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Exporter Dynamics

Carlos Alfonso Cebreros Zurita
Banco de México

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The Rewards of Self-Discovery: Learning and Firm Exporter Dynamics*

Carlos Alfonso Cebreros Zurita[†]
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Abstract: I develop and estimate a model of export dynamics featuring self-discovery that accounts well for new exporter dynamics: (a) continuation rates that are increasing with tenure, and (b) growth rates of export sales that are decreasing with tenure. The option value generated by the acquisition of more information is key to understanding firm dynamics as the discovery stage lasts as long as this option value is positive. I use the model to study the impact of export promotion policies that temporarily subsidize the fixed costs of exporting. These policies can result in long-lived increases in aggregate trade, but their effectiveness crucially depends on the speed of learning.

Keywords: Learning; Uncertainty; Firm dynamics; Dynamic export supply; Option value.

JEL Classification: C15, D21, D22, D83, F12, F14, L11, L25.

Resumen: Desarrollo y estimo un modelo de la dinámica de exportación basado en el auto-descubrimiento que explica bien la dinámica de los nuevos exportadores: (a) la tasa de continuación es creciente con respecto a la experiencia y (b) la tasa de crecimiento de las ventas de exportación es decreciente con respecto a la experiencia. El valor de opción generado por la adquisición de mayor información es clave para entender la dinámica de las empresas, ya que la etapa de descubrimiento dura tanto tiempo como este valor de opción sea positivo. Uso el modelo para estudiar el impacto de políticas de promoción a las exportaciones que temporalmente subsidian los costos fijos de exportar. Estas políticas pueden resultar en incrementos duraderos en el comercio agregado, pero su efectividad depende crucialmente de la velocidad del aprendizaje.

Palabras Clave: Aprendizaje; Incertidumbre; Dinámica de empresas; Oferta de exportaciones dinámica; Valor de opción.

*I am grateful to Stephen Redding for invaluable guidance in the development of this project. I am also indebted to Esteban Rossi-Hansberg, Gene Grossman, Eduardo Morales, and Bo Honoré for helpful comments at various stages of this project. I also thank Princeton's International Economics Section for financial support, and participants of Princeton's Trade Workshop for their valuable comments and suggestions. All remaining errors are my own.

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1 Introduction

What explains the internationalization process of new exporters? The extensive margin of new exporters plays an important role in export booms (see Roberts and Tybout [1997]). New exporters exhibit a process of selection with high rates of exit and rapid growth conditional on survival.¹ Conditional on survival, exporters undergo a period of adjustment in their foreign market presence lasting several years as they transition from new to mature exporters. Export supply responsiveness is of central importance to policymakers who often tie the success of structural adjustment programs to the extent to which strong export responses follow these reforms. Structural models of export supply with micro-economic foundations provide a useful framework to study the dynamics of firm level trade and to evaluate the impact of trade policy on aggregate trade volumes.

The dynamics of new export entrants in structural models of export supply a la Melitz such as Das et al. [2007] and Ruhl and Willis [2015], that focus on the role that sunk entry costs and persistent shocks to foreign market profitability play on the foreign market dynamics of heterogeneous firms, are at odds with the dynamics of new exporters observed empirically. In these models exporters grow too large too quickly and survive for too long (See Ruhl and Willis for details). By generating new exporters that live too long and export too much, these class of models provide an inaccurate depiction of the importance of the contribution of the extensive margin of entrants in aggregate trade growth and fail to capture the dynamics of internationalization that new exporters go through in the process of establishing a secure foreign market presence. As such, a deeper understanding of the micro-economic foundations of export supply is needed to understand the dynamics of firm level trade and to properly assess the contribution of export entrants in aggregate export growth.

In this paper I develop a quantitative model of export supply and new exporter dynamics by embedding the self-discovery process of Jovanovic [1982] into an otherwise standard trade model as in Melitz [2003]. Self-discovery in the export market will lead to a model with “noisy” selection into exporting and where a firm’s tenure in the export market is the firm characteristic determining growth and survival in the foreign market. I structurally estimate the model using firm-level data for Mexican exporters and show that the estimated model accounts both qualitatively and quantitatively for the observed patterns of export dynamics of new exporters observed in the data.

