Exports, Investment and Firm-Level Sales Volatility

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Abstract

This paper presents a dynamic model of risk-averse producers' decision to invest in physical capital and to export. The model features irreversible investment, no capital markets and fixed and sunk costs to export. Several features of the distribution of investment rates and export participation patterns observed in firm-level data are closely matched in a calibration exercise. Counterfactual experiments show that large adjustments in total sales associated with entry into foreign markets increase the volatility of total sales for exporting firms.

Keywords: Exports, Investment, Uncertainty.
JEL Classification Numbers: F12, E22.

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1 Introduction

Investment in physical capital and exporting are both extremely important activities for a firm. Because investment provides a strong indicator of a firm's growth potential and exporting implies an ability to compete in global markets associated with high productivity, firms are often judged by their performance on these two dimensions. Although there is a substantial body of research focusing on each activity independently, there are almost no studies that consider the two in a unified model. This paper attempts to bridge this gap by developing a model of the joint exporting and investment decisions in an environment that seeks to approximate features of the capital markets faced by firms in developing countries. I use a calibrated version of the model to examine whether exporting increases the volatility of firm-level sales or not. This is an important issue in light of the increasing concern among the public and policy makers that individual producers' greater exposure to globalization has rendered them more volatile and vulnerable to external shocks.

A large number of empirical studies have found that across countries, industries and time periods, exporters constitute a minority among manufacturing firms.[1] These studies have also shown that a firm's exporting status is highly persistent over time, and that exporters tend to be larger and more productive than firms that sell only in the domestic market. These features are also present in the the data set of Colombian manufacturing firms used for the calibration, which is described in more detail in Section 3.[2] Only 19% of the firms in the sample export, but the probability that they will continue exporting the following year is about 0.88. Moreover these firms are about four times larger and exhibit twice as much sales volatility as domestic firms. To reproduce these stylized facts, heterogenous-firm models of trade assume the existence of significant fixed and sunk costs associated with exporting.[3]

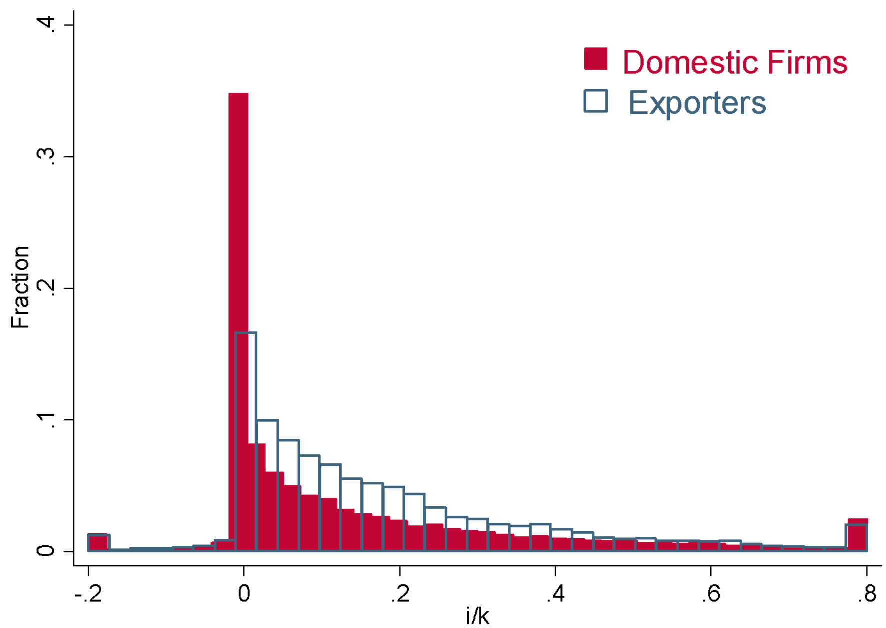
Figure 1 presents a basic histogram of investment rates for machinery and equipment for Colombian manufacturing firms. Three important stylized facts emerge from inspecting Figure 1 and Table 1: (i) Colombian manufacturing firms seldom divest capital by selling it in secondary markets. (ii) For a large number of (firm-year) observations investment rates are smaller than 1%, which means

[1] See for example Bernard and Jensen (1999), Bernard et al. (2007), Lawless (2010), Vogel and Wagner (2010), among many others.

[2] Although the information in this data set is available at the plant level, I will use the term "firm" to maintain consistency throughout the paper.

[3] These costs include setting up a distribution network abroad, adjusting product characteristics to comply with foreign regulations, gathering market-specific information, etc.

Figure 1: Investment Rate Distribution - Data



Source: Author's own calculations based on the Colombian Annual Manufacturing Survey, 1981–1991. See data description in Section 3.

Table 1: Investment Moments - Colombian Manufacturing Survey, 1981-1991.

Statistic	**All**	**Domestic Firms**	**Exporters**
Fraction of obs. with $i/k < 0$	0.041	0.041	0.042
Inaction Rate ($\|i/k\| \leq 1\%$)	0.271	0.316	0.082
Investment Spikes ($i/k \geq 20\%$)	0.264	0.249	0.330

Source: Author's own calculations based on the Colombian Annual Manufacturing Survey, 1981–1991. See data description in Section 3.

that investment inaction is quite common across firms. (iii) However, there is also a significant number of observations featuring intensive adjustment of capital stocks (investment spikes).[4] Like the literature on the decision to export, research on investment seeks to identify what type of adjustment costs help to explain these investment patterns.[5] However, the striking differences

[4]These stylized facts have also been documented by Doms and Dunne (1998) and Cooper and Haltiwanger (2006), among others.

[5]Installation disruptions, capital indivisibilities, retraining and restructuring costs, transaction costs, etc.

between exporters and domestic firms across these dimensions have not been documented before. As Table 1 shows, exporting firms engage in significant investment activity, since they are more likely to experience investment spikes and less likely to experience periods of inaction.

In this paper I set up and calibrate a partial equilibrium model that can match the stylized facts about exporting and investment described above. Furthermore, I use the quantitative model to understand how the decision to become an exporter affects firm-level sales volatility. The model features heterogeneous, risk-averse firms that operate in an environment characterized by firm-specific uncertainty (in terms of productivity and destination-specific demand shocks), irreversible investment and no capital markets. As in most heterogeneous-firm models of trade, exporting is costly. Domestic firms that decide to start exporting need to incur an up-front sunk cost as well as a fixed participation cost every period to maintain a presence abroad. The capital accumulation problem of firms is less standard, and aims to approximate conditions faced by firms in developing countries. The assumption that firms are risk-averse can be rationalized by thinking of firms owned by entrepreneurs who work in their own firms and whose main source of income is the firm's dividends as in Bond et al. (2008).[6] The second key assumption regarding the firm's investment problem is that capital is perfectly irreversible as in Veracierto (2002). That is, once a firm has installed capital it can only divest it by letting it depreciate, since it cannot be freely disposed of or sold in a secondary market. Caballero (1993) notes that because of the relatively small size of the manufacturing sector and a highly volatile macroeconomic environment, secondary markets for capital goods are particularly thin in developing countries. Gelos and Isgut (2001) provide support for this view and show that investment irreversibility is a more important component of capital adjustment costs in developing countries like Mexico and Colombia than in developed economies such as the United States or Norway. Given that I am restricting the sources of funds available for firms to finance capital accumulation, it is natural to restrict the secondary market for capital goods as well. This characterization of capital markets shuts down mechanisms other than exporting that firms could potentially use to stabilize their sales.

