviation from the initial steady state.

The first row confirm that relatively low productivity firms (represented here by the average purely-domestic type $\tilde{z}_d$) enjoy high domestic demand, which more than compensates them for the economy-wide increase in input costs. The average exporter ($\tilde{z}_x$), in turn, exhibits a similar increase in its profits from domestic markets, but because the value of their export sales plummet, they approximately break-even when regarding aggregate profits. The second row shows that the average Low-K type ($\tilde{z}_l$) experience a similar pattern than the average purely-domestic firm ($\tilde{z}_d$).[8] However, the average High-K firm, which is also an exporter, exhibits a strong decline in its total profits as a consequence of their plummeting export sales and large increase in variable costs. The third row illustrates that within exporters, those using capital-intensive technologies are worst-off, as predicted by the model.

Figure (7) Self Selection: Cutoff Dynamics



Notes: The solid lines depict the time series in the baseline model, while the dotted lines correspond to a counterfactual without technology decision. The dark and light gray shades represent the exogenous boom and bust cycle path fed to the model, illustrated in panel (a).

[8]Note that the average Low-K firm is a purely-domestic type, so that $\Pi_x(\tilde{z}_l) = 0$.

Regarding the extensive margin, Figure 7 display the change in the cutoffs that determine the exporting and technology decisions. As emphasized above, the commodity boom induces a composition effect by shifting the aggregate productivity thresholds that determine firm selection into exporting and the capital-intensive technology. In particular, the cutoff that determines entry/exit into the domestic market shifts to the left (panel (b) of Figure (7)), allowing some previously unprofitable low-type firms to enter and enjoy an environment with richer households. In turn, both the exporting and adoption cutoffs shift to the right (panels (c) and (d)), forcing some exporters to exit the foreign markets as well as some adopters to downgrade their technology. While there are not data analogs for these cutoofs, Table 6 shows that the model also does a good job in replicating the untargeted coefficients related to the dynamic linear probability model presented in Section 2.

Table (6) Panel Regressions on Model-Simulated Firms

	$Y_{ft} = X_{ft} = \{0,1\}$		$Y_{ft} = K_{ft} = \{0,1\}$	
	Data	Model	Data	Model
	(1)	(2)	(3)	(4)
$Y_{f,t-1}$	0.343***	0.372***	0.258***	0.0794***
	(0.0120)	(0.0294)	(0.0096)	(0.0303)
$Y_{f,t-2}$	0.0547***	0.0281***	0.0627***	0.115***
	(0.0104)	(0.0038)	(0.0085)	(0.0258)
$Y_{f,t-1} \cdot \tilde{P}_t^{Co}$	0.0384**	0.203***	0.0524***	0.409***
	(0.0184)	(0.0333)	(0.0141)	(0.0916)
$Y_{f,t-2} \cdot \tilde{P}_t^{Co}$	-0.0457**	-0.222***	-0.0805***	-0.390***
	(0.0184)	(0.0320)	(0.0138)	(0.0906)
Firm FE	yes	yes	yes	yes
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.150	0.370	0.140	0.692
N. obs.	49,439	54,871	49,439	54,871

Notes: Results for regression (2.2). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. Sample: 1995-2013. Columns (1) and (2) present results for the exporting dummy, while columns (3) and (4) for the capital-intensive dummy. All specifications include controls for firm size and revenue TFP (not reported).

4.2.2 Productivity Measures

I follow Foster, Haltiwanger, and Krizan (2001) (FHK henceforth) in computing the model-based average productivity using employment weights:

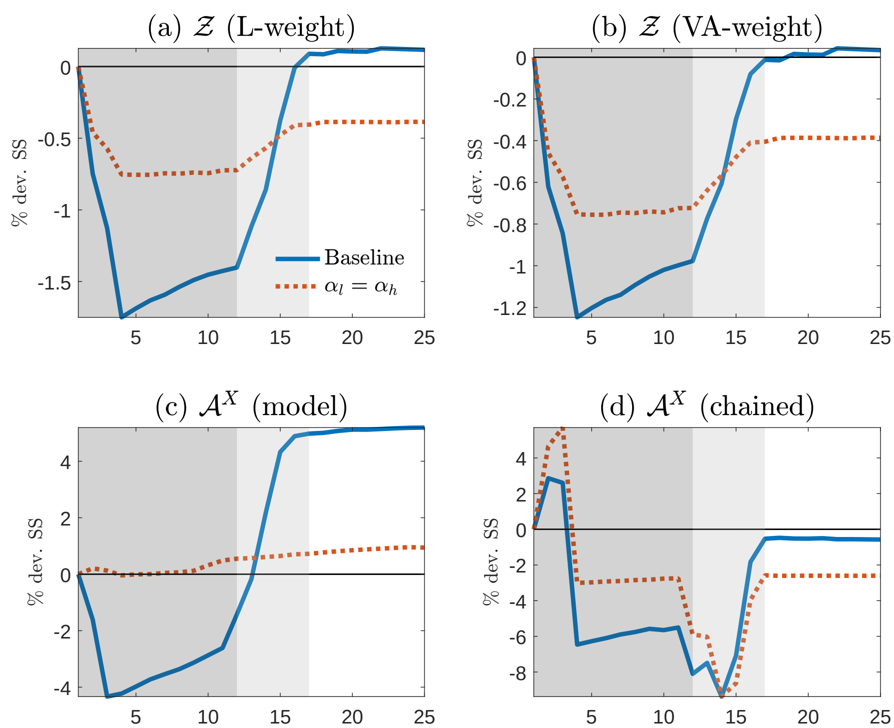
$$\mathcal{Z}_t = \sum_f \omega_{ft} z_f \tag{4.9}$$

