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Capital Adjustment Costs: Implications for Domestic and Export Sales Dynamics

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Abstract

Theoretical and empirical work on export dynamics has generally assumed constant marginal production cost and therefore ignored domestic product market conditions. However, recent studies have documented a negative contemporaneous correlation between firms' domestic and export sales growth, suggesting that firms can be capacity constrained in the short run and face increasing marginal production cost. This paper develops and estimates a dynamic model of export behavior incorporating short-term capacity constraints and endogenous capital investment. Consistent with the empirical evidence, the model features firms' sales substitutions across markets in the short term, and generates time-varying transition paths of firm responses through firms' capital adjustments over time.

The model is fit to a panel of plant-level data for Colombian manufacturing industries and used to simulate how firm-responses transition following an exchange-rate devaluation. The results indicate that incorporating capital adjustment costs is quantitatively important. First, it takes more than five years for firms to fully adjust to a permanent change of the exchange-rate process. Second, the long-run exchange rate elasticity of exports is substantially higher than that in the short run. Firms' expectation on the permanence of the policy changes also matters. The failure to accurately anticipate the duration of the devaluation results in reduction in firms' profits due to over- or under- investment in capital.

Keywords: International trade; heterogeneous firms; capacity constraints; capital adjustment costs; firm dynamics; firm panel data.

JEL Codes: F12, L11, F14

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1 Introduction

How firms and a country's overall economy transition following trade liberalization, changes of exchange-rate regime, or vast macro shocks has long been of interest to trade economists, policy-makers and the broader public. While it is a general consensus that trade liberalization and reduction of trade costs increase aggregate trade volume and consumer welfare, the majority of theoretical and empirical work on export responses has focused on the long-run effects of these policies without concerning about the transitional dynamics. Considering that many of firms' decisions (capital investment, innovation, export entry, etc) are potentially dynamic[1] and affect the return of each other, firm responses can change over time in their transition to the long-run steady state. As a result, the overall effects of trade liberalization or market-condition changes will depend on how these firm responses evolve over time, and how long the transition lasts.

Studies that focus on long-run export responses have generally been conducted under the assumption that firms face constant marginal production cost. Under this assumption, firms can expand or contract their production capacity freely without incurring any extra costs beyond marginal production cost. This implies that domestic product market conditions have no effects on firms' export decisions[2]. In particular, when we examine how exports respond to a trade liberalization, this would imply that firms can ramp up their production for the export market immediately, and export expansion has no consequences on domestic sales and output price. However, recent studies have documented a negative correlation between exporting firms' domestic and export sales growth that challenges the assumption of constant marginal production cost. This is shown by Vannoorenberghe (2012), Blum et al (2013) and Ahn and McQuoid (2012), for example. This negative correlation between domestic and export sales growth suggests that firms can capacity constrained in the short run. However, in these papers capacity is fixed and investment in capital is not allowed.[3] As such they cannot characterize the transition of the economy from the short run to the long run in response to a trade liberalization or changes in the exchange-rate regime.

This paper goes beyond the current literature by developing and estimating a dynamic forward-looking model of firms' sales dynamics in an open economy with capacity constraints and endogenous investment. It incorporates capital adjustment costs that have been studied

[1] In the sense that current actions affect future outcomes, and future conditions also affect current decisions through expectations.

[2] Domestic factor market conditions, however, would affect firms' exports through factor prices under the assumption of constant marginal production cost.

[3] In Ahn and McQuoid (2012) only firms that are capacity constrained have fixed capacity. Firms that are not capacity constrained face constant marginal production cost and have unlimited capacity.

typically in the context of a closed economy.[4] The model has implications that differ from earlier models that assume constant marginal costs in several respects. First, firms that are capacity constrained in the short run face a trade-off between domestic and export sales. The increased export sales growth led by positive foreign demand shocks can induce higher output prices for domestic consumers when firms are capacity constrained. Second, the long-run responses differ from the short-run responses, as producers can adjust their production capacity through capital investment over time. Finally, producers' expectations about the duration of policy changes or persistence of external shocks affect their sales responses. The failure to accurately anticipate the persistence of shocks results in reduction in profits due to over- or under- investment in capital.

The paper quantifies these effects by fitting the model to plant-level panel data from Colombia. The Colombian data is suited for this study as reduced-form empirical evidence suggests that producers cannot easily expand or reduce production capacity in the short run.[5] It shows that the inability of firms to adjust their production capacity affects their export and domestic sales dynamics. With Colombian plant-level data I also confirm the substitution behavior between domestic and export sales for exporters, similar to other studies. In addition, I document that expansion in the export market is accompanied by an increase in the plant-level output price index and followed by high investment level.

The model is estimated using a simulated-method-of-moments approach. The calibrated model does a good job in replicating the basic features of the Colombian micro data, including the exporting patterns, correlation between domestic and export sales growth among continuing exporters, correlation between export sales and price, the distribution of investment rates, and the serial correlation of investment rates. The estimates of the model suggest that the idiosyncratic demand shocks dominate productivity shocks in generating firms' sales variation. The estimated coefficients for capital adjustment costs suggest that both convex and fixed capital adjustment costs exist, and there is substantial price difference in purchasing and selling physical capital.

The calibrated model is then used to conduct policy experiments of changes in the exchange rate regime. The experiment simulates the transitional dynamics of domestic and export sales, price and capital investment from the short run to the long run in response to the policy changes. The results show that incorporating capital adjustment costs is empirically important, and firms' expectation on the duration of the policy changes matters. First, it takes more than five years for firms to fully adjust to a permanent change of the exchange-rate process that depreciates the steady state value of the peso by 20%. The long-run and

[4] Papers include Caballero and Engel (1999) and Cooper and Haltiwanger (2006), etc.

[5] This paper uses firm and plant interchangeably.

short-run export responses also differ: the long-run exchange rate elasticity of exports is 30% higher than that in the short run. Finally, firms' anticipation and expecation on the permanence of the policy changes also matters. (1) When firms correctly perceive a temporary currency devaluation, firms substitute their domestic sales towards the export market. There are no responses in capital adjustments. (2) When the devaluation is temporary but firms incorrectly perceive it to be permanent, firms over-invest in capital and suffer reductions in profit due to increased capital adjustment costs induced by over-investing and downsizing the capital afterward. (3) When the devaluation is permanent but firms incorrectly perceive it to be temporary, firms under-invest in their capacity and the substitution of domestic sales for export sales is prolonged. Firms incur reductions in profit because of the increased marginal cost caused by insufficient capital investment. Domestic consumers also incur welfare losses because of the prolonged periods of high price. (4) When firms correctly perceive permanent currency devaluation, the substitution away from domestic sales for exports is temporary. Firms bring back their domestic sales after they invest in physical capital.

Relation to the Literature This paper is most closely related to contemporaneous work by Rho and Rodrigue (2015, forthcoming). Rho and Rodrigue (2015) focus on capital investment and growth patterns of new exporters compared with non-exporters, featuring increasing marginal production cost (MC) and capital adjustment costs similar to our setting. They show estimates of sunk export entry cost and per-period export fixed cost are over-estimated for models assuming constant MC and no capital adjustment costs by applying their model to two Thailand manufacturing industries. This paper differ from Rho and Rodrigue in several dimensions. First, this paper utilizes output price data at the plant-level to separate plants' cost and demand shocks, while Rho and Rodrigue (2015) back out a plant's foreign demand from observed export intensity, assuming domestic demand is the same across plants. This is important as it has different implications on the correlation between sales growth and affects the productivity estimates. Secondly, this paper focuses on both new and incumbent exporters, while Rho and Rodrigue (2015) largely focus on new exporters.

The paper relates to some recent works that study capacity constraints and export behavior. Vannoorenberghe (2012) establishes reduce-form evidence of negative correlation between output variation on the domestic and export market at the firm level, suggesting short-run convex production cost as an explanation. Blum et at (2013) and Ahn and McQuoid (2012) also provide empirical evidence that supports the view of exporting firms being capacity constrained. Ahn and McQuoid (2012) use firm-level data from the Indonesian wood industry and established a negative correlation between plants' domestic and export sales growth. The authors find stronger negative correlation between domestic and export sales for plants that are either financially or physically constrained than those who are not constrained through reduce-form analysis. While Ahn and McQuoid (2012) treat producers' capacity constraints as exogenous and fixed, this paper focuses on the dynamic adjustments of physical capital that affect the extent to which producers being constrained. As a result of relaxing producers' capacity constraints though capital investment, the dynamic correlation between producers' domestic and export sales growth can be different from their contemporaneous correlation[6].

Blum et al (2013) also document the trade-off between selling domestically and abroad based on Chilean firm-level data. They find that a large fraction of firms enter and exit the same export destination multiple times, and sell the same products to the same importers upon re-entry. They attribute this behavior to firms facing limited production capacity. The paper classify exporters as either "occasional" or "perennial" exporters depending on the number of exporting spells and the length of the exporting spell. Their reduce-form analysis find that occasional exporters reduce their domestic sales when entering into exporting, but it is not the case for perennial exporters. In addition, there is a negative correlation between changes in domestic and foreign sales for continuing exporters. Again in Blum et al (2013) producers' production capacity is fixed and can not be adjusted through capital investment after a producer starts exporting. Instead, in this paper we focus not only on the trade-off between selling in the domestic and foreign market but also the dynamic adjustment of production capacity through capital investment. Similarly, Almunia et al (2018) document a larger increase of export flow for firms with a larger reduction in domestic demand using Spanish data during the Great Recession. Soderbery (2014) also presents a model where firms have heterogeneous and fixed capacity, and show trade liberalization could negatively impact welfare through firms raising output price.

Another closely related paper is Artuc et al (2013). While the patterns Ahn and McQuoid (2012) and Blum et al (2013) focus on are mostly static, Artuc et al (2013) look at the dynamic adjustments of capital investment and labor in response to exogenous trade shocks based on Argentine data under capital adjustment costs and workers' mobility costs. What it differs from this paper is that Artuc et al (2013) do not look at firms' exporting decisions and mainly focus on the factor market adjustments. In this paper we are also interested in the implications of factor adjustments on the interrelation between producers' domestic and export sales dynamics.

This paper is also related to a broader literature that study export dynamics, including

[6]Exceptionally, Berman et al (2015) shows positive correlation between variation in foreign and domestic sales based on French firm-level data. They point to a relaxation of short-run liquidity constraints as the reason for such positive correlation.

Alessandria and Choi (2014), Arkolakis (forthcoming), Eaton et al (2014), Arkolakis, Eaton and Kortum (2012), Das et al (2007) and Ruhl and Willis (2007, 2015). This paper differs from Arkolakis, Eaton and Kortum (2012), Eaton et al (2010), Arkolakis (2010, forthcoming) and Ruhl and Willis (2015) in that it focuses on frictions in the factor market. Alessandria and Choi (2014) develop a general equilibrium model featuring sunk export costs and capital accumulation, emphasizing the contribution of extensive margin to aggregate exports. Ruhl and Willis (2007) look at labor market frictions, but their focus is on new exporter growth and they ignore the domestic product market. This paper differs from theirs in two ways. 1) It introduces idiosyncratic demand shocks besides productivity shocks; 2) This paper also looks at firms' sales substitution patterns between the domestic and export market, and the correlation between price and sales growth, which are not the focus of Ruhl and Willis (2007). The paper is also related to Riano (2011) which studies exports and capital investment. But the focus of Riano (2011) is on firm-level sales volatility.