From a quantitative standpoint, the model performs quite well. Even though it is only calibrated to

[6]Maloney and Azevedo (1995) note that in developing countries it is common for firm managers to own large shares of the firms they run. Even in a developed economy like the United States, Moskowitz and Vissing-Jørgensen (2002) find that around 75% of all private equity is owned by households for whom it constitutes at least half of their total net worth.

match export entry and exit rates and the average export-sales ratio, the model closely approximates the share of investment inaction episodes and spikes for both domestic and exporting firms. The model also reproduces the size and volatility premium of total sales for exporting firms. The implied costs to start exporting that result from the calibration are in line with previous estimates by Alessandria and Choi (2007), Das et al. (2007) and Ruhl and Willis (2008), although the fixed cost required to remain an exporter is substantially higher than what these authors report. The main shortcoming of the calibrated model is the fact that new exporters adjust the amount of output they choose to sell abroad immediately upon entry, contrary to the findings of Eaton et al. (2008) and Ruhl and Willis (2008), who show that new exporters tend to start out by selling small quantities, and only increase their exports if they are successful.

After calibrating the model, two important results emerge. The first is that despite the assumption that firms are risk-averse, deriving higher utility from more stable profits, their export decision is not strongly affected by the correlation of idiosyncratic demand shocks when firm-specific productivity is highly persistent. In fact, given the highly-persistent productivity process used in the calibration, increasing the correlation between domestic and foreign demand shocks induces more firms to start exporting. The reason behind this pattern is that productivity's persistence has a strong positive effect on the value of exporting for firms. Firms can safely expect that the positive productivity shocks that induce them to start exporting will take a long time to dissipate. Under these conditions, positively correlated demand shocks facilitate entry into the export market, trumping the positive effect that the high correlation of demand shocks might have on the volatility of profits. However, when the persistence of the productivity process decreases, demand shocks and their correlation structure become more important determinants of the decision to export. Thus, reductions in demand correlation have a positive impact on the number of exporting firms.

The second finding pertains to the effect that exporting has on firm-level sales volatility. Using the calibrated model, I conduct two counterfactual experiments: in the first one, I shut down the foreign market so that all firms are restricted to selling in the domestic market alone. The second experiment looks at the opposite situation, where the fixed and sunk costs associated with exporting are set equal to zero, so all firms find it optimal to export.[7] Comparing these two scenarios with the benchmark calibration shows that exporting increases firm-level sales volatility. The larger

[7] I am grateful to an anonymous referee for suggesting the inclusion of this experiment.

adjustment of total sales that firms undertake when entering the foreign market in response to the fixed and sunk costs results in higher firm-level sales volatility relative to the two counterfactual scenarios.

This paper builds upon the quantitative models of a firm's decision to export in the presence of sunk entry costs developed by Roberts and Tybout (1997), Alessandria and Choi (2007), Das et al. (2007) and Ruhl and Willis (2008), but goes beyond these studies by also considering the firm's decision to invest in physical capital as in Veracierto (2002), Cooper and Haltiwanger (2006), Khan and Thomas (2008) and several other papers reviewed in Caballero (1999). This paper considers the joint nature of the exporting and investment decision in a unified environment, thus bringing together these two literatures. Although fixed and sunk costs to serve the foreign market are a staple of heterogeneous-firm models of international trade, almost all of these models, with the exception of Alessandria and Choi (2007) and Suwantaradon (2008), ignore the capital accumulation decision of firms.[8]

A second contribution of this paper is to provide a better understanding of how trade openness affects firm-level volatility. Comin and Philippon (2006), probably the most cited paper in this area, does not take into consideration the effect of changes in trade openness on firm-level sales volatility. This research topic has also been overlooked in the international trade literature until very recently.[9] To the best of my knowledge, there are only two recent papers that study how exporting affects firm-level volatility.[10] Buch et al. (2009) use firm-level data from the German state of Baden-Württemberg and find that controlling for firm size and productivity, exporters have lower sales volatility than non-exporters. However, their empirical analysis does not identify the specific mechanisms that drive their result. Vannoorenberghe (2010) develops a partial equilibrium model of heterogeneous firms, where demand shocks determine a firm's decision to become an exporter. Testing the model's predictions using a panel of French firms, he finds that the effect of exporting

[8] However, neither of these papers addresses the substantial degree of lumpiness and high frequency of inaction observed in plant-level investment.

[9] Early theoretical contributions by Clark (1973), Eldor and Zilcha (1987), Donnenfeld and Zilcha (1991) among others, study the export supply decision of risk-averse monopolists and perfectly competitive firms, and how this decision is influenced by exchange rate volatility. These studies did not consider firm heterogeneity or entry and participation costs to start exporting. On the empirical side, Hirsch and Lev (1971), using a small sample of firms in Denmark, Israel and The Netherlands, find that international diversification is positively correlated with total sales stability.

[10] At the three-digit industry level di Giovanni and Levchenko (2009) find that sectors that are more open to international trade are more volatile.

on firm-level sales volatility depends crucially on the share of output that firms sell abroad, with large exporters having more volatile sales than domestic firms. While in Vannoorenberghe's model all firm-level decisions are static, the model developed in this paper is fully dynamic, in the sense that a firm's recursive problem is explicitly solved. This is an important distinction since it allows me to show that the adjustment of sales and capital in the transition towards exporting results in higher sales volatility for exporters. The paper is organized as follows: section 2 outlines the theoretical model, sections 3 and 4 describe the calibration strategy and the benchmark results respectively. Section 5 presents the counterfactual experiments, and Section 6 concludes.

2 Model

This is a partial equilibrium model of an industry populated by heterogeneous firms. There is a fixed number of risk-averse firms, each of which produces a differentiated product, maximizing the expected lifetime utility of profits,

$$\mathbb{E}_0\left\{\sum_{t=0}^{\infty}\beta^t u(\pi_t)\right\}, \quad u(\pi) = \frac{\pi^{1-\nu}}{1-\nu}, \tag{1}$$

with $\beta \in (0,1)$, $\nu > 0$ and $u(\pi) = \ln(\pi)$ if $\nu = 1$.[11] All firms have access to the same technology, which uses capital as the only input to produce a final good:

$$q = e^{\phi}k^{\alpha}, \quad \alpha \in (0,1), \tag{2}$$

where k is the firm's capital stock and ϕ is a firm-specific productivity index that follows a Markov process, $\phi' = \varrho\phi + \upsilon'$, with $\varrho \in (0,1)$ and $\upsilon' \overset{\text{i.i.d.}}{\sim} \mathcal{N}(0,\sigma_\upsilon^2)$, where a $'$ denotes the next-period value for the variable of interest.[12] Capital stock is owned by the firm and is augmented through investment that comes from internal funds. Since capital markets are non-existent, the firm cannot borrow to finance capital investment. A firm's capital stock follows the law of motion,

$$k' = (1-\delta)k + i, \tag{3}$$

[11] The model abstracts from entry and exit into and out of the domestic market.