where ω_{ft} is the time-varying (employment- or value-added-based) weight for firm f in year t, and z_f is the model-based time-invariant productivity of firm f. Alternatively, I construct a Solow residual-based productivity measure as follows:

$$\mathcal{A}_t^X = \frac{p_t^X Y_t^X + X_t^X}{\left(K_t^X\right)^{\alpha^X} \left(L_t^X\right)^{1-\alpha^X}} \tag{4.10}$$

where α^X is the average capital-intensity of the manufacturing sector as a whole.

Figure (8) Productivity Measures: Composition Effect



Notes: The solid lines depict the time series in the baseline model, while the dotted lines correspond to a counterfactual without technology decision. The dark and light gray shades represent the exogenous boom and bust cycle path fed to the model.

The first row of Figure (8) presents the FHK measures while the second row displays the Solow Residual measures. All figures compare the baseline model against the counterfactual economy without the technology choice. While the distance between the zero line and the dotted line reflects the exchange rate channel and its impact on export exit, the distance between the dotted line and the solid line isolates the pure additional amplification effect given by the cost of capital channel and its impact on capital downsizing. Panels (a)-(d) of Figure (8) illustrate how both channels induce composition dynamics that combine to generate a decline in average productivity in the exportable/manufacturing sector. The baseline model generates about half of the productivity decline observed in the data, a figure that is two times larger than in a counterfactual economy with no technology decision.

5 Concluding Remarks

This paper uses Chilean manufacturing firm-level data to study the effects of commodity price cycles on factor reallocation across heterogeneous firms, and their consequences for measured productivity. I argue that in heterogeneous firm models that are consistent with the observed micro-level variation in firms' capital intensity and exporting decisions, the *symptoms* of the old-fashioned Dutch disease, including a decline in manufacturing productivity, emerge *endogenously* in a context of purely *efficient* reallocation.

In addition to the usual channel that hurts exporters due to the appreciation of the exchange rate, I conjecture that the commodity boom might crowd out capital from manufacturing, given that copper extraction is a capital-intensive activity. The data confirms both effects. Interestingly, I document large variations of firm-level capital intensity within manufacturing industries, suggesting that different technologies coexist even within narrowly-defined sectors.

I provide a dynamic general equilibrium model in which firms with heterogeneous productivity decide whether to enter the domestic market, whether to become an exporter, and whether to adopt a (more productive) capital-intensive technology. Thereby, three productivity thresholds arise endogenously, the first one determining endogenous entry/exit, the second one governing the choice of a capital-intensive technology, and the third one governing the exporting decision. These thresholds change endogenously during the boom. Less productive firm enter the domestic market, while the thresholds for technology adoption and exporting become more stringent, thereby implying exit from exporting and capital downsizing.

These composition dynamics are able to rationalize a decrease in measured average productivity of the manufacturing sector, consistent with firm-level data during the commodity boom started in 2003. Notably, unlike most of the literature that opens the door to inefficient reallocation through reduced-form market failures, my model generates Dutch disease-like chain of events, including crowding-out of exporters and productivity declines in manufacturing, in a framework in which reallocation is purely efficient and welfare-improving.

A Cross-country decline in mining productivity

Table 7 compares labor productivity growth in the mining sector, before and after the commodity super cycle started in 2003, across countries with 5% or higher mining share in total output. With the exception of Chin, all countries experience a significant decline in real value added per worker, thereby suggesting some inefficient rent-seeking behavior.

Table (7) Mining Countries: Labor Productivity

	Mining Share in Total Output	Labor Productivity Mining		Difference
		(a) 1990-2003	(b) 2004-2012	(b) - (a)
Argentina	6.8	2.0	-6.8	-8.8
Brazil	6.4	4.6	1.2	-3.4
Chile	17.8	7.8	-3.9	-11.7
Colombia	10.0	0.0	-7.8	-7.8
Mexico	12.5	5.2	0.0	-5.2
Peru	11.2	4.3	-2.1	-6.4
Indonesia	17.6	2.5	-4.7	-7.2
Malaysia	19.5	5.2	-11.7	-16.8
Russia	13.4	4.3	1.4	-2.9
SouthAfrica	13.0	5.9	2.7	-3.3
Australia	10.1	3.8	-3.4	-7.2
Canada	13.1	1.8	-2.6	-4.4
USA	5.0	1.8	-2.0	-3.8
China	7.8	9.2	9.9	0.7

Notes: Author's calculations based on National Accounts data by economic sector from United Nations, combined with information on employment by sector from the 10-Sector-Database.