Another strand of literature that this paper relates to includes research that studies capital adjustment costs and their implications on the aggregate economy. Caballero and Engel (1999), as well as Cooper and Haltiwanger (2006), have argued that non-convex adjustment costs lead to lumpy investment decisions and aggregate nonlinearity. Contreras (2008) looks at the joint adjustment and interrelation of capital and labor using Colombian plant-level data from year 1982 to 1998. Contreras (2008) finds empirical support for congestion effects which means adjusting capital and labor at the same time is more costly than adjusting them separately. While these studies focus on a closed economy, this paper explores the implication of capital adjustment costs on domestic and export sales dynamics in the context of an open economy.

The remainder of the paper proceeds as follows: Section 2 presents the structural model. Section 3 provides descriptive analysis of the Colombian plant-level data used in this paper. Section 4 conducts the quantitative analysis that fits the model to the data. Section 5 concludes the paper.

2 Model

The model features a small open economy where exchange rate and foreign market-size are independent of domestic market conditions. It builds on the existing models of firm heterogeneity and exporting. Firms are heterogeneous in terms of both their underlying efficiency and market-specific demand shocks. Exporting to the foreign market entails fixed costs that are paid every period, as in Melitz (2003). Therefore only a fraction of domestic firms export. Firms switch into or out of exporting as they experience demand and productivity shocks, as in Das et al (2007). What this paper adds to these models is a characterization of the relationship between firms' export behavior and their capital formation. Firms' capital assets are fixed in the short run and face increasing marginal production cost, thus there is a trade-off between the domestic and export sales for exporters. Firms make investment choices given their perception about future market conditions.

The supply side of the model features heterogeneous firms located in the home country with different productivity levels. Each firm produces a single variety using standard Cobb-Douglas technology. The factors of production are labor and physical capital. Labor is variable input that can be freely adjusted at any time, while the amount of physical capital is fixed in the short run. The firms' inability to adjust physical capital in the short run leads to increasing marginal production cost. Over time physical capital can be adjusted through investment but subject to capital adjustment costs.

On the demand side, there is heterogeneous demand for each firm's variety in both the domestic and foreign market. I do not endogenously model demand growth through firms' searching and accumulating customers, or learning about the popularity of their products. This is mainly because I do not observe the necessary demand-side data to do so.

2.1 Demand

The domestic and foreign countries d and f have a continuum of consumers. Consumers in both countries have identical CES preferences with the same elasticity of substitution σ. There is a mass one of varieties available, each produced by a single firm from the domestic country. Consumers in country $k \in \{d, f\}$ have income E_t^k. A representative consumer from country k maximizes its utility

$$U_t^k = \left(\int z_t^k(j)^{\frac{1}{\sigma}} q_t^k(j)^{\frac{\sigma-1}{\sigma}} dj \right)^{\frac{\sigma}{\sigma-1}}, \;\; k \in \{d, f\}$$

subject to the budget constraint

$$\int p_t^k(j) q_t^k(j) dj = E_t^k, \;\; k \in \{d, f\}$$

where $z_t^k(j)$ is the product appeal of product j at country k, or the weight that consumer in country k place on product j, $q_t^k(j)$ is the demand over variety j from consumers in country

k, and $p_t^k(j)$ is variety j's price at country k[7]. The demand for product j at country k is

$$q_t^k(j) = z_t^k(j)\frac{p_t^k(j)^{-\sigma}}{(P_t^k)^{1-\sigma}}E_t^k, \;\; k \in \{d, f\}$$

where $P_t^k = (\int z_t^k(j)p_t^k(j)^{1-\sigma}dj)^{\frac{1}{1-\sigma}}$. Denote $D_{jt}^k = z_t^k(j)\frac{E_t^k}{(P_t^k)^{1-\sigma}}$,The total demand for variety j from country k is

$$q_{jt}^k = (p_{jt}^k)^{-\sigma}D_{jt}^k, \;\; k \in \{d, f\} \tag{1}$$

Note that both foreign price p_{jt}^f and income E_t^f are based on foreign currency here. They are going to be switched to domestic currency when calculate the firm's total revenue.

2.2 Production

On the supply side, each firm produces a single variety and firms compete monopolistically. Firms are heterogeneous in their productivity levels A_{jt}. They employ a Cobb-Douglas production technology with two factors: labor and physical capital. Labor is a variable input so it can be freely adjusted in each period. However, the amount of physical capital in a given period is fixed. The production function for firm j at time t is

$$q_{jt} = A_{jt}K_{jt}^{\alpha_k}L_{jt}^{\alpha_l}$$

Given firm j's capital level K_{jt}, wage w, its marginal production cost as a function of its output q_{jt} is:

$$MC_{jt} = \frac{w}{\alpha_l}q_{jt}^{\frac{1}{\alpha_l}-1}A_{jt}^{-\frac{1}{\alpha_l}}K_{jt}^{-\frac{\alpha_k}{\alpha_l}} \tag{2}$$

The total variable production cost is

$$TVC_{jt} = wq_{jt}^{\frac{1}{\alpha_l}}A_{jt}^{-\frac{1}{\alpha_l}}K_{jt}^{-\frac{\alpha_k}{\alpha_l}} \tag{3}$$

Marginal cost MC_{jt} is therefore an increasing function of its total output q_{jt} as long as the labor share α_l is less than 1. In addition, the higher the firm's productivity A_{jt} and capital level K_{jt}, the lower its marginal production cost is.

2.3 Static problem

In the beginning of each period, a firm observes its productivity and demand shock in both the domestic and foreign market. Given its capital level, the firm chooses its output, whether

[7] Firm j and product j are used interchangeably because each firm produces only one variety.

to export or not, and if so, the allocation of its output in the domestic and foreign market.

Exporting entails a per-period fixed cost f, therefore only firms with productivity or foreign demand above a certain level exports. Denote η_{jt} as the share of its total production that is sold abroad, so $q^f_{jt} = \eta_{jt} q_{jt}$. I solve the problem in two steps: (1) Given a firm's output q_{jt}, a firm decides its export share η_{jt} if it exports. (2) Given the optimal export share if it exports, a firm decides the optimal output q_{jt} and whether to export or not. Based on the demand function (1), the firm's total revenue in domestic currency if it exports is

$$
\begin{aligned}
S(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) &= \max_{\eta_{jt}\in[0,1]} p^d_{jt}(1-\eta_{jt})q_{jt} + e_t p^f_{jt}\eta_{jt}q_{jt} \\
&= \max_{\eta_{jt}\in[0,1]} \left[(1-\eta_{jt})^{\frac{\sigma-1}{\sigma}}(D^d_{jt})^{\frac{1}{\sigma}} + e_t(\eta_{jt})^{\frac{\sigma-1}{\sigma}}(D^f_{jt})^{\frac{1}{\sigma}}\right](q_{jt})^{\frac{\sigma-1}{\sigma}}
\end{aligned}
$$

Here e_t denotes the exchange rate: 1 unit of foreign currency worth e_t domestic currency at time t.

We can solve for the optimal export share η_{jt} by maximization of the above equation. The optimal η_{jt} for an exporting firm is

$$
\begin{aligned}
\eta^*_{jt} &= \left(1 + \frac{D^d_{jt}}{D^f_{jt} e^\sigma_t}\right)^{-1} \\
\frac{q^f_{jt}}{q^d_{jt}} &= \frac{D^f_{jt} e^\sigma_t}{D^d_{jt}} \\
\frac{p^f_{jt}}{p^d_{jt}} &= \frac{(\frac{q^f_{jt}}{D^f_{jt}})^{-\frac{1}{\sigma}}}{(\frac{q^d_{jt}}{D^d_{jt}})^{-\frac{1}{\sigma}}} = \frac{1}{e_t}
\end{aligned}
$$

p^f_{jt} is the price a firm charges abroad in foreign currency, therefore we can denote a firm-level price in domestic currency:

$$p_{jt} = e_t p^f_{jt} = p^d_{jt} \tag{4}$$

This property relies on the assumption that the demand elasticity is the same for both domestic and foreign consumers. Under this assumption firms do not price discriminate across markets. The optimal export share η^*_{jt} only depends on the demand shocks and the exchange rate, but not on the total output level. So essentially the firm faces a world-wide demand and charges the same price. Denote $x_{jt} \in \{0, 1\}$ as an indicator of firm j being an exporter or not, with $x_{jt} = 1$ indicating that firm j exports. Define $D_{jt} =$

$D^d_{jt} + (D^f_{jt} e^\sigma_t) \cdot 1(x_{jt} = 1)$, equivalently,

$$D_{jt} = \begin{cases} (D^d_{jt} + D^f_{jt} e^\sigma_t), \text{ if export: } x_{jt} = 1 \\ D^d_{jt}, \text{ if not export: } x_{jt} = 0 \end{cases}$$

The optimal export share implies the revenue for the firm becomes

$$S^{x_{jt}}(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) = (D_{jt})^{\frac{1}{\sigma}} (q_{jt})^{\frac{\sigma-1}{\sigma}}$$

Given the revenue a firm can potentially get by selling to both markets at any given output level, the firm decides whether to export or not and the amount to produce by solving the problem below:

$$\max_{q_{jt}, x_{jt} \in \{0,1\}} S^{x_{jt}}(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) - TVC(A_{jt}, K_{jt}, q_{jt}) - f \cdot 1(x_{jt} = 1)$$

The optimization problem implies the optimal quantity to produce, revenue and total variable cost to be:

$$\begin{aligned} q_{jt} &= \left\{ \frac{\sigma - 1}{\sigma} \frac{\alpha_l}{w} (A_{jt} K^{\alpha_k}_{jt})^{\frac{1}{\alpha_l}} (D_{jt})^{\frac{1}{\sigma}} \right\}^{\frac{1}{\frac{1}{\alpha_l} - \frac{\sigma-1}{\sigma}}} \\ S(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) &= (\frac{\sigma - 1}{\sigma} \frac{\alpha_l}{w})^{c_3} (D_{jt})^{c_2} \left((A_{jt} K^{\alpha_k}_{jt})^{\frac{1}{\alpha_l}} \right)^{c_3} \\ TVC(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) &= w(\frac{\sigma - 1}{\sigma} \frac{\alpha_l}{w})^{1+c_3} (D_{jt})^{c_2} \left((A_{jt} K^{\alpha_k}_{jt})^{\frac{1}{\alpha_l}} \right)^{c_3} \end{aligned}$$

where $c_1 = \frac{1}{\frac{1}{\alpha_l} - \frac{\sigma-1}{\sigma}}$, $c_2 = \frac{1}{\sigma} \frac{1}{\alpha_l} \frac{1}{\frac{1}{\alpha_l} - \frac{\sigma-1}{\sigma}}$,$c_3 = \frac{\sigma-1}{\sigma} \frac{1}{\frac{1}{\alpha_l} - \frac{\sigma-1}{\sigma}}$.The superscript x_{jt} which indicates the export status is omitted, as it is captured in the aggregate demand shock: $D_{jt} = D^d_{jt} + (D^f_{jt} e^\sigma_t) \cdot 1(x_{jt} = 1)$. Note that the productivity and demand shocks, capital enter the revenue and total variable cost function in the same way, thus total variable cost is a fraction of a firm's total revenue:

$$\frac{TVC(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t)}{S(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t)} = \frac{\sigma - 1}{\sigma} \alpha_l \tag{5}$$

Therefore a firm's per-period profit is:

$$\Pi^{x_{jt}}(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) = (1 - \frac{\sigma - 1}{\sigma} \alpha_l) S(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) - f \cdot 1(x_{jt} = 1)$$

Firm j chooses to export if the profit from selling in both market is greater than that from selling in the domestic market alone:

$$\Pi^{x_{jt}=1}(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) - \Pi^{x_{jt}=0}(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) > 0 \implies x_{jt} = 1$$

It's worth noting that export participation is a static choice since exporting involves only per-period fixed cost but no sunk cost by assumption.