[12] Alternatively, one could assume a technology that uses both capital and labor, where labor is a fully flexible input. The main results of the model remain unchanged.

where i denotes gross investment and δ is the depreciation rate of capital. At period t the firm chooses the capital stock that will be available for production in period $t+1$.[13] Furthermore, investment is assumed to be perfectly irreversible, which implies that gross investment is constrained to be non-negative.

Firms' output can potentially be sold in two markets: Home (h) and Foreign (f). The difference between the two is that it is costly for a firm to sell its output in the foreign market. A firm that decides to *start* exporting has to pay a sunk cost, s_x. Additionally, and independently of its previous exporting status, a firm that exports in any given period has to pay a fixed participation cost, f_x. Both costs are denominated in units of capital. If firms only had to pay a fixed cost per-period to sell abroad, the only determinant of the decision to export would be current profitability in the foreign market, which means that if current foreign profits were to fall below fixed costs, the firm would stop exporting. The existence of sunk entry costs makes the firm's export decision forward-looking. Current exporters know that if they stop exporting today, they will have to pay s_x whenever they decide to sell abroad again. Alternatively, they can choose to weather the rough times and avoid paying the sunk cost. The problem for domestic firms is to determine when to exercise the option to become exporters. If productivity (or foreign demand) is not sufficiently high, they might choose to wait until conditions improve. The high turnover rates observed in export markets justify including the fixed per-period cost in addition to the sunk cost to start exporting. Since the Cobb–Douglas production function assumed in the model implies that gross potential export profits are always positive, not including the fixed participation cost would result in firms never exiting the export market.[14] Let y denote the export status of a firm, with $y = 1$ if the firm decides to export and 0 otherwise. Also, let y_{-1} denote the firm's export status in the previous period. Then the cost of exporting for a firm is given by:

$$C_x(y_{-1}, y) = s_x[\mathbb{I}(y = 1|y_{-1} = 0)] + f_x[\mathbb{I}(y = 1|y_{-1} = 1)], \tag{4}$$

where $\mathbb{I}(\cdot)$ denotes the indicator function. A firm faces the following demand curve for its output

[13] Thus, investment at t completely determines the production possibilities of the firm at $t+1$. This contrasts with the model of Cooley and Quadrini (2001) where there is a market in which firms can rent capital to/from other firms.

[14] In other words, the decision to export would be irreversible.

in market j:

$$q_j = z_j p_j^{-\epsilon}, \tag{5}$$
$$\log(z_j) \overset{\text{i.i.d.}}{\sim} \mathcal{N}(\mu_j - \sigma_j^2/2, \sigma_j^2), \quad j = h, f,$$

where $\epsilon > 1$ is the elasticity of demand, which is assumed to be the same across markets and z_h and z_f are firm–destination specific demand shocks, which are assumed to be independent over time. Demand shocks are assumed to be uncorrelated with each other in the benchmark model used in the calibration. In Section 4, I explore how the correlation of demand shocks affects firms' exporting decisions. Domestic and foreign markets are assumed to be segmented, allowing firms to charge different prices in each. Potential revenues in market j are thus:

$$r_j = (z_j)^{\frac{1}{\epsilon}} q_j^{\frac{\epsilon-1}{\epsilon}}, \quad j = h, f, \tag{6}$$

and total profits are given by:

$$\pi = r_h + y[r_f - C_x(y_{-1}, y)] - i. \tag{7}$$

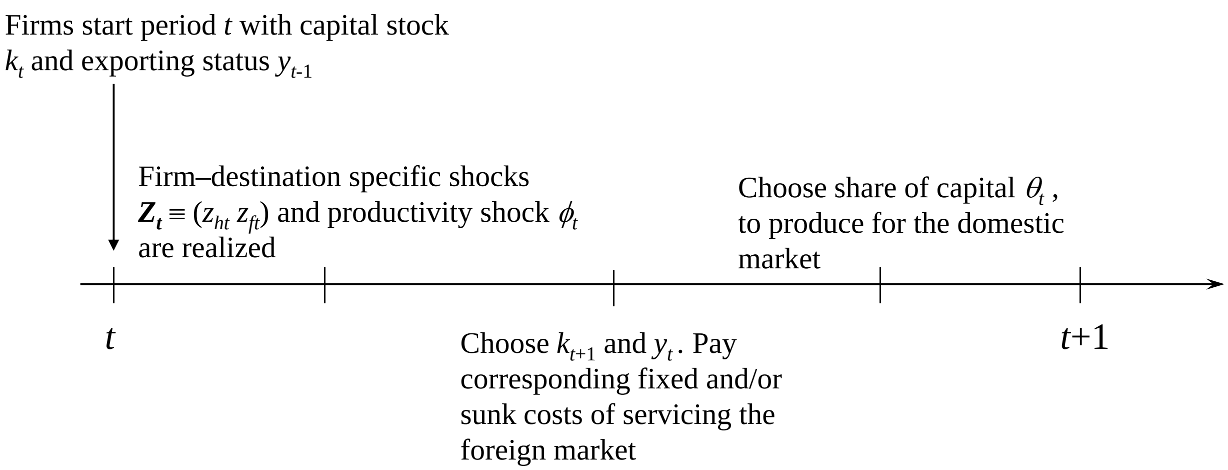
The problem of the firm can be partitioned into two subproblems: a dynamic one that involves the decision of whether or not to export and how much capital to use in the next period, and a static one which entails deciding how much output to produce for each market, conditional on the firm deciding to export. The timing of actions is as follows, and is illustrated in Figure 2:

1. A firm enters period t with a given capital stock k_t and last period's export status $y_{t-1} \in \{0, 1\}$. Demand shocks z_{ft} and z_{ht} and firm-specific productivity ϕ_t draws are realized at the beginning of the period.

2. The firm decides whether to export or not. If the firm did not export in the previous period, it has to pay a sunk cost s_x to break into the foreign market in period t. A firm that is currently servicing the foreign market needs to pay a fixed costs, f_x every period it exports. Conditional on deciding to export, a firm chooses the fraction $\theta \in [0, 1]$ of its capital stock to use for production for the domestic market.

3. Finally, the firm chooses its desired capital stock for period $t+1$. Profits for period t are realized.

Figure 2: Sequence of Actions



Since a firm's capital stock in period t is the result of the firm's decision at $t-1$, the timing assumption implies that output is chosen before the resolution of uncertainty, but the allocation of sales between the two markets is decided ex post. This implies that a firm has greater flexibility in adjusting the distribution of sales across different markets than it does in changing the total scale of its production.