I use the estimated model to quantify the role of learning in shaping the dynamics of export

¹Besedes and Prusa [2011] find that 70% of new export relationships fail within the first two years.

supply. Little is known about the time span of foreign market unfamiliarity. When export entrants perceive their own lack of foreign-market knowledge, how long does it take them to remedy this situation? How does the option value generated by self-discovery shape the export supply decision of firms relative to a purely static model of export supply such as Melitz [2003]? The structural model developed here allows me to broach these issues and to quantify the role that self-discovery at the firm level plays in determining the effectiveness of export promotion on aggregate trade.

In contrast to models which highlight sunk entry costs and production heterogeneity, this model gives prominence to self-discovery as a key determinant of the export supply responsiveness of new exporters. Export promotion agencies (EPAs) often argue that limited information about foreign markets represents an important barrier to the internationalization process of new export entrants. Survey evidence supports this view. In a survey of non-exporting members of the Turkish Chamber of Commerce, Karakaya and Harcar [1999] found that “lack of information about foreign markets” was the most important external barrier to exporting perceived by respondents. The same results were found by Jalali [2012] in a survey of Greek firms, by Pinho and Martins [2010] in a survey of Portuguese firms, and by Milanzi [2012] in a survey of firms in Tanzania.² Furthermore, in a survey of U.K. firms Kneller and Pisu [2011] found that “lack of information about foreign markets” was perceived by firms as a key barrier to exporting, regardless of size or productivity, and that after two years of experience in the export market half of the responding firms no longer perceived this as a barrier to their export activities. The authors argue that their evidence suggests that firms learn how to “cope” with this export barrier through their direct experience in export markets.

Unfamiliarity with demand conditions has also been found to be an important determinant of the observed differences between firms of different ages in domestic markets. Using data for U.S. manufacturing plants, Foster et al. [2008] compare measures of physical and revenue based productivity and find that demand variation across producers are the dominant factor in determining survival. In Foster et al. [2012] the authors argue that the observed size differences between young and old plants are unlikely to be the results of productivity differences since physical TFP levels of new plants are slightly higher than those of incumbents and these differences vanish by the time plants are five years old. On the other hand, these authors document important differences in the idiosyncratic demands faced by plants: at the same price a new plant will sell only 58% of the output of a plant in the same industry that is

²Leonidou [2004] provides a survey of firm-level studies of barriers to exporting and finds that “limited information about foreign markets” can be cataloged as a “very high impact export barrier” amongst the 39 export barriers covered by the 32 empirical studies under his consideration.

more than 15 years old.

Foster et al. [2012] argue that the evidence lends support to a model featuring dynamic demand-side forces that lead to the accumulation of relationship capital along buyer-supplier links as the explanation for the gradual growth of entrants (conditional on survival) that is observed for U.S. manufacturing plants. A model of “learning” about demand would be consistent with these findings. Since the dynamics that differentiate young and old plants may also apply to the dynamics that distinguish new and established exporters, “learning” about conditions in the foreign market could help understand the gradual adjustment in the foreign market presence of new exporters. Consistent with the findings of Foster et al. [2008, 2012], Artopoulos et al. [2013] conducted a study of Argentinian exporters in four selected industries which experienced episodes of export emergence and found that foreign market knowledge was a critical constraint to achieving consistent exports. In fact, these authors find that it is a lack of foreign market knowledge rather than a lack of production knowledge which inhibits firms from developing an established export presence in foreign markets.

The model developed in this paper features self-discovery as the driving force shaping the dynamic behavior of export entrants. The evolution of a firm’s beliefs regarding its “export profitability” is the key determinant of the firm’s expansion in foreign markets. Expectations concerning export profitability will affect a firm’s calculations regarding whether future export profits will cover the costs of maintaining a foreign market presence or not. In fact, all the dynamics in the model will be driven by the learning process that firms undergo and the state dependence that this process generates through the firm’s information sets. However, this force shaping export dynamics will be decreasing in importance with export tenure as firms learn their way out of foreign market unfamiliarity.