2.4 Dynamic Problem

The problem is dynamic because a firm's current investment decision affects its future capital stock and production capacity. The state variables include capital stock K_{jt}, productivity A_{jt}, firm specific demand shocks D^d_{jt}, D^f_{jt}, and the exchange rate e_t. Capital stock K_{jt} is the only endogenous state variable and the rest are exogenous. An incumbent producer in the domestic market chooses the capital investment to maximize the value of continuing operating in the market:

$$\begin{aligned} & V(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) = \\ & \max_{I_{jt}} \Pi(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) - \Lambda(I_{jt}, K_{jt}) \\ & + \frac{1}{1+r} EV(A_{jt+1}, (1-\delta)K_{jt} + I_{jt}, D^d_{jt+1}, D^f_{jt+1}, e_{t+1} | A_{jt}, D^d_{jt}, D^f_{jt}, e_t) \end{aligned} \tag{6}$$

where $K_{jt+1} = (1-\delta)K_{jt} + I_{jt}$. $\Lambda(I_{jt}, K_{jt})$ is the associated capital adjustment costs. The functional form for $\Lambda(I_{jt}, K_{jt})$ is provided in section 2.6. $\frac{1}{1+r}$ is the discount rate for next period's profits. The value function is comprised of the current profit and discounted future profits net of the capital adjustment costs associated with the investment.

Note that export status is not a state variable here because there is no sunk entry cost for new exporters. For simplification the entry and exit into production are not modeled.

2.5 Functional Forms

To solve the model numerically, the log of productivity A_{jt}, idiosyncratic demand shocks D^d_{jt}, D^f_{jt} and real exchange-rate are assumed to follow independent first-order autoregressive processes:

$$
\begin{aligned}
\ln A_{jt} &= m_a + \rho_a \ln A_{jt-1} + \varepsilon^a_{jt} \\
\ln D^d_{jt} &= m_d + \rho_d \ln D^d_{jt} + \varepsilon^d_{jt} \\
\ln D^f_{jt} &= m_f + \rho_f \ln D^f_{jt} + \varepsilon^f_{jt} \\
\ln e_t &= m_e + \rho_e \ln e_{t-1} + \varepsilon^e_t
\end{aligned}
$$

where $\varepsilon^a_{jt} \sim i.i.d.N(0, \sigma^2_{\epsilon^a})$, $(\varepsilon^d_{jt}, \varepsilon^f_{jt}) \sim i.i.d.N(0, (\sigma^2_{\epsilon^d},\ \sigma_{df}\sigma_{\epsilon^d}\sigma_{\epsilon^f};\ \sigma_{df}\sigma_{\epsilon^d}\sigma_{\epsilon^f},\ \sigma^2_{\epsilon^f}\ ))$, $\varepsilon^e_t \sim i.i.d.N(0, \sigma^2_{\epsilon^e})$. σ_{df} allows the innovations to the domestic and foreign demand shocks to be correlated. Given these functional forms, the expected future value $EV(\cdot|A_{jt}, D^d_{jt}, D^f_{jt}, e_t)$ in the value function can be parameterized.

2.6 Capital Adjustment Costs

The evolution of firm j's capital stock follows

$$
K_{jt+1} = (1-\delta)K_{jt} + I_{jt}
$$

where δ is the depreciation rate and I_{jt} is the capital investment. The investment rate, $i_{jt} = \frac{I_{jt}}{K_{jt}}$ can be either positive or negative. There is one-period time-to-build, so investment made at period t becomes effective at period $t+1$.

In addition to the time to build assumption, adjusting the capital stock is costly. The capital adjustment cost function is specified as:

$$
\Lambda(I_{jt}, K_{jt}) = \frac{\lambda_1}{2}\left(\frac{I_{jt}}{K_{jt}}\right)^2 K_{jt} + \lambda_2 1(|\frac{I_{jt}}{K_{jt}}| > 0)K_{jt} + I_{jt}1(I_{jt} > 0) - \lambda_3 I_{jt}1(I_{jt} < 0) \tag{7}
$$

The adjustment costs include a quadratic cost $\frac{\lambda_1}{2}\left(\frac{I_{jt}}{K_{jt}}\right)^2 K_{jt}$ that is usually assumed in traditional investment models, a fixed cost of adjustment λ_2, and transaction costs λ_3 that captures a gap between the buying and selling price of capital. This specification is close to that of Cooper and Haltiwanger (2006).[8] The convex costs dampens the investment responses to shocks and lead to partial adjustment of investment. The fixed cost of adjustment $\lambda_2 K_{jt}$ is independent of the level of investment. It is proportional to the level of capital to eliminate any size effect. Compared with partial adjustment implied by the convex costs, the fixed adjustment costs imply frequent investment inactivity and investment spikes. The price gap

[8] The only difference is that Cooper and Haltiwanger (2006) incoporats an additional type of non-convex adjustment cost that represents a loss of a fraction of the output during the adjustment period. Since their implications are similar to the fixed adjustment costs, I only keep the fixed adjustment costs for simplification.

between purchasing and selling capital would also dampen firms' investment responses to positive productivity or demand shocks, as selling the capital in the future would incur a loss. In addition, the price gap imply that firms will hold on to capital in response to a negative shock.

3 Data

The data used in this paper is a plant-level dataset collected by Departamento Administrativo Nacional de Estadística (DANE). It covers all manufacturing plants with more than ten employees from year 1981 to 1998. However information on exporting is not included for years after 1991, and information on output price is not included for year 1981[9]. For this reason I only use the data from 1982 to 1991. As the focus of the paper is the sales and capital adjustment of an existing plants, I keep a balanced sample and drop the plants that enter or exit the panel in the middle of the sample period. I keep 19 major exporting industries in the Colombian manufacturing sector, as in Roberts and Tybout (1997)[10]. This leaves a total number of 2235 plants for 11 years.

The data set contains plant-level information on each plant including its age, industry classification (four digits SIC), capital stocks, investment flows, employment, expenditure on labor and capital, value of output sold in the domestic market and value of output exported. Each plant's export sales are aggregated across all export markets and we do not observe their destinations and export sales for individual destination. The data also includes a plant-level price index for output and materials. However we do not observe the domestic and foreign output price separately for exporting plants[11]

Plant-level price indices: The plant-level output price indices are constructed by Eslava et al. (2004). Output price indices are constructed using Tornqvist indices. For a plant that produces multiple products, the output price indices are constructed based the weighted average of the growth in prices for all individual products produced by that plant.

[9] The data set used in Eslava et al. (2004) covers the years from 1982 to 1998. It includes price information but not information on export sales. The data set used in Roberts and Tybout (1997) covers the years from 1981 to 1991 which does not have price information. Therefore we merged the two data sets based on plant's industry classification, employment level, energy usage. About 90% of the observations between 1982 and 1991 are matched after the merging.

[10] The 19 industries are: food processing, textiles, clothing, leather products, paper, printing, chemicals, plastic, glass, nonmetal products, iron and steel, metal products, machinery, transportation equipment, and miscellaneous manufacturing.

[11] In the CES model under the assumption that demand elasticities are the same at home and abroad, the foreign price and domestic price collapse into one price, as shown in equation (4) in the model section. This price index provides useful information to separately identify the productivity and demand processes. Also the price responses to shocks reveal how easily firms can adjust their production capacity.

For plant j at time t producing product $h = 1, 2, ..., H$, the weighted average of the growth of price is given by:

$$\Delta P_{jt} = \sum_{h=1}^{H} \bar{s}_{hjt} \Delta \ln(P_{hjt})$$

where

$$\Delta \ln(P_{hjt}) = \ln P_{hjt} - \ln P_{hjt-1}$$

and

$$\bar{s}_{hjt} = \frac{s_{hjt} + s_{hjt-1}}{2}$$

where P_{hjt} and P_{hjt-1} are the prices charges for product h by plant j at time t and $t-1$; s_{hjt} and s_{hjt-1} are the share of product h in plant j's total production for years t and $t-1$. The indices for the level of output prices for each plant j are constructed using the weighted average of the growth of the prices with year 1982 being the base year:

$$\ln P_{jt} = \ln P_{jt-1} + \Delta P_{jt}$$

for $t > 1982$, where $P_{j1982} = 100$. The price levels are obtained by applying an exponential function to the natural log of prices, $P_{jt} = \exp^{\ln P_{jt}}$. Material price indices are similarly constructed based on price and value share of each material used in the production process.

Export Participation, Entry and Exit: The time-series patterns of export participation, export entry and exit among existing domestic producers over the sample period are summarized in Table 1.1. These patterns follow closely the movement in the real exchange rate. From the middle of 1970s until 1982 the Colombian peso appreciated steadily, and then depreciated steadily until 1986. After being stabilized from 1986 to 1989, it appreciate slightly from 1989 to 1990[12]. The fraction of plants that export among existing domestic producers for the major exporting industries fell in the beginning of the 1980s, then started to increase since 1984. Export participation increased greatly in 1990 and 1991 which are 23.8% and 27.7% respectively. The fourth and fifth row of Table 1.1 presents the entry rate (export at t but not t-1) and exit rate (export at t-1 but not t) of exporting among incumbent domestic producers. The export entry rate at year t is the percentage of plants that export at t but not yet t-1, as a fraction of exporting plants at year t. The exit rate is the percentage of plants that export at year t-1 but stop exporting at year t. The enter rate varies from 10.7% to 19.7% during the sampling years. In general for years the exchange-rate

[12] Roberts and Tybout (1997) pointed out the appreciation of the Colombian peso from mid-1970's to 1982 was a response to illegal exports, foreign-capital inflows and a boom in the coffee market. The appreciation of the currency in the 1980's was partly a result of the central-bank currency-market interventions to ease competitive pressure on tradable-goods producers.

is favorable for Colombian exporters, the export enter rate tends to be high and the exit rate tends to be low.

3.1 Patterns of Capital and Labor adjustments

This section presents some basic patterns on how plants dynamically adjust their use of capital and labor which reflect the nature of the underlying adjustment costs. As established in the literature (e.g., Cooper and Haltiwanger (2006)), I find that investment adjustment is lumpy with frequent investment spikes and inaction, and its distribution is asymmetric with few observations of negative investment. Compared with capital adjustment, the adjustment of labor is smoother with more frequent medium-size adjustments. The distribution of labor adjustment is symmetric. Compared with physical capital, labor adjustment is more responsive to shocks. The combined facts suggest that labor is more flexible to be adjusted than physical capital.