An individual firm's state variables can be divided into two separate categories: *endogenous individual states*, capital stock, k, and export status, y_{-1}, and *exogenous individual states*, which include firm-specific productivity, ϕ, and firm–destination specific demand shocks, $\mathbf{Z} \equiv [z_h \quad z_f]$. The dynamic problem of the firm can be represented in recursive form as follows:

$$v(k, y_{-1}, \phi, \mathbf{Z}) = \max \Big\{ v_n, v_x \Big\}, \tag{8}$$

where v_n denotes the value of only servicing the domestic market,

$$v_n \equiv \max_{k' \geq (1-\delta)k} \Big\{ u[r_h(k, y_{-1}, \phi, \mathbf{Z}) - i] + \beta \mathbb{E}_{[\phi', \mathbf{Z}']} v(k', 0, \phi', \mathbf{Z}') \Big\}, \tag{9}$$

and v_x the value of exporting,

$$v_x \equiv \max_{k' \geq (1-\delta)k} \Big\{ u[r_h(k, y_{-1}, \phi, \mathbf{Z}) + r_f(k, y_{-1}, \phi, \mathbf{Z}) - i - C_x(y_{-1}, y)] + \beta \mathbb{E}_{[\phi', \mathbf{Z}']} v(k', 1, \phi', \mathbf{Z}') \Big\}. \quad (10)$$

The term $\mathbb{E}_{[\phi', \mathbf{Z}']}$ denotes the conditional expectation over future productivity and demand shocks and the constraint that future capital has to be greater than or equal to current capital net of depreciation captures the irreversibility of investment. To solve the problem defined in equations (8)-(10), I discretize the state space and use a value function iteration algorithm. Productivity shocks are approximated using the method of Tauchen (1986) in a 15-point grid and demand shocks are approximated using a Gaussian quadrature procedure with 5 nodes for each shock.

The solution to this problem results in two policy rules, one for next-period's capital, $g_k(k, y_{-1}, \phi, \mathbf{Z})$, and the other for exporting, $g_y(k, y_{-1}, \phi, \mathbf{Z}) \in \{0, 1\}$. Figure 3 shows the decision rule for next-period capital for both exporters and domestic firms for two different levels of idiosyncratic productivity, given the same firm–destination specific demand shocks. Under risk neutrality and no adjustment costs, next-period capital would be independent of current capital. Under these circumstances, investment would be excessively responsive to productivity shocks and the model would not be able to reproduce the high inaction rates observed in the data. Adding risk aversion dampens the response of investment to productivity shocks, since large changes in the capital stock reduce the expected utility of profits. In this case, the capital accumulation policy rule is an increasing function of current capital, and is similar to the policy rule for a risk-neutral firm with convex capital-adjustment costs. Firms accumulate more capital during periods of high productivity and when they export. Adding risk aversion, however, is still not sufficient to produce the investment inaction and spikes observed in the data. Assuming that investment is perfectly irreversible bridges this gap. On the one hand, As Figure 3 shows, firms that have accumulated high levels of capital cannot divest their capital stock in response to adverse conditions, all they can do is to let it depreciate. This substantially increases the likelihood of observing episodes where optimal investment is zero. On the other hand, as noted by Caballero (1991), the presence of irreversibilities makes investment more responsive to "good" (realizations in which the capital in place is lower than the desired stock of capital) than to "bad" shocks, since downsizing the capital stock is costlier than building it up. When firms receive shocks that move them across the threshold to start exporting, their current capital stock is often substantially below their desired capital stock given the larger demand they now face, thus producing a significant number of investment spikes.

Figure 3: Capital Policy Rule

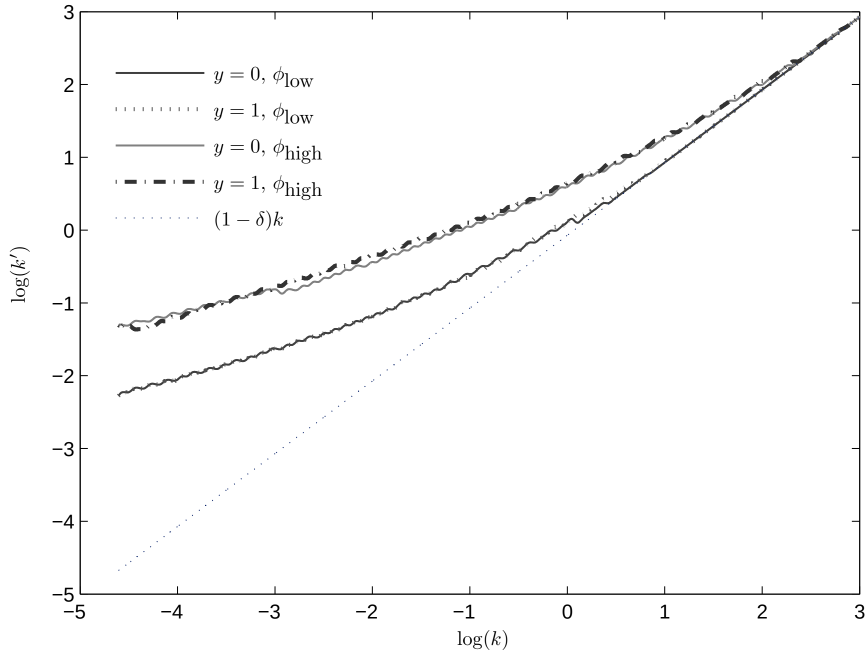
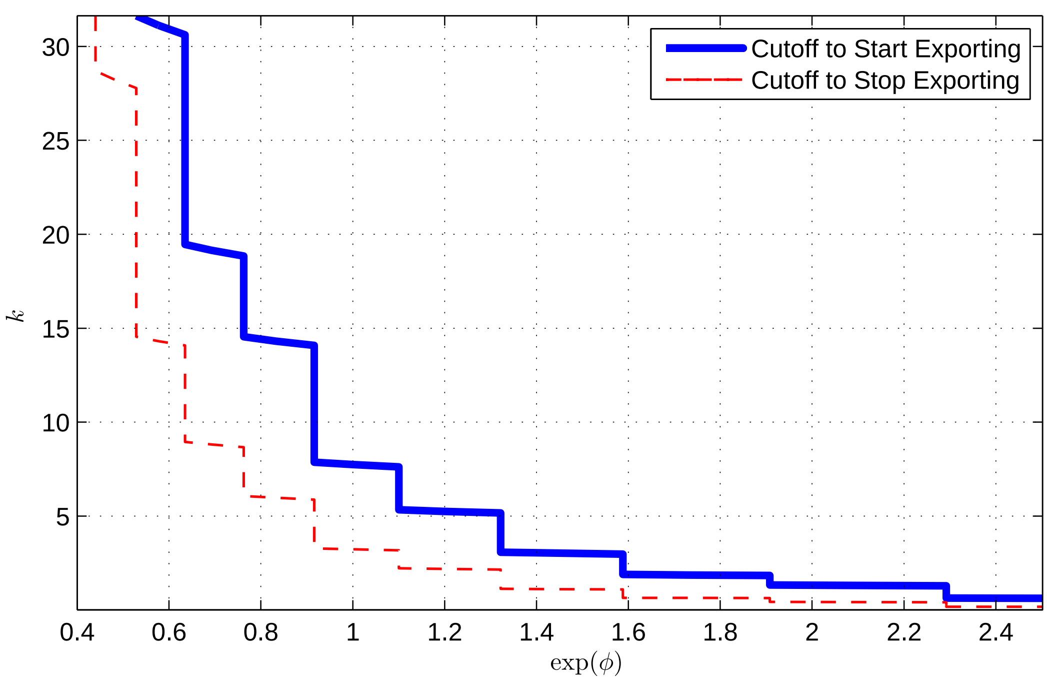