The main results that I obtain from the estimated model and counterfactuals are: (i) first-time exporters expect to incur losses by serving the foreign market, but the option value generated by the acquisition of more precise information regarding export profitability compensates inexperienced exporters for these losses; (ii) the initial period serving the foreign market provides a crucial learning experience for new exporters, but the discovery stage extends beyond the first year: the value of learning remains positive for the first four years of tenure in the export market. The probability of exiting the export market decreases with tenure and after the discovery stage is only 5% higher than the exit probability of well established exporters; the cutoff for exporting experiences 90% of its long-term adjustment over the same period; (iii) firms that continuously export over a period of six years observe a 137% increase in their (ex ante) probability of serving the foreign market and a 900% increase in

their (average) export premia, and (iv) temporary shocks to the profitability of serving the export market can have long-lived consequences on aggregate trade volumes. In particular, export promotion policies that temporarily subsidize the fixed costs of maintaining a presence in the foreign market can result in long-term increases in aggregate trade volumes.

My work is related to a recent literature that has exploited firm- and plant-level data to uncover a set of stylized facts for exporters (see, for example, Eaton et al. [2011] and Bernard et al. [2012]) and to the work of Arkolakis [2010], Ruhl and Willis [2008], and Alessandria et al. [2013] that studies the dynamics of new export entrants. However, rather than focusing on the cost structure faced by firms as these authors have done, I focus on the role of demand side uncertainties on export decisions. In this sense, my work is related to the work on firm experimentation of Rauch and Watson [2003] and, more closely, to Akhmetova and Mitari-tonna [2013]. The latter authors study the effects of demand side uncertainties on exporter behavior, but their focus is on the choice of technology used to serve the foreign market while the focus here is on the observed relationship between growth, survival and export tenure for new export entrants.

This paper is most closely related to the work on exporting and demand uncertainty of Nguyen [2012] and the work on learning in foreign markets of Albornoz et al. [2012] and Arkolakis et al. [2015]. Nguyen focuses on the role that demand uncertainty and learning play in explaining the delays in export entry of non-exporting firms and their subsequent high failure rates upon entry. Albornoz et al. provides reduced form evidence in support of the claim that when firms face ex-ante uncertainty regarding the profitability of serving the export market, shortcomings at the discovery stage are an important explanation for the limited export success of some developing countries. Arkolakis et al. is the most closely related to the present paper and focuses on the general equilibrium and welfare implications of a model of firm learning in foreign markets.³ In contrast to Albornoz et al., I take a structural approach to the role of learning in shaping firm-level dynamics in the foreign market, and in contrast to Arkolakis et al. I focus on quantifying the duration of foreign market unfamiliarity and the option values associated with learning that shape new exporter dynamics.

The model studied here is also related to the work of Arkolakis [2015] who studies the dy-

³The framework developed in section 3 of the present paper is very similar to the one developed independently by Arkolakis et al. [2015]. While the first version of this paper was available before the first draft of theirs, I acknowledge the overlap between both. Our papers are, nevertheless, complementary in some respects. Their analysis is focused on the general equilibrium and welfare implications of the learning mechanism, while I spend more time on estimation and the model's ability to account for the firm-level dynamics of new exporters that are observed in the data.

namics of selection and growth in a general equilibrium model of international trade. However, here self-discovery is the driving force behind firm dynamics in the foreign market so it is export tenure rather than size which determines the opportunities for growth and survival. Finally, my work also relates to the dynamic structural models of export supply of Das et al. [2007] and Morales et al. [2014] which structurally estimate micro-founded models of export dynamics. Das et al. focus on the firm level dynamics implied by sunk entry costs and production heterogeneity and their consequences for aggregate trade in response to devaluations and export subsidies. Morales et al. focus on the dynamics of the extensive margin of destinations served and study “extended gravity” forces that lead exporting firms to enter foreign markets which are similar to markets previously served. In contrast, the focus here is on the firm level dynamics implied by demand-side uncertainties and the adjustment of firms along the intensive margin of trade.