The analysis conducted here is similar to Contreras (2008). While Contreras (2008) focuses on factors including capital, labor, materials and energy, here I look at capital and labor inputs only. In addition, the analysis in Contreras (2008) regarding the interrelations between the adjustments for different inputs is conditional on estimates of demand and productivity shocks from Eslava et al. (2004), while here I only look at the unconditional relationships between the factor adjustments.

Distributions of Capital and Labor Adjustments: The distribution for capital and labor growth is shown in Table 1.2. We can see that capital adjustment is lumpy with frequent investment inactions and spikes. This can be seen from the high fraction of observations with investment rate above 20%, and the high fraction of observations with zero or near-zero capital investment. This suggests the existence of fixed cost in adjusting capital. Under fixed adjustment cost, plants would reduce the frequency of adjustment. That implies that they would over-shoot when they do adjust, or simply let the capital depreciate. Compared with the lumpiness of capital adjustment, labor adjustment is relatively smooth, as the proportion of large adjustments is small relative to the proportion of medium-size adjustments.

In addition to the lumpiness of capital adjustment, the capital investment rate distribution also exhibits asymmetry with a very small proportion of negative investment. The asymmetry reflects the irreversibility of capital investment, which can be a result of a low selling price of capital compared with the purchasing price due to a lack of a secondary market. On the other hand, the distribution for labor growth rate is fairy symmetric.

Contemporaneous and Serial Correlations: To illustrate how capital and labor adjustments and sales growth are interrelated, Table 1.3 presents the contemporaneous correlations between capital, labor and total sales growth rate. There is a high positive correlation between labor growth and total sales growth $Corr(\frac{\Delta L_{jt}}{L_{jt}}, \frac{\Delta S_{jt}^{total}}{S_{jt}^{total}})$, which can be due to a high labor adjustment in response to a positive profit shock, as a profit shock would also increase sales. The correlation between sales growth and subsequent capital growth $Corr(\frac{\Delta K_{jt}}{K_{jt}}, \frac{\Delta S_{jt}^{total}}{S_{jt}^{total}})$ is also positive, but smaller than that between labor and total sales growth. It indirectly suggest labor adjustment is more flexible than capital adjustment. The correlation between capital and labor adjustment is slightly positive. This positive correlation can be due to both factors responding to profit shock, but can also be dependent on the adjustment cost that makes firms to adjust both factors together.

Table 1.4 shows the probability of having an investment spike conditional on having an labor growth spike, and vice versa. The results come from a logit estimation. We can see that having a labor adjustment spike increases the probability of having an investment spike, and vice versa. Again the adjustment in both capital and labor together can be due to both factors responding to positive shocks.

The serial correlation of labor, capital and total sales growth are shown in Table 1.5. The serial correlation for total sales growth and labor growth are close and both are slightly negative. If we believe the profit shock follows an autoregression process, then the serial correlation of sales growth would be negative. We would also see negative correlation for the factor growth if the factors adjust perfectly in response to the shocks. The serial correlation for capital growth is slightly positive. It can be a mixed effect of both convex and fixed costs of adjusting capital. The convex cost leads to a positive serial correlation of capital growth as plants' tend to make partial adjustment in capital under convex costs. Table 1.6 looks at the dynamic relationship between capital and labor growth. Having a high labor growth in the previous period have a positive effect on the subsequent-year capital growth, and having a high capital growth also signals a higher labor growth later.

3.2 Capacity Constraints, Domestic and Export Sales Dynamics

After establishing the factor adjustment and exporting patterns, we now turn to explore the interactions between factor adjustments and producers' export and domestic sales dynamics. Below I present key features of the data that characterize the interactions between domestic and export sales, plant-level price and physical capital at the micro-level. First, there is a robust negative correlation between exporting producers' domestic and export sales growth. In particular, the expected growth rate for domestic sales is negative for producers that have experienced a high export sales growth. In addition, the sales substitution[13] and the expansion in the export market is accompanied by an increase in the plant-level output price index. Third, the sales substitution and export expansion is followed by a high level of capital investment. Finally, compared with a strong negative contemporaneous relationship between domestic and export sales growth, the dynamic relationship between domestic and export sales growth is slightly positive but not strong. I discuss each of these features in detail below.

Contemporaneous Correlation between Domestic and Export Sales Growth: The key feature that suggests plants cannot easily adjust their production capacity in the short run is the substitution between exporters' domestic and export sales. Substitution between domestic and foreign sales could happen when plants receive a more favorable demand shock in one market relative to the other and it is costly for plants to adjust their production capacity. The sales substitution across markets is shown by a negative correlation between firms' domestic and export sales growth rate[14]. It can be seen from a simple OLS regression of an exporter's domestic sales growth $\frac{\Delta S_{jt}^{d}}{S_{jt}^{t}}$ on its export sales growth $\frac{\Delta S_{jt}^{f}}{S_{jt}^{t}}$:

$$\frac{\Delta S_{jt}^{d}}{S_{jt}^{total}} = \beta_0 + \beta_1 \frac{\Delta S_{jt}^{f}}{S_{jt}^{total}} + \varepsilon_{jt}$$

The coefficient (standard error in parentheses) $\beta_1 = -0.228(.025^{*})$ is negative and statistically significant. Here export and domestic sales growth are defined as[15]:

$$\begin{aligned}
\frac{\Delta S_{jt}^{f}}{S_{jt}^{total}} &= \frac{S_{jt}^{f} - S_{jt-1}^{f}}{\frac{1}{2}(S_{jt}^{total} + S_{jt-1}^{total})} \\
\frac{\Delta S_{jt}^{d}}{S_{jt}^{total}} &= \frac{S_{jt}^{d} - S_{jt-1}^{d}}{\frac{1}{2}(S_{jt}^{total} + S_{jt-1}^{total})}
\end{aligned}$$

Figure 1 plots the results from a kernel regression of domestic sales growth on export sales growth. It depicts the mean domestic sales growth conditional on plants' export sales growth. We can see that without imposing a linear relationship between the two variable, the negative

[13] A sales substitution is loosely defined as an incidence when an exporter increases its sales in one market and decrease sales in the other.

[14] The focus here is the relationship between domestic and export sales growth, rather than that between domestic and export sales in scale. The latter is positive as usually more productive firms sell more both at home and abroad.

[15] S_{jt}^{f}, S_{jt}^{d},and S_{jt}^{t} indicate a plant's export, domestic and total sales separately. The export sales growth rate for plant j at year t is calculated as the difference of export sales between year t and $t-1$ divided by the mean total sales between year t and $t-1$, and similarly for domestic sales growth. The growth rates for domestic and export sales are both weighted by the total sales so they are comparable.

relationship between domestic and export sales growth is still robust. It shows that plants that expand significantly in the export market reduce their domestic sales even though their total sales grow, suggesting those plants can be capacity constrained. In contrast, plants that contract their export sales increase their domestic sales even though their total sales decline. The conjecture is that these plants suffer a bad demand shock in the foreign market. They temporarily reallocate their output away from the foreign market towards the domestic market because it's costly to reduce the production capacity.

Correlation between Price and Sales Growth: In additional to the sales substitution patterns, changes in the plant-level output price provide further support for those plants either being capacity constrained or having excess capacity. The idea is that if plants are capacity constrained when the level of their output fails to keep up pace with demand, output-price should go up. To the contrary, if plants have excess capacity and output is beyond the market demand, then price should fall. An OLS regression of the price growth rate on export sales growth rate shows a positive correlation:

$$\frac{\Delta p_{jt}}{\bar{p}_{jt}} = \beta_0 + \beta_1 \frac{\Delta S_{jt}^f}{S_{jt}^{total}} + \varepsilon_{jt}$$

The coefficient (standard error in parentheses) $\beta_1 = 0.121(0.029^*)$ is positive and statistically significant. Price growth $\frac{\Delta p_{jt}}{\bar{p}_{jt}}$ is defined as $\frac{\Delta p_{jt}}{\bar{p}_{jt}} = \frac{p_{jt} - p_{jt-1}}{\frac{1}{2}(p_{jt} + p_{jt-1})}$. The way how this plant-level output price indice p_{jt} is constructed is described in data section above.

Figure 2 plots the results from a kernel regression of output price growth on export sales growth. It depicts the expected output-price growth conditional on plants' export sales growth. Again the positive relationship is robust and does not depend on the linearity assumption. An high export sales growth is accompanied by an increase in the output-price. For the plants that expand in the export market and decrease their domestic sales which suggest them being capacity constrained, we also see an increase in the plant-level price. On the contrary, we observe a price decrease for the plants that contract their export sales and increase domestic sales.

The availability of plant-level price indices is potentially useful in separately identifying the effects of heterogeneous productivity and demand shocks. Without establish-level price information much of the existing literature measures output as revenue deflated by a common industry-level price index. Therefore their productivity measures embody both the idiosyncratic demand shifts and efficiency. The ability to measure plant-level prices can help with correcting the measurement errors. Separating efficiency and demand shocks is particularly important for the question of interest in this paper as the source of shocks affects the interrelation of domestic and export sales under factor adjustment costs. While the efficiency shocks lead to a positive correlation of exporting producers' domestic and export sales growth, demand shocks can induce a negative correlation of the two variables under physical capacity constraints.

Table 1.7 explores further whether having a sales substitution have an additional effect on the price growth. The dummy for a sales substitution equals to one if an exporting plant's sales growth is positive for one market and negative for the other market. The idea is to see if having a sales substitution to some extent indicates a plant being capacity constrained and puts an upward pressure on output prices. The second column reports the results of a regression of price growth on export sales growth and also the sales substitution dummy. Conditional on the export sales growth, the effect of having a sales substitution is close to zero and not statistically significant. The third column looked at the effects of total sales growth instead of export sales growth. The effect of total sales growth on price growth is similar to that of export sales growth, and again the effect of having a sales substitution is not significant.

The coefficient for the sales substitution dummy being insignificant, however, is not in contradiction with those plants with sales substitution being capacity constrained. It only states that having sales in both markets moving in opposite direction does not a higher price effect than having domestic and export sales moving in the same direction. This largely depend on the source of the shocks. If plants have sales in both markets grow in respond to positive demand shocks in both markets, we do not expect the price effect to be lower compared with the case where plants have sale grow in one market and fall in the other market.

Sales Growth and Subsequent Capital Growth[16]**:** Plants' adjustment in capital in response to export sales growth is summarized in Figure 3. It plots the results from a kernel regression of subsequent-period capital growth on export sales growth. There is a robust positive relationship between the mean capital growth and export sales growth for exporting plants. The capital growth rate is defined as $GK_{i,t} = \frac{K_{i,t}-K_{i,t-1}}{0.5\cdot(K_{i,t-1}+K_{i,t})}$. The plants that are suggested to be capacity constrained have high capital growth rate $GK_{i,t}$ in the subsequent period. On the contrary, those plants that are believed to have excess capacity, have near zero or negative capital growth rate. The fact that we do not see much negative capital growth rate partly reflects the irreversibility of capital, that is, there is a price gap between

[16] Some studies find investment in advance of exporting, e.g., Bustos (2010). For new exporters that survive their early exporting years, I also find that their is an increase in investment one year prior to and the year of their export entry. But the investment is more substantial during the years after their entry into the export market.

buying and selling the capital. Therefore firms may choose to hold on to instead of selling the capital in response to negative shocks.