Figure 4 shows the contour lines of the exporting policy rule for domestic firms and current exporters given the mean value for demand shocks in both markets. As Baldwin and Krugman (1989) note, under the existence of a sunk entry cost to access the export market, a firm needs to take into consideration that in later periods it can continue exporting without incurring this cost again.[15] This will affect the expected present discounted utility of profits, generating hysteresis. If, for instance, a firm decides to start exporting after a positive foreign demand shock, the firm will continue to export even after the foreign demand returns to its pre-shock level. For a given level of productivity, the policy rule for exporting is characterized by two cutoff levels of capital, $\underline{k} < \overline{k}$, such that a firm currently producing only for the domestic market would decide to start exporting if its capital stock is above $\overline{k}$, while an exporting firm whose capital stock falls below $\underline{k}$ would

[15] Roberts and Tybout (1997) find evidence of non-zero entry costs into foreign markets for manufacturing plants in Colombia. They also find that plants that have not operated in the export market for two years or more face re-entry costs that are not significantly different from the entry costs faced by plants that have not exported before. This is why I assume that a firm that stops exporting has to pay the sunk entry cost whenever it decides to start exporting again, regardless of its previous exporting experience. This assumption greatly simplifies the solution of the dynamic problem of the firm.

choose to exit the foreign market. Similarly, for a given capital stock, the level of productivity that would induce a domestic firm to enter the export market is always greater than the level that would cause an exporter to drop out of the foreign market. It follows that firms with capital stocks and productivity between the two thresholds can potentially be domestic firms or exporters depending on the history of the shocks they have received. The hysteresis generated by the sunk cost to enter the foreign market has important implications for the volatility of sales. If sunk costs are significant, exporters will be reluctant to exit the foreign market when foreign demand is unfavorable and/or productivity falls. Exporters that have experienced prolonged spells of low demand or productivity, and whose capital is significantly below their desired level when conditions turn around, have the incentive to incur in substantial bursts of investment. These dramatic changes in the level of the capital stock of exporters would be reflected in higher sales volatility than that experienced by domestic firms.

Figure 4: Export Cutoffs



The static problem of how much output to export, conditional on the capital stock and the realizations of the stochastic processes, is given by:

$$\max_{\theta\in[0,1]}\left\{(z_h)^{1/\epsilon}\left[\theta e^{\phi}k^{\alpha}\right]^{1-1/\epsilon}+(z_f)^{1/\epsilon}\left[(1-\theta)e^{\phi}k^{\alpha}\right]^{1-1/\epsilon}\right\}, \tag{11}$$

which results in:

$$\theta=\frac{1}{\left[1+\left(\frac{z_f}{z_h}\right)^{\frac{1}{\alpha+(1-\alpha)\epsilon}}\right]}. \tag{12}$$

The key variables that determine the fraction θ of capital used in the production for the domestic market are the relative magnitudes of domestic and foreign demand shocks. When the size of the foreign market increases relative to that of the domestic market, θ decreases. Assuming that the demand elasticity is the same in both markets also implies that θ is independent of the capital stock.

3 Calibration

Table 2 presents the parameters used in the benchmark solution of the model. The model period is set to one year. The coefficient of relative risk aversion, discount factor, depreciation rate and capital's share of output are standard in the macroeconomics literature. The discount rate $\beta = 0.90$ implies an annual real interest rate of 11%, which is higher than the usual 4% based on the US real interest rate. The depreciation rate is set to 6.9% annually as in Cooper and Haltiwanger (2006).[16] The coefficient of relative risk aversion of 1 implies a logarithmic utility of profits. In Section 4, I show how the decision to export is affected by changes in the firms' degree of risk aversion.

The elasticity of demand is assumed to be the same in both markets and is set to 3.8 as in Bernard et al. (2007) based on estimates for the elasticity of substitution across varieties in a monopolistic competition environment (in this setting, and assuming CES preferences, the elasticity of substitution coincides with the elasticity of demand faced by individual firms), which in turn is very close to the median of the estimates that Broda and Weinstein (2006) find for 7-digit industries in the United States.

The plant-level data used for the calibration of parameters comes from Colombia's Annual Man-

[16]Gelos and Isgut (2001) use a similar depreciation rate of 7% for machinery and equipment in their study of Colombian and Mexican manufacturing plants.

Table 2: Parameters for the Baseline Economy

Parameter	Description	Value
ν	Relative risk aversion coefficient	1.0
α	Curvature of production function	0.36
β	Discount factor	0.90
δ	Depreciation rate for capital	0.069
ϵ	Demand elasticity	3.8
s_x	Sunk entry cost to start exporting	0.315
f_x	Fixed cost to remain an exporter	0.221
Shocks		
ϱ	Persistence productivity shock	0.961
σ_v^2	Variance productivity innovations	0.0259
e^{μ_h}	Mean domestic demand shock	1.0
e^{μ_f}	Mean foreign demand shock	0.013
σ_j^2	Variance demand shocks, $j = h, f$	0.0259

ufacturing Survey conducted by the Colombian Statistical Agency (*Departamento Administrativo Nacional de Estadística*, DANE). The data covers all manufacturing plants with 10 or more employees for the period 1981-1991. I work with a balanced panel of all continuing plants in the sample. All investment figures correspond to investment in machinery, transport and other equipment. Capital stocks are constructed following a permanent inventory method described in Roberts and Tybout (1996). The main advantage of using this data set is that it has been widely used to study both the decision to export (Roberts and Tybout, 1997; Das et al., 2007; Ruhl and Willis, 2008) and capital adjustment patterns (Gelos and Isgut, 2001) at the the firm level, which makes the results of this paper more easily comparable with the existing literature.