B Firm Characteristics and Estimated Revenue TFP

To document in a systematic fashion how exporters and capital-intensive firms outperform their non-exporters and labor-intensive counterparts, I run the following panel regression:

$$\ln(Y_{ft}) = \alpha X_{f0} + \beta K_{f0}^{int} + \delta X_{f0} \cdot K_{f0}^{int} + \gamma' Z_{ft} + \varphi_{st} + \varepsilon_{ft} \tag{B.1}$$

where Y_{ft} denotes a productivity measure for firm f in year t, X_{f0} is a dummy variable that takes de value of 1 if firm f exports in its first period $t = 0$ in the sample (conditional on $t = 0$ being in the pre-boom period 1995-2003), K_{f0}^{int} denotes firm f period $t = 0$ capital intensity, Z_{ft} are firm-level controls, and φ_{st} represents sector-year fixed effects. Firm-level multi-factor productivity is estimated using the method of Wooldridge (2011) and, under the assumption of constant returns to scale, using cost shares as in Foster, Haltiwanger, and Krizan (2001).

Table 8 presents the results. Pre-boom exporters and capital-intensive firms are significantly more revenue-productive than their non-exporters and labor-intensive analogs. Similar results emerge when using alternative firm-level outcome variables such as real value added and real profits.

Table (8) Panel Regressions: Firm Characteristics and Productivity

	Dependent Variable: ln(Productivity)			
	CRS	WLP	CRS	WLP
	Sample: 1995-2007		Sample: 1995-2013	
X_{f0}	0.569***	0.691***	0.611***	0.657***
	(0.0258)	(0.0281)	(0.0253)	(0.0281)
K_{f0}^{int}	0.084***	0.108***	0.098***	0.111***
	(0.0061)	(0.0066)	(0.0060)	(0.0066)
$X_{f0} \cdot K_{f0}^{int}$	0.155***	0.159***	0.149***	0.172***
	(0.0142)	(0.0155)	(0.0140)	(0.0157)
Firm FE	no	no	no	no
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.080	0.030	0.116	0.066
N. obs.	52,138	52,138	63,687	63,687

Notes: Results for regression (B.1). ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. Control by size included (not reported). CRS: Elasticities obtained using cost shares (constant returns to scale). WLP: Wooldridge (2011) estimation (decreasing returns to scale).

C Robustness

Table 9 augments the baseline panel regressions presented in Section 2 with an interaction between firm-level size and the commodity price shock. The purpose of this interaction is to check the robustness of my main results to a financial friction channel that affects differentially firms with different sizes. Column (1) in Table 9 displays the baseline result. Columns (2)-(4) shows that the results survives to the introduction of these interactions.

Table (9) Panel Regressions: Commodity Booms and Outcome Variables

	Dependent Variable: ln (Real Profits)			
	(1)	(2)	(3)	(4)
$X_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.079***	-0.082***	-0.059***	-0.062***
	(0.0292)	(0.0291)	(0.0302)	(0.0302)
$K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.024***	-0.026**	-0.019***	-0.022***
	(0.0074)	(0.0076)	(0.0076)	(0.0077)
$X_{f0} \cdot K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.032**	-0.031*	-0.033**	-0.033**
	(0.0152)	(0.0152)	(0.0152)	(0.0152)
$TFP_{f0} \cdot \tilde{P}^{Co}_{t-1}$		-0.033*		-0.036**
		(0.0181)		(0.0182)
$SIZE_{f0} \cdot \tilde{P}^{Co}_{t-1}$			-0.018**	-0.019**
			(0.0074)	(0.0074)
Firm FE	yes	yes	yes	yes
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.169	0.169	0.169	0.169
N. obs.	59,281	59,281	59,281	59,281

	Dependent Variable: ln (Real Value Added)			
	(1)	(2)	(3)	(4)
$X_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.092***	-0.095***	-0.077***	-0.079***
	(0.0291)	(0.0292)	(0.0300)	(0.0300)
$K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.021***	-0.023**	-0.018***	-0.020***
	(0.0073)	(0.0074)	(0.0075)	(0.0075)
$X_{f0} \cdot K^{int}_{f0} \cdot \tilde{P}^{Co}_{t-1}$	-0.032**	-0.031*	-0.033**	-0.032**
	(0.0157)	(0.0156)	(0.0157)	(0.0157)
$TFP_{f0} \cdot \tilde{P}^{Co}_{t-1}$		-0.027*		-0.029
		(0.0190)		(0.0190)
$SIZE_{f0} \cdot \tilde{P}^{Co}_{t-1}$			-0.014**	-0.015**
			(0.0075)	(0.0075)
Firm FE	yes	yes	yes	yes
Sector×Year FE	yes	yes	yes	yes
Adj. R^2	0.169	0.169	0.169	0.169
N. obs.	59,281	59,281	59,281	59,281

Notes: Results for regression (2.1) with additional controls. ***: $p < 0.01$, **: $p < 0.05$, *: $p < 0.1$. The variables $SIZE_{f0}$ and TFP_{f0} are constructed as firm f quintile in the size and productivity distributions in its first period $t = 0$ in the sample. Size is measured as the number of workers, while firm-level productivity is estimated using the method of Wooldridge (2009).