Table 1.8 looks at the probability of having a spike in capital growth conditional on export sales growth. It shows the result of estimating a logit model, where the dependent variable is a dummy for having an investment spike defined as $1(\frac{\Delta K_{jt}}{K_{jt}} > 0.20)$, and the independent variable is export sales growth. The logit estimation is to show the comovement between growth in export sales and capital in the subsequent period, which depends on both the exogenous shocks and also the underlying adjustment costs. We can see that the probability of having an investment spike increases when there is a high growth in the plant's export sales.

Dynamic relationship between Domestic and Export Sales Growth: Figure 4 depicts the mean domestic sales growth in the subsequent year $\frac{\Delta S^d_{jt+1}}{S^{total}_{jt}}$ conditional on the current export sales growth $\frac{\Delta S^f_{jt}}{S^{total}_{jt}}$. The relationship is slightly positive but not very strong, comparing with a robust negative contemporaneous relationship between domestic and export sales growth shown in Figure 1. In particular, those plants that substitute their domestic sales towards the foreign market in the previous year, have a faster growth rate of domestic sales than that of an average plant in the following year. This suggests these previously capacity-constrained plants bring up their output by investing in capital.

In summary, the empirical evidence above supports the argument that the inability for plants to freely adjust their production capacity in the short run induces substitution behavior between plants' domestic and export sales, as well as the corresponding output price changes. It also shows that plants adjust their production capacity through capital investment over time, which leads to a different dynamic correlation between domestic and export sales growth compared with their contemporaneous correlation.

4 Quantitative Analysis

4.1 Fitting the Model to Data

In fitting the model to data, I calibrate the parameters of the model to replicate features of Colombian micro data. First, The real-exchange rate process is estimated using the real exchange-rate series. Second, the production function parameters are calibrated based on the wage share of firms. I also fix some parameters at values reported by previous studies. Finally, the remaining parameters are estimated to match a set of moments based on firm-level behavior.

4.1.1 Pre-determined parameters

Table 1.9 summarizes the parameters that are set or estimated without solving the model. Some standard parameters are fixed at values reported by previous studies. First, the real borrowing rate r is set to be 0.15 (Bond et al, forthcoming). The depreciation rate of capital δ is set to be 7%. The elasticity of substitution is σ is set to be 3.5, which is within the range that is typical of the literature. The mean of log productivity is normalized to be 0.

The coefficients for the real exchange-rate process is obtained from Das et al (2007), where they fit an AR(1) process to the log of the real effective exchange-rate series for the Colombian peso, 1968-1992. The coefficients (standard errors in parentheses) are $m_e = 0.549(0.429)$, $\rho_e = 0.883(0.094)$, and $\sigma^2_{\epsilon^e} = 0.0043$. The exchange rate parameters are treated as fixed in solving the model to estimate the remaining the parameters.

The labor share α_l in the production function is determined based on the equation which states that the wage cost is a fixed share of the total revenue: $\frac{TVC_{jt}}{R_{jt}} = \frac{\sigma-1}{\sigma}\alpha_l$. Given that the mean wage cost share is 0.51 in the Colombian micro-data[17], and σ is set to be 3.5, we can back out the labor share α_l to be 0.72. The capital share is determined by assuming constant return to scale, therefore $\alpha_k = 1 - \alpha_l = 0.28$ .The constant term $\frac{\sigma-1}{\sigma}\frac{\alpha_l}{w}$ that appears in the revenue function, is normalized to be 1.

4.1.2 Remaining Parameters

The remaining parameters of interest are estimated using a simulated method of moments approach (a description of the computation algorithm is provided in the appendix). Thirteen parameters remain to be determined: parameters that govern the evolution of the idiosyncratic domestic and foreign demand shocks: m_d, ρ_d, σ_{ϵ^d} and m_f, ρ_f, $\sigma_{\epsilon^f}, \sigma_{df}$, coefficients for the log productivity process: ρ_a and σ_{ϵ^a}, f, and parameters that govern the capital adjustment cost: the coefficient for the quadratic adjustment costs λ_1, coefficient for the fixed adjustment cost λ_2, and the selling price for investment λ_3. Fitting the model to the data involves estimating the parameters to fit the following thirteen targets (listed in Table 1.10): fraction of plants that export, export turnover rate, mean export-to-total-sales ratio, new exporter survival rate, correlation between export and domestic sales growth for all continuing exporters, correlation between current export sales growth and subsequent domestic sales growth, correlation between export sales and price growth, autocorrelation of plants' log domestic sales, autocorrelation of log total sales, fraction of plants with investment spike, fraction of plants with investment inaction, fraction of plants with negative investment, and the autocorrelation of plants' investment rate.

[17] In calculating wage cost share, I use the value added instead of total sales.

While there is no one-to-one mapping between individual parameters and individual statistics, certain statistics respond more to particular parameters and thus help to identify these parameters. First, identification of the parameters of the capital adjustment costs function λ_1, λ_2 and λ_3 mainly depend on the investment and capital growth patterns at the plant level. These parameters directly affect the distribution of capital growth rate. The selling price for capital, λ_3, affects the fraction of plants with negative investment rate. High values of the coefficient for fixed adjustment costs, λ_2, creates investment spikes and inaction at the plant level. Instead, if the convex adjustment costs governed by λ_1 dominates, there is more small adjustment of capital and less investment spikes and inaction. Therefore the fraction of plants with investment spikes, investment inaction and negative investment rate are informative. The auto-correlation of investment rate $Corr\left(i_{jt}, i_{jt-1}\right)$ is sensitive to the type of adjustment cost. In the absence of capital adjustment costs, the autocorrelation of investment rate is negative because of the AR(1) process of productivity and demand shocks. Under convex adjustment cost, plants adjust capital partially and it leads to a positive investment autocorrelation. It worth noting the distribution and persistence of investment rate also depend on the exogenous shock processes for demand and productivity.

Second, there are parameters that governs the demand ρ_d, σ_{ϵ^d} and ρ_f, σ_{ϵ^f}, σ_{df}, and those govern the productivity processes ρ_a and σ_{ϵ^a}. One statistic that is sensitive to these parameters is the correlation between domestic and export sales growth for continuing exporters $\mathrm{Corr}(\frac{\Delta S^f_{jt}}{S^t_{jt}}, \frac{\Delta S^d_{jt}}{S^t_{jt}})$. Productivity growth drives up sales in both the domestic and foreign markets, which leads to a positive $Corr(\frac{\Delta S^f_{jt}}{S^t_{jt}}, \frac{\Delta S^d_{jt}}{S^t_{jt}})$. On the contrary, demand growth could generate negative correlation between domestic and foreign sales growth when plants cannot freely adjust their production capacity. In addition, the correlation between plant-level price index and sales growth further helps to separate the demand and productivity process. This is because when a plant receives a positive productivity shock, its sales go up and price goes down as production cost falls. On the contrary, if a plant receives a positive demand shock, both sales and price are driven up. The target moment I use is the correlation between export sales growth and price growth $Corr(\frac{\Delta S^f_{jt}}{S^t_{jt}}, \frac{\Delta p_{jt}}{p_{jt}})$. A positive correlation between sales and price growth gives more weight to demand variation, while a negative one favors productivity variation. The autocorrelation for log domestic sales $\mathrm{Corr}(\log S^d_{jt}, \log S^d_{jt+1})$, autocorrelation for log total sales $\mathrm{Corr}(\log S^t_{jt}, \log S^t_{jt+1})$ are also informative about the persistence of demand and productivity processes.

Finally, the fraction of firms that exports is very responsive to fixed exporting cost f: a lower fixed exporting cost encourages more firms to export. The mean export-to-total-sales ratio is very responsive to the drift of the log domestic and foreign demand m_d and m_f.

A higher $\frac{m_f}{m_d}$ implies a higher export share for exporting firms. Export turn-over rate and survival rate for new exporters respond to the persistence of the productivity and demand shocks: a high persistence of the shocks leads to low export turn-over rate and high survival rate for new exporters.

Table 1.10 reports the data-based statistics that the model targets to match, and their model-based simulated counterparts. The simulated model does a good job in matching the correlation between the domestic and export sales growth for continuing exporters, which represents the short-run trade-off between domestic and export sales when firms are capacity constrained. It captures the autocorrelation of log domestic sales and log total sales. It also fits well the fraction of plants with investment inaction and spikes.

It is also worth noting that a few moments are not matched very precisely. First, there is slightly higher export turn-over rate and lower survival rate for new exporter in the simulated model than in the data. This potentially can be improved by introducing sunk export entry cost for new exporters. Second, the export-sales ratio in the model is also slightly over-predicted. This is because in the data there are a lot of firms exporting a very small share of their output (less than 1 percent) which is not captured in the model. The correlation between export growth and price growth, and the correlation between current export sales growth and the subsequent domestic sales growth are also slightly over-predicted in the model. Finally, the fraction of plants with negative investment rate is higher in the model than that in the data.[18]

Table 1.11 reports the parameters associated with the estimation. The coefficients for the adjustment costs imply both convex and fixed adjustment costs exist, and there is sizable gap between buying and selling the capital. These parameters are close to what Cooper and Haltiwanger (2006) obtain in calibrating their model to the U.S. economy. The implied variance suggests demand fluctuation dominates productivity fluctuation in generating plants' sales variation. This is consistent with the sales substitution patterns between domestic and exporter sales among exporters.

4.2 Simulated Effect of a Devaluation

I simulate firms' responses to a change in the exchange-rate process that depreciates the steady state value of the peso by 20%.[19] It is implemented by increasing the intercept of

[18] While this statistics is affected by the price gap between purchasing and selling the capital, it is also affected by the fraction of plants that receive negative productivity and demand shocks.

[19] Alternatively we can look at reduction of trade costs or increase in foreign demand. These policies would have similar effects as changes in the exchange-rate process, as the model assumes that the real exchange rate only affects the effective price paid by foreign consumers and thus foreign demand. Since the model does not separately identify the trade cost from foreign demand, reduction in trade cost and increase in foreign

the log exchange rate process m_e from 0.549 to 0.572, while keeping the persistence and variance of the innovation term unchanged. The regime shifts take place in the middle of the sample period t_m. There are four scenarios: (I): Correctly-perceived temporary devaluation: the currency devaluation lasts only one period and firms have the correct expectations. (II): Incorrectly-perceived temporary devaluation: the currency devaluation lasts only one period, but firms incorrectly perceive it as permanent. Firms correct their expectation in the following period $t_m + 1$. (III): Incorrectly-perceived permanent devaluation: the currency devaluation is permanent, but firms thought it lasts only one period. They correct their expectation in the subsequent period $t_m + 1$. (IV): Correctly-perceived permanent devaluation: the currency devaluation is permanent, and firms have the right expectations. Under all four scenarios the shift of exchange-rate regime was not expected before it takes place at period t_m.

Short-run and Long-run Exchange Rate Elasticity of Exports

How exports respond to the exchange rate devaluation is of particular interest to this paper. The importance of capital adjustment costs in affecting the export responses is reflected by different exchange rate elasticities of exports in the short run and long run. Its importance is also seen in how long it takes to have the export responses fully realized. Here I only focus on scenario IV where the devaluation is permanent and firms have the correct expectations. The other three scenarios are of more interest when we look at the transitional dynamics of sales, investment and output price in the following section.