The parametrization of the idiosyncratic productivity process, demand shocks and the export costs deserves more comment. The parameters that govern the productivity process ϱ and σ_v^2 are taken from Ruhl and Willis (2008), who estimate these in a structural model of the decision to export using the same data as this paper. I set μ_h so that domestic demand shocks have mean 1, and the variance of domestic and foreign demand shocks is assumed to be the same as the variance of productivity innovations. The three remaining parameters, the sunk cost to start exporting, s_x, the cost to maintain a presence in the foreign market, f_x and μ_f, the parameter that determines the average size of foreign demand shocks, are calibrated to match three moments from the data that characterize the decision to export: (i) the entry rate into exporting (starter rate), (ii) the exit rate out of exporting (stopper rate) and (iii) the mean export-sales ratio. Table 3 shows the values of these moments for Colombian manufacturing firms and the fit achieved by the calibration.

Table 3: Calibration Targets

Statistic	**Data**	**Model**
Starter rate	0.027	0.025
Stopper rate	0.125	0.125
Mean export-sales ratio	0.165	0.165

Given the calibrated values for s_x and f_x, domestic firms breaking into the foreign market would expect to pay on average 24.6% of their pre-export profits as an entry cost, and established exporters would have to sacrifice on average 13.4 % of their profits to maintain their presence abroad.

The export penetration costs are in line with other estimates found in the literature: Alessandria and Choi (2007), based on their calibration for U.S. manufacturing plants, report sunk entry costs of 12.6% of sales, Ruhl and Willis (2008) estimate these to be between 17 and 23% of the median exporter's profits (this statistic is 20.1% in my calibration exercise) and Das et al. (2007), who allow these costs to be affected by idiosyncratic shocks and to vary by firm size, estimate export entry costs to be between 51,000 to 64,000 thousand Colombian Pesos, that is, between 60 and 75% of the median exporter's profits.

The cost to remain an exporter implied by the calibrated value of f_x is substantially higher than the ones Alessandria and Choi (2007) and Ruhl and Willis (2008) report (1.7 and 4.2% of total sales respectively).[17] This is due to the assumption of risk aversion. The curvature that risk aversion introduces into the firm's value function increases the hysteresis band relative to the case of risk neutrality, as shown in Riaño (2010). Thus, a very high value of f_x is needed to match the conditional probability of exiting the foreign market. The mean of foreign demand shocks is about one-hundredth of the size of the average for domestic demand shocks. The main advantage

[17] Another way to compare the relative size of the entry and continuation costs of exporting is simply to look at the ratio of the calibrated/estimated parameters that different authors report. Alessandria and Choi (2007) find a ratio of 4.8 and Ruhl and Willis (2008), 9.2. Das et al. (2007) estimates for the continuation costs are not statistically different from zero.

of including idiosyncratic demand shocks is that it allows me to closely match *both* the average share of total sales accounted by exports and the share of exporters in the data, even though the last moment is not directly calibrated. This is important because as noted by Armenter and Koren (2009), a Melitz-type model where productivity is the only source of firm heterogeneity cannot simultaneously match these two moments.[18]

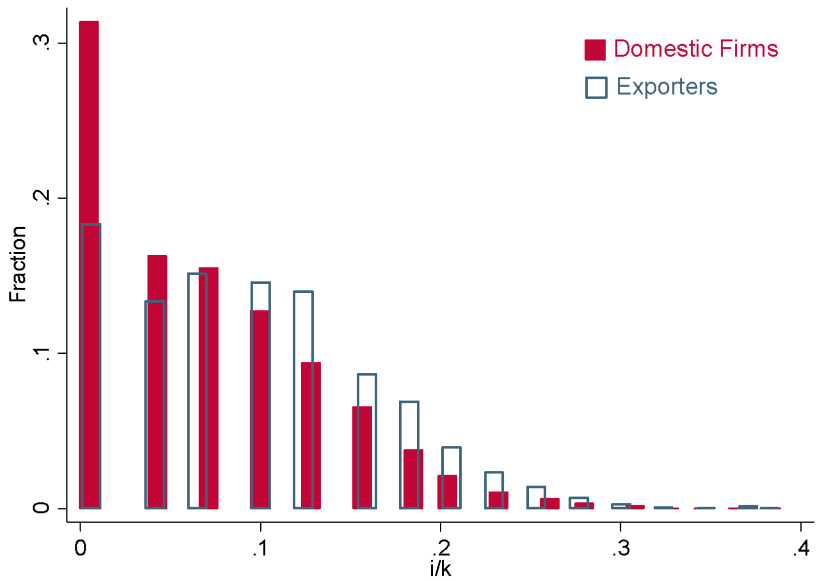
Table 4: Moments Produced by the Model

Statistic	**Data**	**Model**
Fraction of exporting firms	0.192	0.177
Relative mean total sales, exporters	3.721	1.955
Relative total sales volatility, exporters	1.897	2.052
Mean investment rate	0.142	0.077
Domestic firms	0.134	0.070
Continuing exporters	0.169	0.087
New exporters	0.147	0.143
Exiting exporters	0.134	0.024
Fraction of obs. with $\|i/k\| \leq 1\%$	0.271	0.274
Domestic firms	0.316	0.294
Exporters	0.082	0.179
Fraction of obs. with $i/k \geq 20\%$	0.264	0.244
Domestic firms	0.248	0.217
Exporters	0.363	0.372

Table 4 shows how the model fits the data along several dimensions that have not been directly calibrated. The model fits the data quite well. The share of exporting firms is just slightly lower than in the data, and the fraction of inaction episodes and investment rate spikes are matched closely. The fact that exporters are less likely to experience inaction episodes and more likely to present investment spikes is also captured by the model. Although presenting less dispersion, the distribution of investment rates shown in Figure 5 looks remarkably similar to the empirical distribution of investment rates presented in Figure 1.

[18] In a Melitz-type model, calibrating the entry and continuation costs of exporting in order to match the share of exporting firms alone would result on mean export-sales ratios that are too high relative to the data. Similarly, matching the mean export-sales ratio would necessitate relatively low fixed and sunk costs, thus producing too many exporting firms.

Figure 5: Investment Rate Distribution - Calibrated Model



4 Results

In this section, I explore in greater detail the quantitative implications of the calibrated model, comparing them to the data, emphasizing the patterns of investment and total sales around the time that firms decide to start exporting. In the model firms accumulate capital when either their idiosyncratic productivity and/or domestic demand improves. Changes in idiosyncratic foreign demand shocks are less important for investment since they only affect exporters and are significantly smaller than domestic demand shocks. Conversely, low productivity and demand realizations induce firms to stop investing. Firms that have had a history of high productivity and domestic demand shocks accumulate a substantial stock of capital which makes it profitable for them to incur the entry costs to start exporting. Thus it follows that exporters are 1.95 times larger in terms of their total sales, and their sales volatility is 2.05 times higher than that of firms that only sell in the domestic market.[19] The corresponding figures for Colombian producers presented in Table 4 are 3.72 and 1.89 respectively, which shows that the model also provides a good approximation to the exporters' size and volatility sales premium observed in the data.