D General Equilibrium System

$$
\begin{aligned}
\text{Endogenous (33)} &= \left\{C, C^X, C^M, Y^X, Y^C, r^k, w, p, p^X\right\} = 9 \\
&= \left\{L^X, L^C, L, K^X, K^C, K, I, X^X, X, M, TB, B\right\} = 12 \\
&= \left\{V(z), V_{dj}(z), V_{xj}(z), \mu(z), \overline{z}_d, \overline{z}_a, \overline{z}_x, \mathcal{M}, \mathcal{M}_e, \phi_j, \Phi(.), \mathcal{F}\right\} = 12
\end{aligned}
$$

D.1 Household

$$
p_t = \left[\chi\left(p_t^X\right)^{1-\epsilon} + (1-\chi)\left(p_t^M = 1\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{D.1}
$$

$$
\varphi L_t^{\zeta-1} = \frac{w_t}{p_t} \tag{D.2}
$$

$$
\frac{1}{(1+r^*)} = \beta\left[\frac{C_t - \varphi\frac{L_t^{\zeta}}{\zeta}}{C_{t+1} - \varphi\frac{L_{t+1}^{\zeta}}{\zeta}}\right]^{v}\left(\frac{p_t}{p_{t+1}}\right) \tag{D.3}
$$

$$
1 + \phi\left(\frac{K_{t+1}}{K_t} - 1\right) = \beta\left[r_{t+1}^k + 1 - \delta^k + adj_{t+1}\right] \tag{D.4}
$$

$$
adj_t = \phi\left(\frac{K_{t+1}}{K_t}\right)\left(\frac{K_{t+1}}{K_t} - 1\right) - \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - 1\right)^2
$$

$$
K_{t+1} = (1-\delta^k)K_t + I_t \tag{D.5}
$$

$$
C_t^X = \chi\left(\frac{p_t}{p_t^X}\right)^{\epsilon} C_t \tag{D.6}
$$

$$
C_t^M = (1-\chi)\left(\frac{p_t}{p_t^M = 1}\right)^{\epsilon} C_t \tag{D.7}
$$

D.2 Exportable Goods

$$
\phi_{jt} = \left(\frac{r_t^k}{\alpha_j}\right)^{\alpha_j}\left(\frac{w_t}{1-\alpha_j}\right)^{1-\alpha_j}, \quad j = l, h \tag{D.8}
$$

$$
V_t(z) = \max\{V_{dlt}(z), V_{dht}(z), V_{xlt}(z), V_{xht}(z)\} \tag{D.9}
$$

$$
V_{djt}(z) = \max\left\{0, \pi_{djt}(z) + (1-\delta)\beta V_{t+1}(z)\right\}, \quad j = l, h \tag{D.10}
$$

$$
V_{xjt}(z) = \max\left\{0, \pi_{djt}(z) + \pi_{xjt}(z) + (1-\delta)\beta V_{t+1}(z)\right\}, \quad j = l, h \tag{D.11}
$$

$$
V_{dlt}(\overline{z}_{dt}) = 0 \tag{D.12}
$$

$$
V_{dlt}(\overline{z}_{xt}) = V_{xlt}(\overline{z}_{xt}) \tag{D.13}
$$

$$
V_{xlt}(\overline{z}_{at}) = V_{xht}(\overline{z}_{at}) \tag{D.14}
$$

$$
\int_{\overline{z}_{dt}}^{\infty} V_t(z)g(z)dz = \overline{f_e} + \phi_e\left[\exp\left(\mathcal{M}_{et} - \overline{\mathcal{M}}_e\right) - 1\right] \tag{D.15}
$$

$$\mathcal{M}_{t+1}\mu_{t+1}(z) = \begin{cases}(1-\delta)\mathcal{M}_t\mu_t(z)+\mathcal{M}_{et+1}g(z), & \text{if} \quad z \geq \overline{z}_{dt+1} \\ 0, & \text{otherwise}\end{cases} \tag{D.16}$$

$$\mathcal{M}_{t+1} = (1-\delta)\mathcal{M}_t\int_{\overline{z}_{dt+1}}^{\infty}\mu_t(z)dz+\mathcal{M}_{et+1}\int_{\overline{z}_{dt+1}}^{\infty}g(z)dz \tag{D.17}$$

$$Y_t^X = \left[\mathcal{M}_t\left(\int_{\overline{z}_{dt}}^{\overline{z}_{at}}(q_{dlt}(z))^{\rho}\mu_t(z)dz+\int_{\overline{z}_{at}}^{\infty}(q_{dht}(z))^{\rho}\mu_t(z)dz\right)\right]^{\frac{1}{\rho}} \tag{D.18}$$

$$X_t^X = \mathcal{M}_t\left[\int_{\overline{z}_{xt}}^{\overline{z}_{at}}p_{xlt}(z)q_{xlt}(z)\mu_t(z)dz+\int_{\overline{z}_{at}}^{\infty}p_{xht}(z)q_{xht}(z)\mu_t(z)dz\right] \tag{D.19}$$

$$L_t^X = \mathcal{M}_t\left[\int_{\overline{z}_{dt}}^{\overline{z}_{at}}l_{dlt}(z)+\int_{\overline{z}_{at}}^{\infty}l_{dht}(z)+\int_{\overline{z}_{xt}}^{\overline{z}_{at}}l_{xlt}(z)+\int_{\overline{z}_{at}}^{\infty}l_{xht}(z)\right]\mu_t(z)dz \tag{D.20}$$

$$K_t^X = \mathcal{M}_t\left[\int_{\overline{z}_{dt}}^{\overline{z}_{at}}k_{dlt}(z)+\int_{\overline{z}_{at}}^{\infty}k_{dht}(z)+\int_{\overline{z}_{xt}}^{\overline{z}_{at}}k_{xlt}(z)+\int_{\overline{z}_{at}}^{\infty}k_{xht}(z)\right]\mu_t(z)dz \tag{D.21}$$