Figure 5 summarizes the transition of the accumulated aggregate export sales following the permanent shift of the exchange-rate regime. I focus on the growth rate of the accumulated aggregate export sales after the devaluation, relative to that in the base case.

$$\widehat{S}_{\widetilde{t}} = \frac{\left(\sum_{t=t_m}^{\widetilde{t}} S_t^f\right)^{\text{counter-factual}} - \left(\sum_{t=t_m}^{\widetilde{t}} S_t^f\right)^{\text{base}}}{\left(\sum_{t=t_m}^{\widetilde{t}} S_t^f\right)^{\text{base}}}$$

where $\sum_{t=t_m}^{\widetilde{t}} S_t^f$, the accumulated aggregate export sales at time $\widetilde{t}$, is the sum of aggregate export sales from the devaluation period t_m to $\widetilde{t}$: $\sum_{t=t_m}^{\widetilde{t}} S_t^f = \sum_{t=t_m}^{\widetilde{t}} \sum_j S_{jt}^f$. While the immediate export response is big, there is still substantial adjustments in the subsequent years. The accumulated aggregate export sales increase by 70% right after the devaluation takes place at t_m. The growth rate keeps rising over time, particularly during the first two

demand are equivalent.

or three years after the devaluation. It stabilizes after about five years. The accumulated aggregate export sales has doubled 5 years after the permanent devaluation.

Figure 6 shows that the exchange rate elasticity of exports has increased from 2.63 at t_m to 3.46 five years after.[20][21] Similarly, the exchange rate elasticity of exports rises fast during the first three years after the devaluation takes place, and it stabilizes about five years after. The exchange rate elasticity of exports at $\widetilde{t}$ is calculated as the change of the log of accumulated export sales from the base case to after the devaluation, compared the base case, divided by the change in the log real exchange rate.

$$\xi^{\widetilde{t}} = \frac{\left(\ln \sum_{t=t_m}^{\widetilde{t}} S_t^f\right)^{\text{counter-factual}} - \left(\ln \sum_{t=t_m}^{\widetilde{t}} S_t^f\right)^{\text{base}}}{(\ln e)^{\text{counter-factual}} - (\ln e)^{\text{base}}}$$

Transitional Dynamics of Investment, Output Price, Domestic and Export sales

The effects on domestic and export sales, investment and prices under each scenario, relative to a base case of no regime change, are summarized in Table 1.12. Table 1.12 focuses on the adjustments on the intensive margin (among incumbents), so it limits to the exporters that export in period t_m, t_m+1,t_m+2 in the base case. I compare the aggregate domestic sales for those incumbent exporters in three years following the devaluation, relative to the base case weighted by the average aggregate total sales. The change in investment is weighted by the aggregate capital. In terms of the price change after the devaluation, I look at the average price change among the incumbent exporters. Note that here the changes are year-by-year, not accumulative. The changes in domestic and foreign sales, investment and price for each scenario, in each of the three years following in the experimental devaluation

[20] The short-run exchange rate elasticity of exports are the same in other three scenarios, regardless the duration of the devaluation and firms' expectations. When the devaluation is temporary and being correctly perceived (scenario I), the long-run exchange rate elasticity of exports converges to zero because there is no export growth after period t_m.

[21] Here I look at export sales instead of quantity. Since there is complete exchange-rate pass through assumed in the model, the long-run exchange rate elasticity of export quantity among export incumbents should converge to the demand elasticity.

are defined as:

$$
\begin{aligned}
\frac{\Delta S_t^d}{\overline{S_t^{total}}} &= \frac{\sum_{j\in E}(S_{jt}^d)^{\text{counter-factual}} - \sum_{j\in E}(S_{jt}^d)^{\text{base}}}{0.5\left(\sum_{j\in E}(S_{jt}^{total})^{\text{counter-factual}} + \sum_{j\in E}(S_{jt}^{total})^{\text{base}}\right)} \\
\frac{\Delta S_t^f}{\overline{S_t^{total}}} &= \frac{\left(\sum_{j\in E} S_{jt}^f\right)^{\text{counter-factual}} - \left(\sum_{j\in E} S_{jt}^f\right)^{\text{base}}}{0.5\left(\left(\sum_{j\in E} S_{jt}^{total}\right)^{\text{counter-factual}} + \left(\sum_{j\in E} S_{jt}^{total}\right)^{\text{base}}\right)} \\
\frac{\Delta I_t}{\overline{K_t}} &= \frac{\left(\sum_{j\in E} I_{jt}\right)^{\text{counter-factual}} - \left(\sum_{j\in E} I_{jt}\right)^{\text{base}}}{0.5\left(\left(\sum_{j\in E} K_{jt}\right)^{\text{counter-factual}} + \left(\sum_{j\in E} K_{jt}\right)^{\text{base}}\right)} \\
\frac{\Delta p_t}{\overline{p_t}} &= \frac{1}{N(E)}\sum_{j\in E}\frac{(p_{jt})^{\text{counter-factual}} - (p_{jt})^{\text{base}}}{0.5\left((p_{jt})^{\text{counter-factual}} + (p_{jt})^{\text{base}}\right)}
\end{aligned}
$$

In all four scenarios, at period t_m when the devaluation takes place, incumbent exporters substitute their domestic sales towards export sales and price goes up. The aggregate export sales for the incumbent exporters increase by 18.3% compared with that the base case, while domestic sales decrease by 3.6%.The mean price has increased by 6.0%. Foreign demand increases as the domestic-produced products become cheaper for foreign consumers after the devaluation. As the marginal production cost increases on total output given the fixed amount of capital in the short run, firms sacrifice their sales at home to meet up the increased demand in the foreign market. It induces welfare losses for domestic consumers as price goes up.

However, firms' investment responses $\frac{\Delta I_t}{\overline{K_t}}$ at t_m differ depending on their perception about the duration of the devaluation. In scenario II and IV where firms expect the exchange-rate process to be permanent, firms expand their production capacity in response: the aggregate investment for the incumbent exporters increase by 25.2% as a share of their total capital. In contrary, in scenario I and IV where firms expect the exchange-rate process to move back to the base case in the following period, there are no changes in the investment level for the incumbent exporters compared with the base case.

The corresponding investment adjustment at t_m in each scenario directly impact firms' sales and output prices in the subsequent periods, especially for scenario II and III where there is misperception about the duration of the devaluation. In scenario II, the incumbent exporters over-invest in capital at t_m as they thought the devaluation is permanent while it lasts only one period. Therefore in the subsequent period $t_m + 1$ as foreign demand falls back to the level of the base case, firms have excess production capacity. As a result, price falls by 6.3%, and both domestic and export sales are higher than their counterparts in the base case. The aggregate investment decrease by 8.2% at period $t_m + 1$, showing that they are reducing their excess capacity. The investment and price reduction, as well as the sales rise continue at period $t_m + 2$, but the magnitude is smaller. Note that the size of capital reduction in the subsequent periods is lower than the capital expansion made in period t_m, as firms tend to hold up to their capital in response to a negative shock because of the price gap between purchasing and selling the capital. The increased capital adjustment costs induced by over-investing and downsizing the capital afterward cause profit reductions for these exporters.

In contrast to the over-investment in capital in scenario II, in scenario III the incumbent exporters under-invest in their capital as they mistakenly expect the devaluation to be temporary while it is actually permanent. As a result, the substitution from domestic sales towards export sales, and the price rise are prolonged. Firms remain to be capacity constrained in period t_m+1: domestic sales decrease by 3.4% at period t_m+1 relative to the base case. Output prices keep rising as output continues to be falling behind the demand: the mean price for the incumbent exporters' products rise by 6.1%. This increased price leads to welfare losses for domestic consumers. As firms correct their expectations about the duration of the devaluation in period $t_m + 1$, they increase their capital investment. As a result, in period t_m+2, they bring back their domestic sales and price stops rising: domestic sales increase by 2.8% in period t_m+2. The inadequate capital investment induced by firms' misperception causes profits reductions for firms and welfare losses for domestic consumers.

When firms correctly perceive the permanent currency devaluation in scenario IV, the substitution away from domestic sales for export sales is temporary. After they increase the capital investment at period t_m, the incumbent exporters bring back their domestic sales in period $t_m + 1$: domestic sales increase by 1.9%. There is a greater response in export sales: aggregate export sales increase by 25.3% in $t_m + 1$, which shows that the frictions in adjusting firms' production capacity generate lagged responses Price falls slightly and aggregate investment in $t_m + 1$ increase by 8.1% suggesting firms make partial adjustments in capital. In period $t_m + 2$ sales continue to grow, but in a smaller magnitude. At last, in scenario I where firms correctly perceive the temporary devaluation, the economy moves back to the base case after the temporary sales substitution and price rise at period t_m.

5 Conclusion

In this paper I develop and estimate a dynamic structural model of export dynamics with capacity constraints and endogenous investment. The model features increasing marginal production cost and capital adjustment costs. The short-run capacity constraints imply that exporters face a trade-off between domestic and export sales in response to external demand shocks. It also implies that firms' export sales growth led by positive foreign demand shocks causes a rise in output price and induces welfare losses for domestic consumers. As firms can adjust their production capacity through capital investment over time, the long-run responses differ from the short-run responses.

Using a simulated method of moments approach, I fit the model to plant-level data for Colombian manufacturing industries. The estimates suggest that the idiosyncratic demand shocks dominate productivity shocks in generating firms' sales growth. The estimates also show that both convex and fixed capital adjustment costs exist, and there is substantial price difference in purchasing and selling physical capital.

The resulting model is used to conduct policy experiments of changes in the exchange-rate regime. I quantify firms' responses in different scenarios where the shift in the exchange-rate regime can either be temporary or permanent, and firms may or may not accurately anticipate the duration of the exchange-rate regime shift. The results show that incorporating capital adjustment costs is empirically important. It takes more than five years for firms to fully adjust to a permanent change of the exchange-rate process that depreciates the steady state value of the peso by 20%. The long-run and short-run export responses differ: the long-run exchange rate elasticity of exports is 30% higher than that in the short run.

The fact that there are costs in adjusting capital also makes expectations matter. In the short run, firms' responses are the same regardless of the expectations and the duration of the policy: incumbent exporters sacrifice their domestic sales to meet up the increased foreign demand after a devaluation, and output prices goes up. However investment responses differ in different scenarios and directly impact firms' sales growth in the long run: (1) when the exchange-rate regime shift is permanent but firms thought it is temporary, exporters under-invest in their capital and the substitution of domestic sales for export sales is prolonged. Firms incur profit losses because of the increased marginal cost caused by insufficient capital investment. Domestic consumers also incur losses because of the prolonged periods of high price. (2) When the regime shift is temporary but firms inaccurately anticipated it to be permanent, exporters over-invest in capital and suffer reductions in profit due to increased capital adjustment costs induced by over-investing and downsizing the capital afterward.

6 Appendix: Numerical Solution Algorithm

This appendix describes the computational details of the algorithm used in the estimation. Denote Θ as the vector of parameters to be estimated. The estimation follows the following routine:

(1) For a given value of Θ, solve the dynamic problem of firms, captured by the value function described in section 2.4. This step yields the value and policy functions for the firms.