The rest of the paper is organized as follows. Section 2 uses Mexican firm-level data to document the dynamics of new export entrants that motivate the rest of the paper. Section 3 develops a model of export-supply featuring self-discovery, and Section 4 describes the estimation approach and presents the results from estimation. Section 5 uses the estimated model to quantify the role of self-discovery in the export supply decisions of new exporters, and Section 6 uses the model to perform counterfactuals regarding export promotion and the speed of learning. Section 7 concludes.

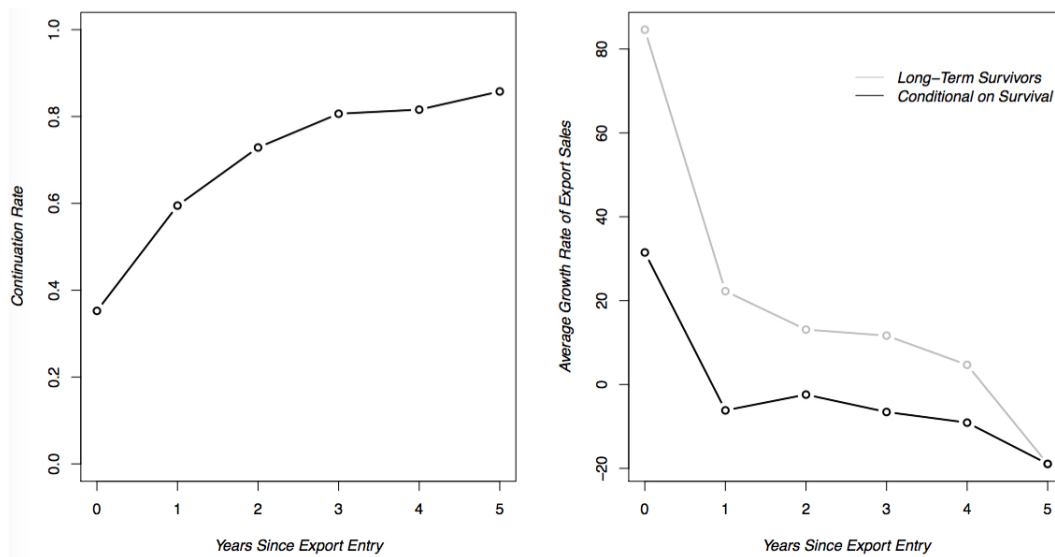
2 Data and empirical regularities

Micro-level data reveal that new exporters experience a period of adjustment that continues after entry into export markets. Using transaction-level customs data for Mexican exporters for the period 2000-2007, this section documents the dynamics of export entrants as they transition from new to experienced exporters which is the focus of this paper. The data was collected by the Trade and Integration Unit of the World Bank Research Department, as part of their efforts to build the Exporter Dynamics Database described in Fernandes et al. [2015].⁴ The cross-sectional features of the Mexican micro-level trade data is consistent with the stylized facts that have informed trade models that emphasize the importance of selection into exporting to account for the observed patterns in transaction-level data. Details concerning the cross-sectional features of the Mexican trade data can be found in Cebrenos

⁴The sources for the data are detailed at <http://econ.worldbank.org/exporter-dynamics-database>

[2015].

I concentrate my attention on the cohort of exporters whose first period reporting positive exports is 2001 (i.e. “new” exporters) and track the outcomes of these firms over the period 2001-2007. Figure 2.1 documents two prominent features of new exporter dynamics present in the Mexican firm-level trade data: (a) continuation rates are increasing with tenure, and (b) average growth rates of export sales are decreasing with tenure. The profile of continuation rates implies that there is a sharp drop in export participation amongst new exporters after their initial venture into the export market: after the first year only 35 percent of the cohort will continue to serve the foreign market. Also notice that declining average growth rates after export entry are not entirely driven by *selection effects*: these dynamics also play out for the subset of firms that maintained a consistent export presence throughout the sample period (i.e. the “long-term survivors” are those new exporters that exported every period after export entry). Similar patterns have been documented for Colombian firm-level trade data by Ruhl and Willis [2015] and for Chilean firm-level data by Kohn et al. [2015], while Besedes and Prusa [2011] also document a downward sloping exit hazard in a sample of disaggregated bilateral manufacturing exports for 46 countries for the period 1975-2003.⁵



x – axis : Years since export entry. y – axis : Continuation rate (panel a); Average growth of Export sales (panel b).