[19] I calculate sales volatility using a 10-year rolling window as follows: $\mathrm{sd}(r_t) = \left(\frac{1}{10}\sum_{\tau=t-4}^{t+5}(r_\tau - \overline{r_t})^2\right)^{1/2}$, where r_t denotes total sales at time t.

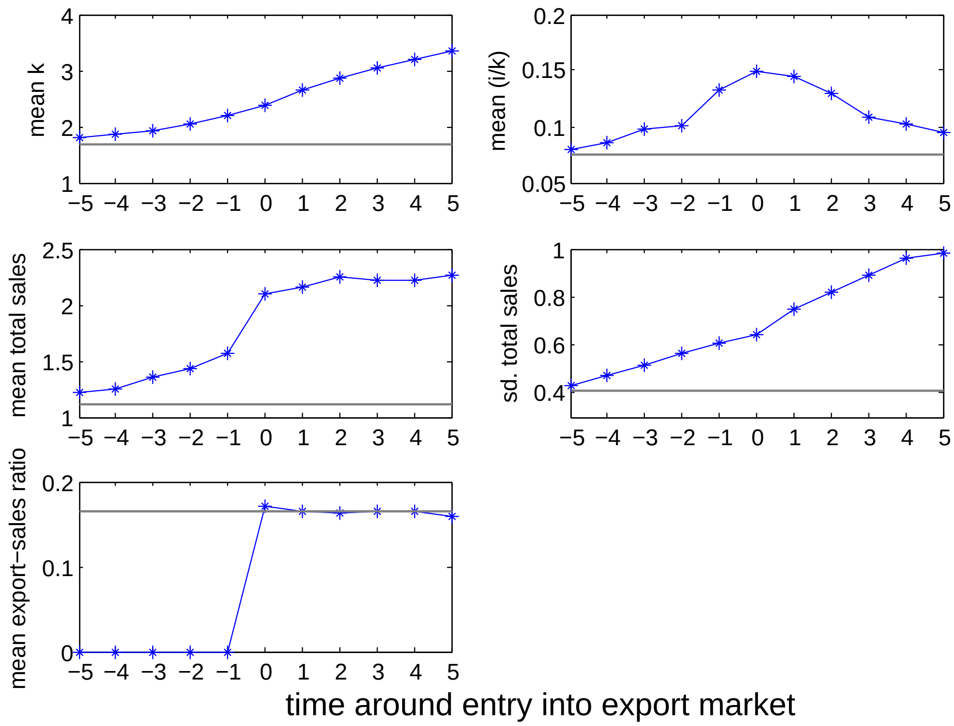
Figure 6 shows the patterns of capital, investment rates and sales around the transition into exporting. Firms that will start exporting in 5 years are already 8% larger in terms of capital than the average domestic firm. Because of the smoothing of profits induced by risk aversion, firms increase their capital stock gradually before they start exporting, with the highest investment rates taking place during the period two years before and after entering the foreign market, in which close to two thirds of all investment spikes occur.[20] This pattern has also been documented by Iacovone and Javorcik (2009), who show that Mexican manufacturing plants are significantly more likely to present investment spikes one and two years before starting to export a new product. Thus, the mean investment rate for new exporters is 14.3%, which is significantly higher than that of domestic firms and existing exporters (7.0 and 8.7% respectively), with exiting exporters presenting the lowest investment rate of the four, 2.4%. Even though the model correctly predicts the higher investment rates of exporters, the differences across export statuses are more pronounced than in the data.

Upon entry into the export market, firms' total sales increase on average 33.5 % on impact. A similar, albeit more gradual, response is observed in the data, at least immediately after entry, with average total sales of new exporters increasing by 20.4% after their first year selling abroad. After five years exporting, total sales of these firms more than double relative to their pre-export levels, whereas in the model sales growth after starting to export is considerably lower. This pattern also emerges when studying the behavior of the export-sales ratio. The share of exports on total sales jumps immediately to 16.8% after entry at a level 2% higher than the average export-sales ratio for all exporters, slightly decreasing over time as the positive productivity and demand shocks that induced entry die out. This dynamic pattern is at variance with the findings of Eaton et al. (2008) and Ruhl and Willis (2008), who show that the export-sales ratio increases gradually conditional on survival in the foreign market. Because of the immediate adjustment of the export-sales ratio after entry, new exporters are just 6% smaller than established exporters, but because of the hysteresis produced by the large entry costs, they are about 17% larger in terms of sales than firms dropping out of the export market, which are substantially larger than the average non-exporting firm.[21]

[20] Firms starting to export are on average 33.7% larger in terms of capital stock relative to five periods before exporting.

[21] New exporters are 24% larger than exiting exporters, and these firms are twice as big as domestic firms in terms of their sales in the Colombian data.

Figure 6: Selected Variables Around Entry into Export Market



The solid grey line indicates the mean of the respective variable for non-exporting firms, except for export-sales ratio, where it indicates the mean ratio for all exporters.

Since irreversibility delays the divestment of capital, it takes about 5 years for these firms to reach a similar volume of sales as the average domestic firm.

After examining the patterns of investment and sales around entry into the export market, I study how the correlation of demand shocks affects the export participation decision of firms. Table 5 shows how the share of exporting firms is affected by changes in the correlation of demand shocks. The first thing to notice is that changes in the correlation of demand shocks do not have a significant impact on export participation. Increasing the correlation from -0.45 to +0.45 increases the share of exporters by only 1.6 percentage points. The second important point is that the share of exporters increases with the correlation of demand shocks. This is the opposite of what one would expect if firms were taking advantage of the foreign market as a means to diversify their sales revenue. The reason behind this puzzling pattern is that the high persistence of the productivity process dramatically increases the value of becoming an exporter. A combination of positive demand shocks in both markets provides a stronger incentive to accumulate capital, so when productivity improves, firms know that paying the entry cost is worthwhile, because it will be profitable to export for several periods.

Table 5: Share of Exporting Firms

corr(z_h, z_f)										
-0.75	-0.6	-0.45	-0.3	-0.15	0	0.15	0.3	0.45	0.6	0.75
0.164	0.169	0.171	0.173	0.175	0.177	0.178	0.180	0.187	0.189	0.190

Lastly, I study how the decision to export is influenced by a firm's degree of risk aversion. Increasing the coefficient of relative risk aversion, ν, from 1 to 2 induces more firms to start exporting, increasing the share of exporting firms by 11%. This higher curvature increases the expected utility of selling in two markets, which results in a higher mean capital stock across firms (because of the new exporters) but has a negligible effect on the investment behavior of firms with the fraction of inaction episodes and investment spikes both decreasing by less than 1% relative to the benchmark calibration.

5 Counterfactual Experiments

To quantify the effect that exporting has on the volatility of sales, I take advantage of the calibrated model and conduct two counterfactual experiments. In the first one, the foreign market is shut down, so firms do not have the opportunity to export. In the second experiment, I assume that the fixed and sunk costs of exporting are zero, so all firms export.[22] The comparison between the benchmark calibration and the two counterfactual experiments is presented in Table 6.