(2) Using the policy functions, simulate the decisions for a panel of S firms for T periods. Calculate a set of moments from the simulated data.

(3) Update Θ based on the distance between the simulated moments and the data moments.

Step 1. To solve the Bellman equation below,

$$\begin{aligned} & V(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) \\ = \; & \max_{I_{jt}} \Pi(A_{jt}, K_{jt}, D^d_{jt}, D^f_{jt}, e_t) - \Lambda(I_{jt}, K_{jt}) \\ & + \frac{1}{1+r} EV(A_{jt+1}, (1-\delta)K_{jt} + I_{jt}, D^d_{jt+1}, D^f_{jt+1}, e_{t+1} | A_{jt}, D^d_{jt}, D^f_{jt}, e_t) \end{aligned}$$

first I use Tauchen's method to discretize the state space for the continuous state variables including productivity A_{jt}, capital K_{jt}, domestic and foreign demand shocks D^d_{jt}, D^f_{jt} and exchange rate e_t. Following section 2.3, I compute the per-period revenue, output and export choices at each state in the grid. Capital investment is the only dynamic choice. It is determined as a firm maximizes the sum of its current and discounted future profits. The value function is iterated, and it stops when a certain convergence criterion is met.

Step 2. Using the policy functions from step 1, I simulate the decisions for a panel of 2000 firms for 20 periods. Firms' idiosyncratic productivity and demand shocks are simulated following the specified AR(1) processes, and mapped to the grids of the state space respectively. The shocks in the initial period are drawn from the stead-state distribution implied by the AR(1) processes. Firms' decisions follow the policy functions described in step 1. The moments specified in Table 1.10 are calculated from the simulated data. The first 10 periods are considered as burn-in periods and not used to calculate the data moments. The moments depend on Θ in a nonlinear way.

Step 3. Steps 1 and 2 together generate the moments of interest for any given Θ. In step 3, Θ is updated to minimize a weighted distance between the data moments and the simulated moments. The minimization is performed using the genetic algorithm.

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Figure 1: Comtemporaneous Correlation between Domestic and Export Sales Growth

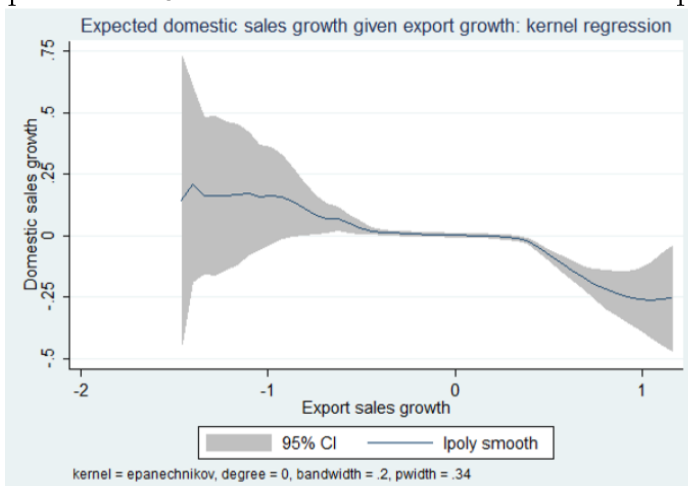


Figure 2: Comtemporaneous Correlation between Price and Export Sales Growth

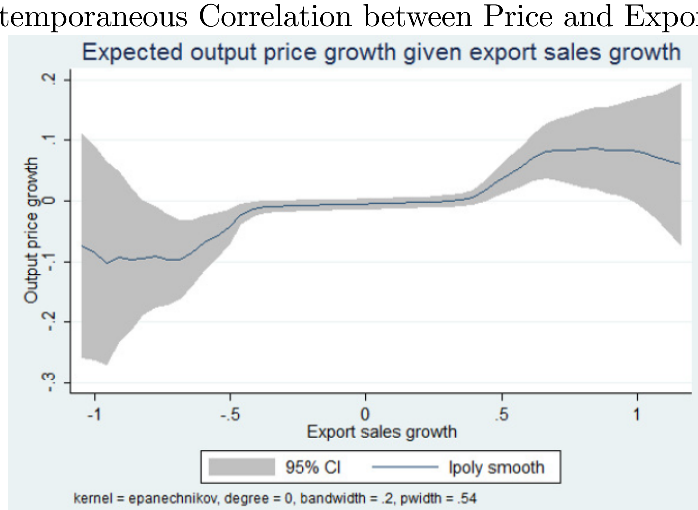


Figure 3: Export Sales Growth and Subsequent Capital Growth

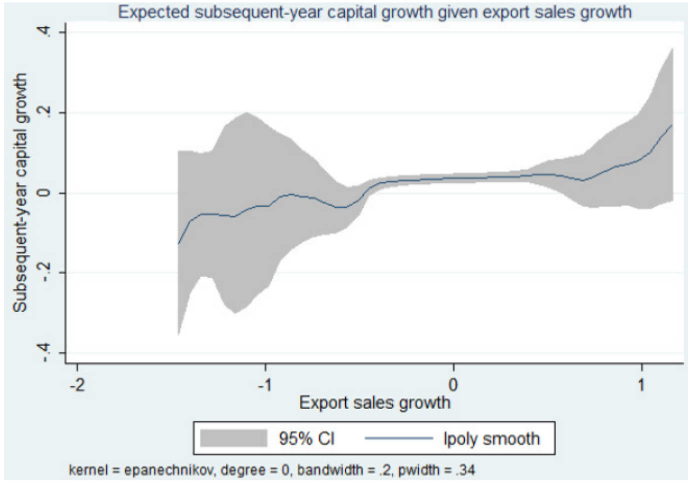
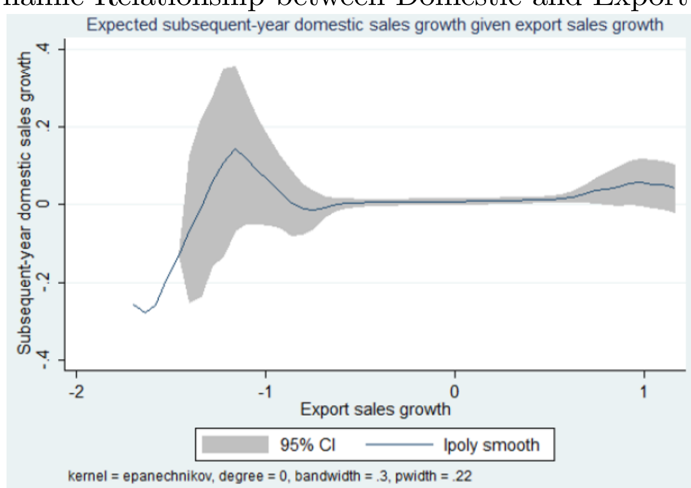


Figure 4: Dynamic Relationship between Domestic and Export Sales Growth



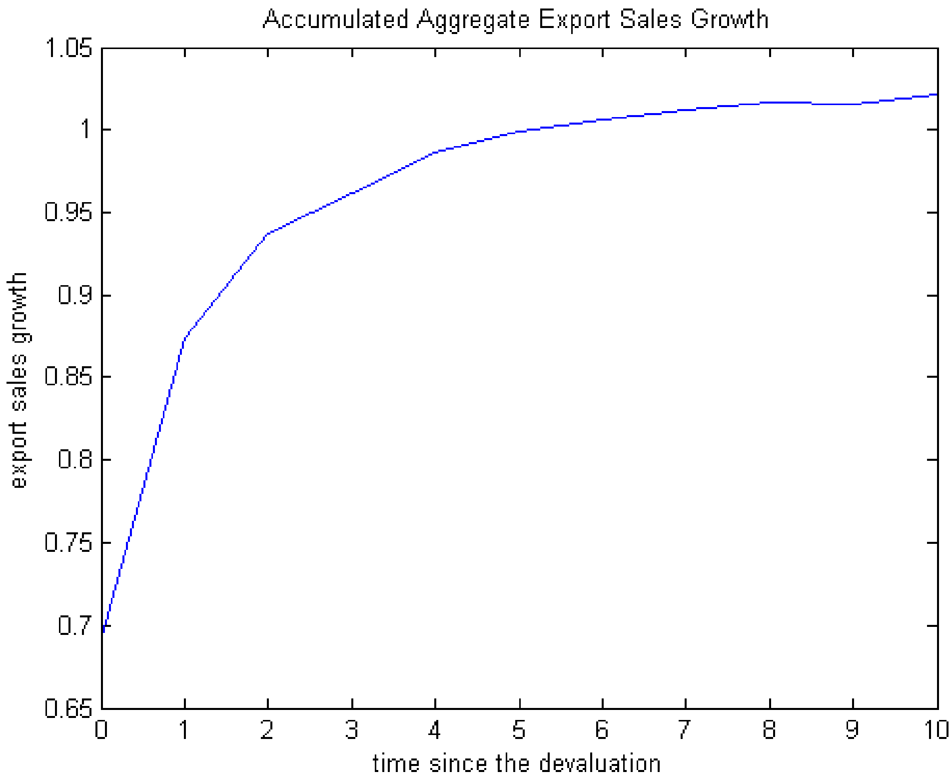


Figure5: Growth Rate of Accumulate Aggregate Export Sales

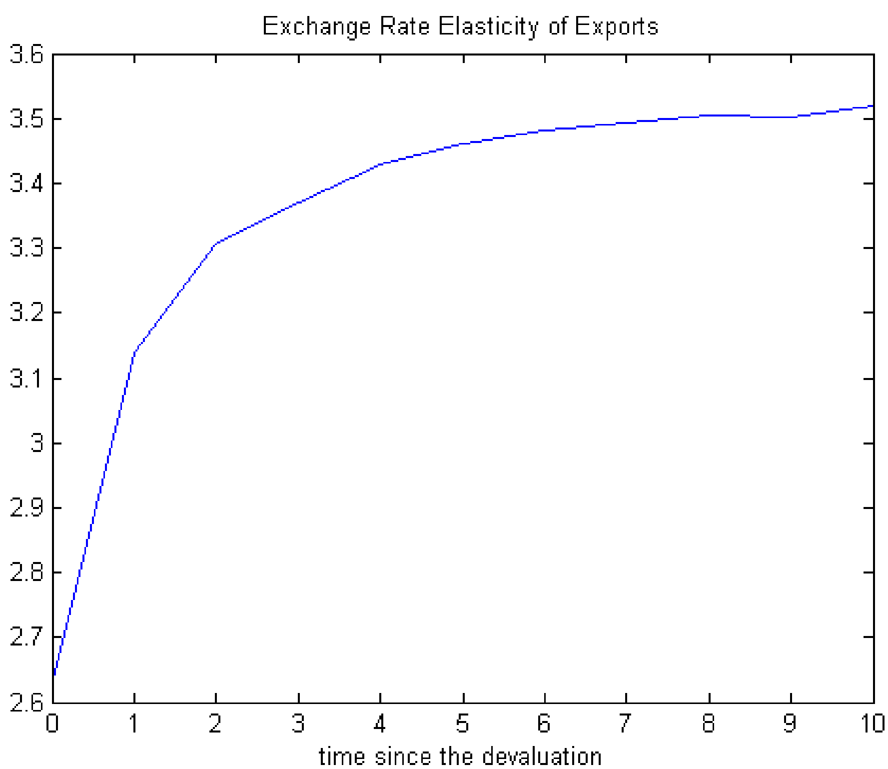


Figure 6: Short-run and Long-run Exchange Rate Elasticity of Exports

Table 1.1: Time Series Patters of Export Participation, Entry and Exit

year	export intensity	%exporting plants	entry rate	exit rate	real exchange rate†
81	0.167				84.0
82	0.168	0.176	0.107	0.148	79.5
83	0.148	0.172	0.128	0.155	80.5
84	0.142	0.175	0.146	0.125	89.8
85	0.154	0.187	0.182	0.117	102.2
86	0.157	0.194	0.147	0.111	113.6
87	0.163	0.191	0.121	0.136	113.7
88	0.172	0.198	0.129	0.095	112.3
89	0.189	0.209	0.145	0.092	115.3
90	0.193	0.238	0.171	0.053	127.2
91	0.194	0.277	0.197	0.055	121.1

† :The real effective exchange rate index use 1975 as the base year (1975=100). An increase in the index corresponds to a devaluation of the Colombian peso. Source: Roberts and Tybout (1997).