D.3 Commodity Good

$$w_t = \eta(1-\alpha^C)p_t^{Co}\frac{Y_t^C}{L_t^C} \tag{D.22}$$

$$r_t^k = \eta\alpha^C p_t^{Co}\frac{Y_t^C}{K_t^C} \tag{D.23}$$

$$Y_t^C = \overline{R}\left[\left(K_t^C\right)^{\alpha^C}\left(L_t^C\right)^{1-\alpha^C}\right]^{\eta} \tag{D.24}$$

D.4 Aggregation

$$L_t = L_t^X + L_t^C \tag{D.25}$$

$$K_t = K_t^X + K_t^C \tag{D.26}$$

$$Y_t^X = C_t^X \tag{D.27}$$

$$X_t = p_t^{Co}Y_t^C + X_t^X \tag{D.28}$$

$$M_t = C_t^M + I_t + \Phi_t + \mathcal{F}_t \tag{D.29}$$

$$\Phi_t = \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t}-1\right)^2 K_t \tag{D.30}$$

$$\mathcal{F}_t = \mathcal{M}_t f_d + \mathcal{M}_t p_{xt} f_x + \mathcal{M}_t p_{at} f_a + \mathcal{M}_{et} f_e\left(\mathcal{M}_{et}\right) \tag{D.31}$$

$$TB_t = X_t - M_t \tag{D.32}$$

$$B_{t+1} = (1+r^*)B_t + TB_t \tag{D.33}$$

D.5 Auxiliar Equations

$$\begin{aligned}
\pi_{sjt}(z) &= \left[p_{jt}(z) - c_{jt}(z)\right] q_{sjt}(z) - \mathbb{F}_t, \quad s = d, x, \quad j = l, h \\
\mathbb{F}_t &= \left[f_d + f_a \mathbf{1}\left(j_t = h\right)\right] \mathbf{1}\left(s_t = d\right) + f_x \mathbf{1}\left(s_t = x\right) \\
p_{jt}(z) &= \frac{1}{\rho}\frac{\phi_{jt}}{z}, \quad j = l, h \\
q_{sjt}(z) &= \begin{cases} \left(p_t^X\right)^{\sigma} C_t^X \left(p_{jt}(z)\right)^{-\sigma} & \text{if } s = d, \quad j = l, h \\ \gamma\left(p_{jt}(z)\right)^{-\sigma} & \text{if } s = x, \quad j = l, h \end{cases} \\
l_{sjt}(z) &= \begin{cases} \frac{(1-\alpha_j)\phi_{jt}}{w_t} \cdot \left[\left(p_t^X\right)^{\sigma} C_t^X \left(\frac{\rho}{\phi_{jt}}\right)^{\sigma} z^{\sigma-1}\right] & \text{if } s = d \\ \frac{(1-\alpha_j)\phi_{jt}}{w_t} \cdot \left[\gamma \left(\frac{\rho}{\phi_{jt}}\right)^{\sigma} z^{\sigma-1}\right] & \text{if } s = x \end{cases} \\
k_{sjt}(z) &= \begin{cases} \frac{\alpha_j\phi_{jt}}{r_t^k} \cdot \left[\left(p_t^X\right)^{\sigma} C_t^X \left(\frac{\rho}{\phi_{jt}}\right)^{\sigma} z^{\sigma-1}\right] & \text{if } s = d \\ \frac{\alpha_j\phi_{jt}}{r_t^k} \cdot \left[\gamma \left(\frac{\rho}{\phi_{jt}}\right)^{\sigma} z^{\sigma-1}\right] & \text{if } s = x \end{cases}
\end{aligned}$$

D.6 Transition Dynamics Equilibrium Definition

Given an exogenous sequence of commodity prices $\{P_t^{Co}\}_{t=1}^T$ and initial conditions for the net foreign asset position (B_1), the economy-wide stock of capital (K_1), the mass of firms $(\mathcal{M}_1)$ and productivity distribution $(\mu_1(z))$, a competitive equilibrium consists of sequences of (i) value functions $\{V_t(z)\}_{t=1}^T$, (ii) masses of producers and entrants $\{\mathcal{M}_t, \mathcal{M}_{et}\}_{t=1}^T$, (iii) operational, exporting, and adoption cut-off rules $\{\overline{z}_{dt}, \overline{z}_{xt}, \overline{z}_{at}\}_{t=1}^T$, (iv) distribution $\{\mu_t(z)\}_{t=1}^T$, (v) decision rules for firms $\{\left(l_{sjt}(z), k_{sjt}(z), p_{jt}(z)\right)\}_{t=1}^T$, (vi) decision rules for the representative household $\{C_t, C_t^X, C_t^M, L_t, K_{t+1}\}_{t=1}^T$, and (vii) aggregate prices $\{w_t, r_t^k, p_t, p_t^X\}_{t=1}^T$, such that, for all $t = 1, ..., T$:

1. Given prices in (vii), the value functions (i), cut-off rules (iv), and decision rules (v) solve the firms' problem in the exportable sector.

2. Given prices in (vii) and value functions (i), the mass of entrants satisfy the free-entry condition (D.15).

3. Given prices in (vii), the distribution in (iv) is consistent with the decision rules in (v).

4. Given prices in (vii), the decision rules in (vi) solve the problem of the household.

5. The markets for labor, capital, and domestically-traded varieties clear, that is, equations (D.25), (D.26) and (D.27) hold.