5.1 Experiment 1: Shutting Down the Export Market

Having the foreign market available has a significantly positive effect on the average scale of firms. Total sales for all firms are 4.5% higher and 22% more volatile than when no exports are allowed. Looking at the firms that would have become exporters had the option been available, it can be seen that total sales are 16.4% lower and 12.5% less volatile. In Section 4, I showed that firms that will

[22]To make the second experiment comparable with the benchmark, I adjust the mean of the foreign demand shock downwards to make sure that the mean export-sales ratio is the same in both scenarios.

become exporters are actively accumulating capital and are larger on average than non-exporting firms. In the counterfactual, the capital accumulation pattern of these firms is quite similar to what is depicted in Figure 6, with firms in the counterfactual scenario being just slightly smaller in terms of capital up to the time of entry. However, when positive productivity shocks die out, firms in the counterfactual let their capital start to fall relative to the case in which they can export. Potential exporters would have been 3.6% larger in terms of capital two years after starting to export, and 7.2% larger five periods afterwards had they been able to sell in the two markets. Closing down the foreign market reduces both the occurrence of investment spikes and inaction episodes by 3.4 and 1.1% respectively. Shutting down the foreign market has two main implications for the behavior of firms. First, it reduces the optimal scale of firms, thus reducing the incentive to accumulate capital. Second, the lack of a second market to sell to, dampens the jump in total sales associated with entry into exporting observed in the benchmark calibration.

5.2 Experiment 2: Costless Exports

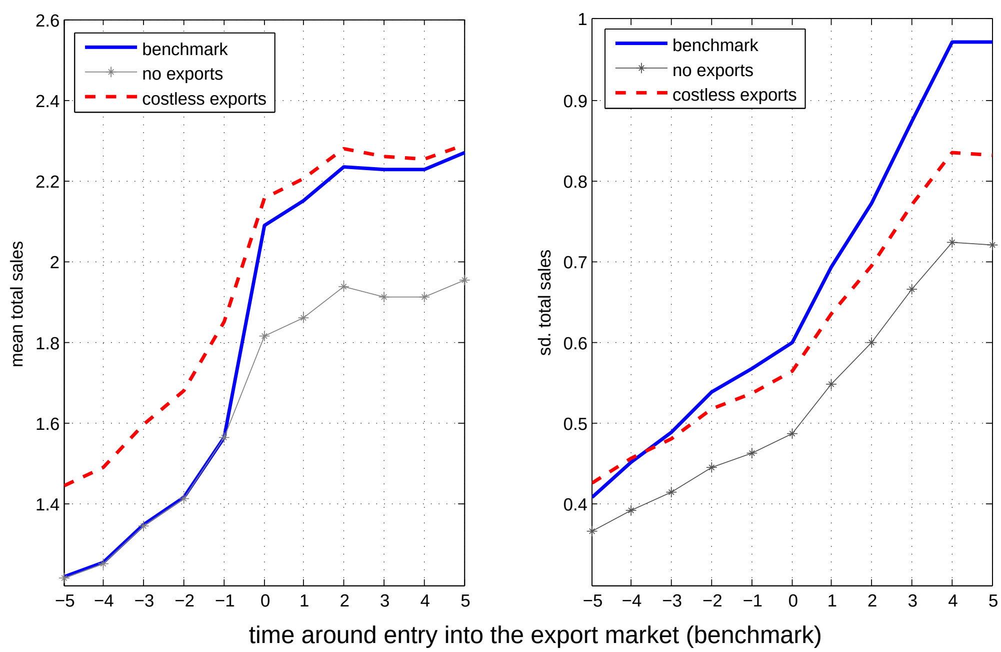
In the second counterfactual experiment I set all the costs of exporting to zero so that all firms find optimal to sell in the foreign market. In this case, total sales are 5.6% less volatile than in the benchmark even though mean total sales are 14% larger as all firms sell in both markets. Firms face smaller deviations from their desired capital stocks, which reduces substantially both the occurrence of investment spikes and inaction episodes by 22.1% and 6% respectively, relative to the benchmark.

The contrast between the two opposite counterfactual scenarios and the benchmark case in which selling abroad is costly, presented in Figure 7, clarifies the reason why exporting makes firms' sales more volatile. The figure presents the behavior of mean total sales and sales volatility around the time in which firms would enter the export market in the benchmark calibration. In the benchmark, average total sales increase by 33% on impact when firms enter the export market, whereas in the counterfactual scenarios the change in mean total sales is not as abrupt (mean total sales rise by 16 and 16.4% in experiments 1 and 2 respectively), either because there is not a second market to enter to, or because these firms are already exporting. The larger change in sales in the benchmark feeds into the measure of sales volatility which is on average 22% higher relative to experiment 1 and 10.8% higher compared to experiment 2. Thus, the large changes in total sales caused by the fixed and sunk costs of exporting when firms enter the export market leads to greater sales volatility for exporting firms.

Table 6: Counterfactual Experiments (All firms)

Statistic	**Benchmark**	**No Exports**	**Costless Exports** ($s_x = f_x = 0$)
Capital	100	97.6	114.1
Mean total sales	100	95.6	113.4
Sd. total sales	100	81.8	94.6
Mean investment rate	100	99.8	98.7
Share of obs. with $\|i/k\| \leq 1\%$	100	98.8	94.0
Share of obs. with $i/k \geq 20\%$	100	96.7	77.9

Figure 7: Mean Sales and Volatility across Counterfactual Scenarios



6 Concluding Remarks

I set up and calibrate a dynamic model of a firm's decision to invest in physical capital and to export. The model has three distinctive features: (i) firms are risk-averse, (ii) investment is perfectly irreversible and (iii) firms face significant costs to start exporting and maintaining a presence abroad. The model is calibrated to match export entry and exit patterns as well as the average share of exports in total sales for Colombian manufacturing firms. The calibrated model replicates several characteristic moments of the distribution of investment rates observed in the data, such as the frequency of inaction and investment spikes, quite closely, in particular the fact that exporting firms are more likely to experience bursts of investment and substantially fewer inaction episodes than non-exporting firms. To my knowledge, this is the first paper documenting how the investment behavior of firms is shaped by their decision to sell in foreign markets.

Two important contributions are derived from the calibrated model: (i) Even though firms are assumed to be risk-averse and thus preferring more stable sales revenues, I show that the correlation between demand shocks is not an important determinant of the decision to export when idiosyncratic firm productivity is highly persistent. This conclusion is reversed when productivity's persistence decreases, in which case, a negative correlation of demand shocks induces more firms to start exporting. (ii) Using the calibrated model to conduct counterfactual experiments allows me to establish that exporting tends to make firms' sales more volatile. Comparing the benchmark simulations with two extreme counterfactual scenarios in which either firms are not allowed to export or all firms find it optimal to export, shows that the large changes in total sales that occur when firms transition into the export market are the main reason why the volatility of total sales increases when firms decide to start exporting.

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