Source: Author’s own calculations using Mexican firm-level export data from the World Bank’s Exporter Dynamics Database.

Figure 2.1: New Exporter Dynamics

⁵The exit hazard is mechanically related to the export continuation rate.

To show that the dynamics exhibited in Figure 2.1 are unique to new export entrants and not all firms serving the export market during the same reference period, Figure 2.2 compares the growth dynamics of new and mature exporters. Specifically it contrasts the growth dynamics of the subset of “long-term survivors” from the 2001 cohort of new exporters to the growth dynamics of “perennial exporters”, which are the subset of firms that exported continually from 2000-2007. Data limitations preclude a more nuanced definition of mature exporters, so I take the group of perennial exporters as my proxy for firms with a well developed export presence. Figure 2.2a shows that the growth dynamics documented in Figure 2.1 are not shared by mature exporters. Figure 2.2b plots the coefficients from the regression

$$\log(X_{ijt}) - \log(X_{ijt-1}) = \lambda_{jt} + (D_i \times \lambda_t) + \varepsilon_{ijt},$$

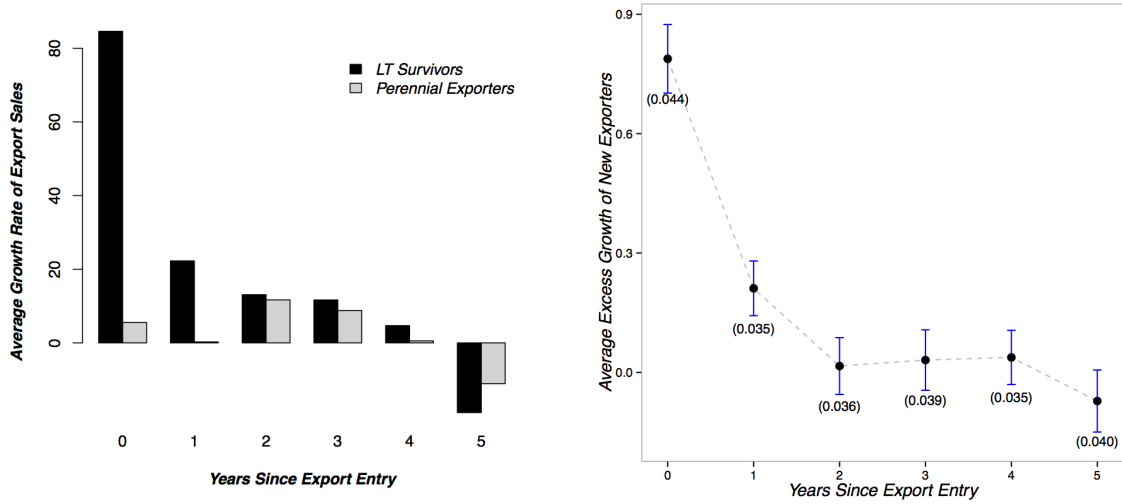
where the dependent variable is the growth rate of export sales for firm i in sector j between $t - 1$ and t , λ_{jt} is a sector-time fixed effect that controls for aggregate shocks to sector j at time t , and D_i is equal to 1 if firm i is a long-term survivor and 0 if the firm is a perennial exporter. The coefficient on the interaction $D_i \times \lambda_t$ is the average excess growth rate of long-term survivors over perennial exporters at time t .⁶ It can be seen that the growth premium of new over mature exporters is statistically significant and declining over time as new exporters develop their presence in foreign markets.