6. The aggregate resource constraint induce a law of motion for the net foreign asset position given by equation (D.33).

7. In period $t = T$ the economy has settled in the new steady state with a finite and stable net foreign asset position.

D.7 Transition Algorithm

- **Setup:** The economy is in the calibrated initial steady state up until $t = 0$. The commodity price boom-bust cycle $\{p_t^{Co}\}_{t=1}^{T}$ (illustrated in Figure 5, panel (a)) is revealed once and for all in period $t = 1$.
- **Initial State:** $\{B_1, K_1, \mathcal{M}_1, \mu_1(z)\}$ is given.
- **Outer Loop:** Guess C_1. Bisection update using transversality condition.
- **Inner Loop:** Guess $\{w_t, p_t^X, K_{t+1}\}_{t=1}^{T}$.
  - **Households.**
    - Get $\{p_t\}_{t=1}^{T}$ using (D.1).
    - Get $\{L_t\}_{t=1}^{T}$ using (D.2).
    - Get $\{C_{t+1}\}_{t=1}^{T}$ using (D.3).
    - Get $\{r_{t+1}^k\}_{t=1}^{T}$ using (D.4).
    - Get $\{I_t\}_{t=1}^{T}$ using (D.5).
    - Get $\{C_t^X, C_t^M\}_{t=1}^{T}$ using (D.6), (D.7).
  - Get $\{\phi_{jt}\}_{t=1}^{T}$, $j = l, h$,using (D.8).
  - Set period $t = T$ (final steady state) value function vector $V_T(z)$.
  - **Iterate Backward.** For $t = T - 1 : -1 : 1$
    - Compute value functions and cutoffs via (D.9)-(D.14).
    - Use (D.15) to get the mass of entrants $\mathcal{M}_{et}$.
  - **Iterate Forward.** For $t = 1 : T$
    - Get mass $\mathcal{M}_t$ and distribution $\mu_t(z)$ using (D.16)-(D.17).
  - **Aggregation.**
    - Get $\{X_t^X, K_t^X, L_t^X, Y_t^X\}_{t=1}^{T}$ using (D.19), (D.20), (D.21), and (D.27).
    - Get $\{L_t^C, K_t^C, Y_t^C\}_{t=1}^{T}$ using (D.22)-(D.24).
  - **Updating: Model-Implied Sequences.**
    - $\{w_t\}_{t=1}^{T}$ using (D.25). (Solver)
    - $\{p_t^X\}_{t=1}^{T}$ using (D.18). (Analytic)
    - $\{K_{t+1}\}_{t=1}^{T}$ using(D.26). (Analytic)
  - **Iterate** over $\{w_t, p_t^X, K_{t+1}\}_{t=1}^{T}$ until convergence.
- **Fixed Costs:** Get $\{\Phi_t, \mathcal{F}_t\}_{t=1}^{T}$ using (D.30), (D.31).
- **Trade Balance:** Get $\{X_t, M_t, TB_t\}_{t=1}^{T}$ using (D.28), (D.29), (D.32), respectively.
- **NFA:** Get $\{B_{t+1}\}_{t=1}^{T}$ from (D.33).
- **Iterate** over C_1 until $\{B_{t+1}\}_{t=1}^{T}$ is stable in the long run.

E Steady State System

$$\begin{aligned}
\text{Endogenous (36)} &= \left\{C, C^X, C^M, Y^X, Y^C, r^k, w, p, p^X\right\} = 9 \\
&= \left\{L^X, L^C, L, K^X, K^C, K, I, X^X, X, M, TB, \beta, Y, YCY, TBY\right\} = 15 \\
&= \left\{V(z), V_{dj}(z), V_{xj}(z), \mu(z), \overline{z}_d, \overline{z}_a, \overline{z}_x, \mathcal{M}, \mathcal{M}_e, \phi_j, \Phi(.), \mathcal{F}\right\} = 12
\end{aligned}$$

Given a net foreign asset position level B.

E.1 Household

$$p = \left[\chi \left(p^X\right)^{1-\epsilon} + (1-\chi)\left(p^M\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{E.1}$$

$$\varphi L_t^{\zeta-1} = \frac{w_t}{p_t} \tag{E.2}$$

$$\beta = \frac{1}{(1+r^*)} \tag{E.3}$$

$$r^k = \frac{1}{\beta} - 1 + \delta^k \tag{E.4}$$

$$I = \delta^k K \tag{E.5}$$

$$C^X = \chi \left(\frac{p}{p^X}\right)^{\epsilon} C \tag{E.6}$$

$$C^M = (1-\chi)\left(\frac{p}{p^M}\right)^{\epsilon} C \tag{E.7}$$

E.2 Exportable Goods

$$\phi_j = \left(\frac{r^k}{\alpha_j}\right)^{\alpha_j}\left(\frac{w}{1-\alpha_j}\right)^{1-\alpha_j}, \quad j = l, h \tag{E.8}$$

$$V(z) = \max\{V_{dl}(z), V_{dh}(z), V_{xl}(z), V_{xh}(z)\} \tag{E.9}$$

$$V_{dj}(z) = \max\left\{0, \frac{(1+r^*)}{(\delta+r^*)}\pi_{dj}(z)\right\}, \quad j = l, h \tag{E.10}$$