Table 1.2: Distribution of factor adjustment (percentage rate)

Variable		$\frac{\Delta K_{jt}}{K_{jt}}$	$\frac{I_{jt}}{K_{jt}}$	$\frac{\Delta L_{jt}}{L_{jt}}$
inaction	(y=0)		25.9	13.1
	abs(y)<0.01		30.1	20.0
positive spike (y>20%)		30.1	35.8	11.7
negative spike (y<-20%)		2.70	1.78	11.6
positive(y>0)		41.1	68.8	46.4
negative (y<0)		58.9	5.34	40.4
observations		19892	22207	22332

To get the same share of observations with investment inaction, the interval for capital growth rate is -0.07

Table 1.3: Contemporaneous Correlations in Factor and Sales Adjustment

Variable	$\frac{\Delta K_{jt}}{K_{jt}}$	$\frac{\Delta L_{jt}}{L_{jt}}$	$\frac{\Delta S^{total}_{jt}}{S^{total}_{jt}}$
$\frac{\Delta K_{jt}}{K_{jt}}$	1	0.061	0.093
$\frac{\Delta L_{jt}}{L_{jt}}$		1	0.223
$\frac{\Delta S^{total}_{jt-1}}{S^{total}_{jt-1}}$			1

Table 1.4: Prob of Factor Inaction/spike conditional on Inaction/Spike on another factor

Variable	P(Investment Spike)	P(labor growth spike)
investment spike		0.510^{**} (0.052)
labor growth spike	0.509^{**} (0.051)	
Observations	20115	20115

Table 1.5: Auto-Correlations in Factor and Sales Adjustment

Variable	$\frac{\Delta K_{jt}}{K_{jt}}$	$\frac{\Delta L_{jt}}{L_{jt}}$	$\frac{\Delta S_{jt}^{total}}{S_{jt}^{total}}$
$\frac{\Delta K_{jt-1}}{K_{jt-1}}$	0.021		
$\frac{\Delta L_{jt}}{L_{jt}}$		-0.121	
$\frac{\Delta S_{jt}^{total}}{S_{jt}^{total}}$			-0.103

Table 1.6: Dynamic Relation in Factor Adjustment

Variable	$\frac{\Delta K_{jt}}{K_{jt}}$	$\frac{\Delta L_{jt}}{L_{jt}}$
$\frac{\Delta K_{jt-1}}{K_{jt_{-1}}}$	0.017^{**} (0.007)	0.027^{**} (0.005)
$\frac{\Delta L_{jt-1}}{L_{jt-1}}$	0.072^{**} (0.009)	-0.121^{**} (0.007)
Observations	20115	20115

Table 1.7: Effects of Sales Growth on Price growth

Variable	Price growth ($\frac{\Delta p_{jt}}{\overline{p}_{jt}}$)	Price growth ($\frac{\Delta p_{jt}}{\overline{p}_{jt}}$)	Price growth ($\frac{\Delta p_{jt}}{\overline{p}_{jt}}$)
$\frac{\Delta S^f_{jt}}{S^{total}_{jt}}$: Export sales growth	0.114^{**} (0.008)	0.115^{**} (0.019)	
Dummy for sales substitution $1(\frac{\Delta S^d_{jt}}{S^{total}_{jt}}\frac{\Delta S^f_{jt}}{S^{total}_{jt}} < 0)$		-0.011 (0.006)	-0.0002 (0.008)
$\frac{\Delta S^{total}_{jt}}{S^{total}_{jt}}$: Total sales growth			0.120^{**} (0.013)
Observation	3767	3767	3767

Table 1.8: Probability of Investment Spike Conditional on Export Growth

Variable	P(Investment Spike) $1(\frac{\Delta K_{jt}}{\overline{K}_{jt}} > 0.20)$	P(Investment Spike) $1(\frac{\Delta K_{jt}}{\overline{K}_{jt}} > 0.20)$
$\frac{\Delta S^f_{jt}}{S^{total}_{jt}}$: Export sales growth	0.608^{**} (0.228)	0.615^{**} (0.229)
observations	3767	3767

Table 1.9: Parameters set without solving the model

Parameter	Description	Value
α_k	capital share in production function	0.28
α_l	labor share in production function	0.72
σ	elasticity of substitution	3.5
m_a	intercept of log productivity process	0
m_e	intercept of log exchange-rate process	0.549
ρ_e	persistence of log exchange-rate process	0.883
$\sigma^2_{\epsilon^e}$	variance of innovation of log exchange-rate	0.0043

Table 1.10: Data-based versus Simulated Moments†

Moment	Data	Model	Moment	Data	Model
Fraction of plants that export	0.20	0.19	$Corr\,(i_{j,t}, i_{j,t-1})^{\ddagger}$	0.02	0.09
Export turnover rate	0.14	0.27	investment spike: $\%(i_{j,t}>0.4)^{\star}$	0.23	0.19
Export-sales ratio	0.21	0.29	investment inaction: $\%(\lvert i_{j,t}\rvert<0.03)$	0.36	0.39
New exporter survival rate	0.65	0.59	negative investment: $\%(i_{j,t}<-0.03)$	0.05	0.17
$\text{Corr}(\frac{\Delta S^f_{jt}}{S^{total}_{jt}}, \frac{\Delta S^d_{jt}}{S^{total}_{jt}})\vert_{\text{exporters}^*}$	-0.15	-0.14			
$\text{Corr}(\frac{\Delta S^f_{jt}}{S^{total}_{jt}}, \frac{\Delta S^d_{jt+1}}{S^{total}_{jt+1}})\vert_{\text{exporters}^*}$	0.06	0.15	$\text{Corr}(\log S^d_{jt}, \log S^d_{jt+1})$	0.93	0.94
$\text{Corr}(\frac{\Delta S^f_{jt}}{S^{total}_{jt}}, \frac{\Delta p_{jt}}{p_{jt}})\vert_{\text{exporters}^*}$	0.12	0.22	$\text{Corr}(\log S^{total}_{jt}, \log S^{total}_{jt+1})$	0.97	0.95

†: the metric for model fit is $\left\|M^{data}-M^{simulated}\right\| / \left\|M^{data}\right\|$ =0.162, where M^{data} is the vector of data-based moments, $M^{simulated}$ is the vector of simulated moments, and $\|\cdot\|$ is the Euclidean distance norm.

*: exporters include those that export at both period t and period $t+1$.

‡: investment rate $i_{j,t} = I_{jt}/K_{jt}$, where I_{jt}, K_{jt} are the investment and capital level at time t.

⋆: the moment is the fraction of plant-year observations with investment rate greater than 40%.

Table 1.11: Estimated Parameter Values

Parameter	Description	Value
m_d	intercept of log domestic demand	2.40
ρ_d	persistence of log domestic demand	0.87
σ_{ϵ^d}	std of innovation of log domestic demand	0.65
m_f	intercept of log foreign demand	-3.47
ρ_f	persistence of log foreign demand	0.89
σ_{ϵ^f}	std of innovation of log foreign demand	1.50
σ_{df}	correlation for innovations of log domestic and foreign demand	0.10
ρ_a	persistence of log productivity	0.88
σ_{ϵ^a}	std of innovation of log productivity	0.16
f	export fixed cost	1.6
λ_1	coefficient on convex adjustment costs	0.002
λ_2	coefficient on fixed adjustment costs	0.002
λ_3	selling price of investment	0.80

Table 1.12: Effects of a devaluation for incumbent exporters

Scenario I: temporary devaluation, correctly-perceived				Scenario II: temporary devaluation, perceived as permanent			
	period t_m	t_m+1	t_m+2		period t_m	t_m+1	t_m+2
$\frac{\Delta S_t^d}{S_t^{total}}$	-3.6%	0%	0%	$\frac{\Delta S_t^d}{S_t^{total}}$	-3.6%	6.0%	2.7%
$\frac{\Delta S_t^f}{S_t^{total}}$	18.3%	0%	0%	$\frac{\Delta S_t^f}{S_t^{total}}$	18.3%	6.1%	1.8%
$\frac{\Delta S_t^{total}}{S_t^{total}}$ †	14.7%	0%	0%	$\frac{\Delta S_t^{total}}{S_t^{total}}$	14.7%	12.1%	4.5%
$\frac{\Delta I_t}{K_t}$	0%	0%	0%	$\frac{\Delta I_t}{K_t}$	25.2%	-8.2%	-4.8%
$\frac{\Delta p_t}{\bar{p}_t}$	6.0%	0%	0%	$\frac{\Delta p_t}{\bar{p}_t}$	6.0%	- 6.3%	- 3.5%
Scenario III: permanent devaluation, perceived as temporary				**Scenario IV: permanent devaluation, correctly-perceived**			
	period t_m	t_m+1	t_m+2		period t_m	t_m+1	t_m+2
$\frac{\Delta S_t^d}{S_t^{total}}$	-3.6%	-3.4%	2.8%	$\frac{\Delta S_t^d}{S_t^{total}}$	-3.6%	1.9%	4.6%
$\frac{\Delta S_t^f}{S_t^{total}}$	18.3%	17.5%	16.8%	$\frac{\Delta S_t^f}{S_t^{total}}$	18.3%	25.3%	18.0%
$\frac{\Delta S_t^{total}}{S_t^{total}}$	14.7%	14.1%	19.6%	$\frac{\Delta S_t^{total}}{S_t^{total}}$	14.7%	27.2%	22.6%
$\frac{\Delta I_t}{K_t}$	0%	19.4%	-0.1%	$\frac{\Delta I_t}{K_t}$	25.2%	8.1%	-3.6%
$\frac{\Delta p_t}{\bar{p}_t}$	6.0%	6.1%	-0.6%	$\frac{\Delta p_t}{\bar{p}_t}$	6.0%	-0.2%	-3.1%

†: changes in aggregate total sales $\frac{\Delta S_t^{total}}{S_t^{total}} = \frac{\Delta S_t^d}{S_t^{total}} + \frac{\Delta S_t^f}{S_t^{total}}$ as $\frac{\Delta S_t^d}{S_t^{total}}$, $\frac{\Delta S_t^f}{S_t^{total}}$ are weighted by the total sales.