While Figure 2.2 establishes that the adjustment dynamics depicted in Figure 2.1 are characteristic of new export entrants, but not of more established exporters, Figure 2.3 shows that these dynamics are common to export entrants of all sizes. Classifying firms by quartiles of their export sales upon entry, Figures 2.3a and 2.3b show that the adjustment dynamics of new export entrants play out across the size distribution of new export entrants. Table 1 shows the results from the following econometric specification

$$\begin{aligned} Y_{ijt,t-1} &= \lambda_{jt} + \delta_T \text{Tenure}_{it} + \tilde{\delta}_T \text{Tenure}_{it}^2 \\ &\quad + \sum_{k=2}^4 \gamma_k (Q_{i,t-1}^k \times \text{Tenure}_{it}) + \sum_{k=2}^4 \tilde{\gamma}_k (Q_{i,t-1}^k \times \text{Tenure}_{it}^2) + \varepsilon_{ijt} \\ \ln X_{it+1} - \ln X_{it} &= \lambda_{jt} + \delta_T \text{Tenure}_{it} + \tilde{\delta}_T \text{Tenure}_{it}^2 \\ &\quad + \sum_{k=2}^4 \gamma_k (Q_{i,t-1}^k \times \text{Tenure}_{it}) + \sum_{k=2}^4 \tilde{\gamma}_k (Q_{i,t-1}^k \times \text{Tenure}_{it}^2) + \varepsilon_{ijt}, \end{aligned}$$

where λ_{jt} is a time-sector fixed effect that captures aggregate shocks to sector j at time t that might affect the export participation decision of all firms in that sector, Q_{it-1}^k is a dummy

⁶I assign firms to a sector according to their best-selling HS-6digit product in their first year in the sample.



(a) Growth Dynamics: New vs Mature Exporters (b) Average Excess Growth Rate of New Exporters. Robust standard errors clustered at the firm level in parentheses.
x – axis : Years since export entry. *y* – axis : Average growth of Export sales (panel *a*); Average excess growth of new exporters (panel *b*).

Source: Author’s own calculations using Mexican firm-level export data from the World Bank’s Exporter Dynamics Database.

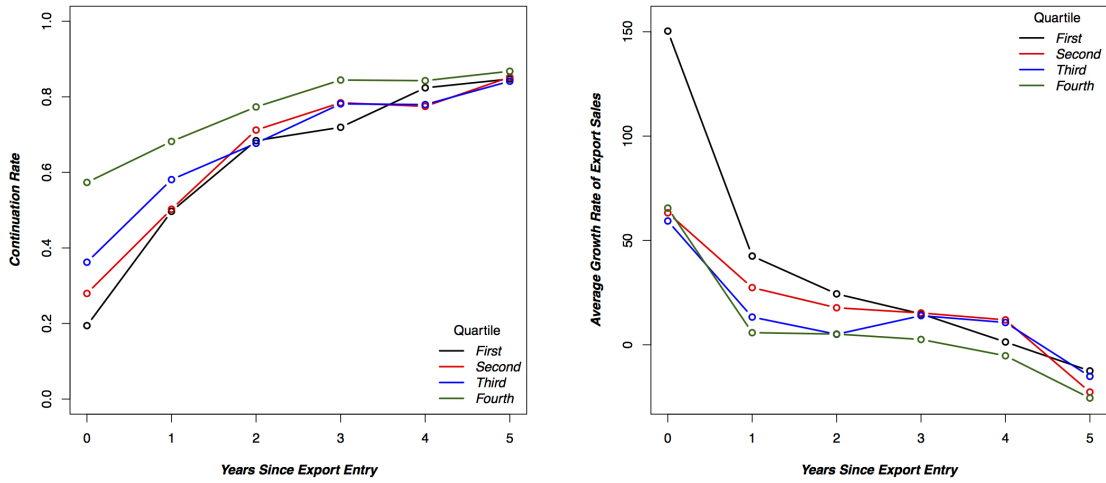
Figure 2.2: New vs Mature Exporter Dynamics

variable for whether firm i belonged to the k th quartile of the sales distribution at time $t - 1$, $Tenure_{it}$ denotes firm i 's tenure in the export market at time t (i.e. the number of periods it has exported before time t), X_{it} are firm i 's export sales at time t , and conditional on exporting at time $t - 1$,

$$Y_{ijt,t-1} = \begin{cases} 1 & \text{if firm } i \text{ exports at time } t \\ 0 & \text{otherwise} \end{cases}.$$

The omitted category is the first quartile, so the γ 's should be interpreted relative to the first quartile and the growth regression only includes observations for long-term survivors. Table 1 confirms that the effects of tenure on growth and survival across size quartiles depicted in Figure 2.3 are statistically significant. These results show that both continuation and growth rates of export sales are strongly correlated with size upon entry⁷, but that regardless of initial size new export entrants experience a period of gradual adjustment in the foreign market.