$$V_{xj}(z) = \max\left\{0, \frac{(1+r^*)}{(\delta+r^*)}\left[\pi_{dj}(z) + \pi_{xj}(z)\right]\right\}, \quad j = l, h \tag{E.11}$$

$$V_{dl}(\overline{z}_d) = 0 \tag{E.12}$$

$$V_{dl}(\overline{z}_x) = V_{xl}(\overline{z}_x) \tag{E.13}$$

$$V_{xl}(\overline{z}_a) = V_{xh}(\overline{z}_a) \tag{E.14}$$

$$\int_{\overline{z}_d}^{\infty} V(z)g(z)dz = \overline{f_e} + \phi_e\left[\exp\left(\mathcal{M}_e - \overline{\mathcal{M}}_e\right) - 1\right] \tag{E.15}$$

$$\mu(z) = \begin{cases} \frac{g(z)}{1-G(\overline{z}_d)}, & \text{if} \quad z \geq \overline{z}_d \\ 0, & \text{otherwise} \end{cases} \tag{E.16}$$

$$\delta\mathcal{M} = [1 - G(\overline{z}_d)]\,\mathcal{M}_e \tag{E.17}$$

$$Y^X = \left[\mathcal{M}\left(\int_{\overline{z}_d}^{\overline{z}_a} (q_{dl}(z))^\rho \mu(z)dz + \int_{\overline{z}_a}^{\infty} (q_{dh}(z))^\rho \mu(z)dz\right)\right]^{\frac{1}{\rho}} \Leftrightarrow \tag{E.18}$$

$$p^X = \frac{1}{\rho}\left[\phi_l^{1-\sigma} \cdot \left(\mathcal{M}\int_{\overline{z}_d}^{\overline{z}_a} z^{\sigma-1}\mu(z)dz\right) + \left(\frac{\phi_h}{\kappa}\right)^{1-\sigma} \cdot \left(\mathcal{M}\int_{\overline{z}_a}^{\infty} z^{\sigma-1}\mu(z)dz\right)\right]^{\frac{1}{1-\sigma}}$$

$$X^X = \mathcal{M}\left[\int_{\overline{z}_x}^{\overline{z}_a} p_{xl}(z)q_{xl}(z)\mu(z)dz + \int_{\overline{z}_a}^{\infty} p_{xh}(z)q_{xh}(z)\mu(z)dz\right] \tag{E.19}$$

$$L^X = L_{dl}^X + L_{dh}^X + L_{xl}^X + L_{xh}^X \tag{E.20}$$

$$K^X = K_{dl}^X + K_{dh}^X + K_{xl}^X + K_{xh}^X \tag{E.21}$$

E.3 Commodity Goods

$$w = \eta(1-\alpha^C)p^{Co}\frac{Y^C}{L^C} \tag{E.22}$$

$$r^k = \eta\alpha^C p^{Co}\frac{Y^C}{K^C} \tag{E.23}$$

$$Y^C = \overline{R}\left[\left(K^C\right)^{\alpha^C}\left(L^C\right)^{1-\alpha^C}\right]^\eta \tag{E.24}$$

E.4 Aggregation

$$L = L^X + L^C \tag{E.25}$$

$$K = K^X + K^C \tag{E.26}$$

$$Y^X = C^X \tag{E.27}$$

$$X = p^{Co}Y^C + X^X \tag{E.28}$$

$$M = C^M + I + \mathcal{F} \tag{E.29}$$

$$\Phi = 0 \tag{E.30}$$

$$\mathcal{F} = \mathcal{M}f_d + \mathcal{M}p_x f_x + \mathcal{M}p_a f_a + \mathcal{M}_e f_e\left(\mathcal{M}_e\right) \tag{E.31}$$

$$TB = X - M \tag{E.32}$$

$$TB = -r^* \cdot B \tag{E.33}$$

$$Y = p^X Y^X + X^X + p^{Co}Y^C - \mathcal{F} \tag{E.34}$$

$$YCY = \frac{p^{Co}Y^C}{Y} \tag{E.35}$$

$$TBY = \frac{TB}{Y} \tag{E.36}$$

E.5 Steady State Solution Algorithm

$$\begin{aligned} \text{Targets} &= \{r^*, TBY, YCY, Y\} \\ \text{Parameters} &= \{\beta, B, \overline{R}, \varphi\} \end{aligned}$$

- p^{Co} is exogenously given.
- Assumption: No congestion cost in this steady state.
- Given r^*, get $\beta = \frac{1}{(1+r^*)}$ from (E.3).
- Given β, get $r^k = r^* + \delta^k$ from (E.4).
- Guess (w, p^X, C).
- Residuals: X free entry condition (E.15), GDP definition (E.34), and balance of payments (E.32).
- Get (Y^C, TB) from (E.35) and (E.36).
- Get B from (E.33).
- Get (L^C, K^C) from (E.22) and (E.23), respectively.
- Get $\overline{R}$ from (E.24).
- Get (p, C^X, C^M, Y^X) from (E.1), (E.6), (E.7), and (E.27).
- Get ϕ_j from (E.8).
- Get values and cutoffs from (E.9)-(E.14).
- Get distribution from (E.16).
- Get $(\mathcal{M}, \mathcal{M}_e)$ from (E.18), (E.17).
- Get (X^X, L^X, K^X) from (E.19), (E.20), (E.21).
- Get (L, K) from (E.25) and (E.26).
- Get φ from (E.2).
- Get I from (E.5)
- Get Φ $(\mathcal{F})$ from (E.30) and (E.31).
- Get (X, M) from (E.28), (E.29).
- Residuals: X free entry condition (E.15), GDP definition (E.34), and balance of payments (E.32).
- Iterate over (w, p^X, C) until convergence.

F Analytical Cutoffs

Combining the static versions of equations (3.7)-(3.7) in the main text, we can obtain anaytical expressions for the long-run productivity thresholds that determine self-selection into the capital-intensive technology and into exporting. The domestic cutoff can be written as:

$$\bar{z}_d = \left[\frac{\sigma f_d}{p^\sigma \cdot C}\right]^{\frac{1}{\sigma-1}} \left(\frac{\phi_l}{\rho}\right). \tag{F.37}$$

Given the proposed sorting pattern $\bar{z}_d < \bar{z}_x < \bar{z}_a$, the marginal exporter uses the Low-K technology. The condition that determines the exporting cutoffs is given by $\pi_{dl}(\bar{z}_x) = \pi_{xl}(\bar{z}_x)$, which implies:

$$\bar{z}_x = \left[\frac{\sigma f_x}{\gamma}\right]^{\frac{1}{\sigma-1}} \left(\frac{\phi_l}{\rho}\right). \tag{F.38}$$

Finally, the lowest productivity type that is willing to choose the High-K technology is an exporter. Thereby, the adoption cutoff satisfies $\pi_{xl}(\bar{z}_a) = \pi_{xh}(\bar{z}_a)$. Solving for $\bar{z}_a$ yields:

$$\bar{z}_a = \left[\frac{\sigma f_a}{p^\sigma C + \gamma}\right]^{\frac{1}{\sigma-1}} \frac{\left[\phi_h^{1-\sigma} - \phi_l^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}{\rho}. \tag{F.39}$$

Testable Predictions. Positive commodity price (windfall) shocks induce higher consumption ($\frac{\partial C}{\partial p^{Co}} > 0$), currency appreciation ($\frac{\partial p}{\partial p^{Co}} > 0$), and an increase in the rental rate of capital relative to the cost of labor $\frac{\partial (r^k/w)}{\partial p^{Co}} > 0$. These are, the wealth or demand channel, the substitution or exchange rate channel, and the cost of capital channel, respectively. These well-known basic correlations can be easily shown in the full general equilibrium model presented in Section 3. In this section, I take them as given.

Prediction 1 (Intensive margin). *For any given exporting type, export sales shrink relative to domestic sales after a positive windfall shock.*

From equation (3.7), it can be seen that, for any given exporting type (either Low-K or High-K), the ratio of export sales to domestic sales, R_{xd}, is given by:

$$R_{xd} = \frac{\gamma}{(p)^\sigma C} \tag{F.40}$$

Given that $\frac{\partial C}{\partial p^{Co}} > 0$ and $\frac{\partial p}{\partial p^{Co}} > 0$, then it must be the case that $\frac{\partial R_{xd}}{\partial p^{Co}} < 0$.

Note that the shrinking of exporters relative to non-exporters is a combination of textbook wealth and substitution channels. The intuition is as follows. First, the economy is richer, so the household increases demand immediately to smooth consumption (income effect). Second, higher demand pushes domestic prices up (currency appreciation), thereby leading to further adjustments in favor of purely-domestic producers and at the expense of exporters (substitution effect).[9]

Prediction 2 (Extensive margin: Exporters vs Non-exporters). *The exporting cutoff increases after a positive windfall shock.*

From equation (F.38) it is direct that higher costs during the boom ($\uparrow \phi_l$) unambiguously leads to a one-to-one increase in the exporting cutoff $\bar{z}_x$, therefore inducing some previously profitable exporter types to stop selling their varieties abroad. Notice that, under monopolistic competition, increasing composite costs are passed through to consumers via the pricing rule, ultimately raising the average basket price $p = \left[\int_z (p_d(z))^{1-\sigma} dz\right]^{\frac{1}{1-\sigma}}$, that is, a real appreciation of the domestic currency. In essence, firm exit from exporting is associated with the exchange rate channel.

Prediction 3 (Extensive margin: High-K vs Low-K). *The adoption cutoff increases after a positive windfall shock.*

From equation (F.39) it is direct that both larger aggregate demand ($\uparrow C$) and currency appreciation ($\uparrow p$) push $\bar{z}_a$ down. Then, the overall effect depends crucially on the cost of capital channel, that is, on the term $\Omega \equiv \left[\phi_h^{1-\sigma} - \phi_l^{1-\sigma}\right]^{\frac{1}{1-\sigma}}$ in equation (F.39). It can be shown that $\Delta\Omega$ is proportional to $\left(\alpha^h - \alpha^l\right)\left(\Delta r^k - \Delta w\right)$, which is positive as long as $\Delta r^k > \Delta w$. Intuitively, if the cost of capital increases more than the cost of labor, then capital-intensive firms face a cost disadvantage, and some of them will be forced to downgrade into the less profitable technology. If the cost channel is large enough, that is, if $(\alpha_h - \alpha_l)$ is large, it may offset the effects of wealth and substitution channels, leading to an increase in $\bar{z}_a$.

[9] See Corden and Neary (1982) and Vegh (2013).