⁷A logistic regression for the outcome of being a long-term survivor shows that size on entry is a statistically significant determinant of long-term survival prospects and that a one standard deviation increase in initial size is associated with a 20% increase in the odds of becoming a long-term survivor.



(a) Continuation Rates by Quartile

(b) Growth Dynamics of Long-term Survivors by Quartile

x – axis : Years since export entry. y – axis : Continuation rate (panel *a*); Average growth of Export sales (panel *b*).

Source: Author’s own calculations using Mexican firm-level export data from the World Bank’s Exporter Dynamics Database.

Figure 2.3: New Exporter Dynamics by Size

A common explanation for the process of gradual adjustment experienced by new exporters is that their scale of operation in the foreign market is constrained by access to credit and/or liquidity (see, for example, Kohn et al. [2015]). In this case, survival and growth are related to tenure as firms accumulate assets and become unconstrained. While credit constraints may be an important internal constraint on the export presence of new export entrants, survey evidence indicates that non-exporting firms and new exporters perceive a lack of foreign market knowledge as an important outside constraint on establishing their export presence (see, for example, Karakaya and Harcar [1999], Kneller and Pisu [2011], and Jalali [2012]). Albornoz et al. [2012], using firm-level data for Argentinean firms, provide reduced form evidence that the kind of adjustment dynamics displayed in Figure 2.1 cannot be entirely explained by credit constraints faced by firms. These authors argue, as I do here, that learning about foreign markets through exporting is an important determinant of new exporter dynamics.

Unfortunately I lack firm-level data on access to credit and liquidity constraints, but I explore the role of financial frictions on new exporter dynamics for Mexican exporters by relating firm-level outcomes to sectoral measures of financial vulnerability as in Manova et al.

	Continuation Rate	Export Growth
<i>Tenure</i>	-0.02 (0.03)	-1.86 (2.45)
<i>Quartile</i> ₂ × <i>Tenure</i>	0.09*** (0.01)	-0.48*** (0.10)
<i>Quartile</i> ₃ × <i>Tenure</i>	0.17*** (0.01)	-0.79*** (0.11)
<i>Quartile</i> ₄ × <i>Tenure</i>	0.31*** (0.01)	-0.75*** (0.10)
<i>Tenure</i> ²	0.01** (0.00)	0.30 (0.40)
<i>Quartile</i> ₂ × <i>Tenure</i> ²	-0.01*** (0.00)	0.05* (0.02)
<i>Quartile</i> ₃ × <i>Tenure</i> ²	-0.02*** (0.00)	0.10*** (0.02)
<i>Quartile</i> ₄ × <i>Tenure</i> ²	-0.05*** (0.00)	0.09*** (0.02)
<i>R</i> ²	0.21	0.17
No. Obs.	21344	4992

OLS regression. Standard errors in parentheses (clustered at the firm level).

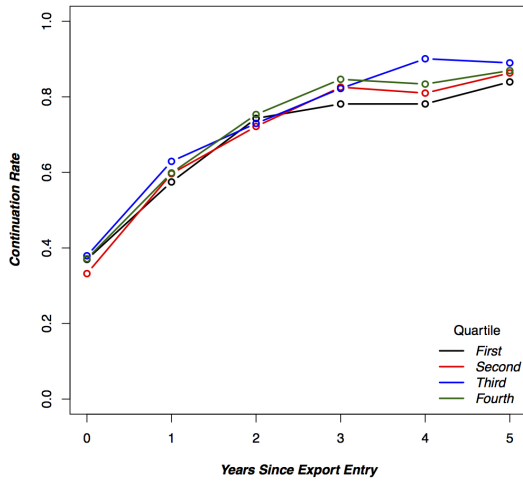
Significance codes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 1: Growth and Survival by Size

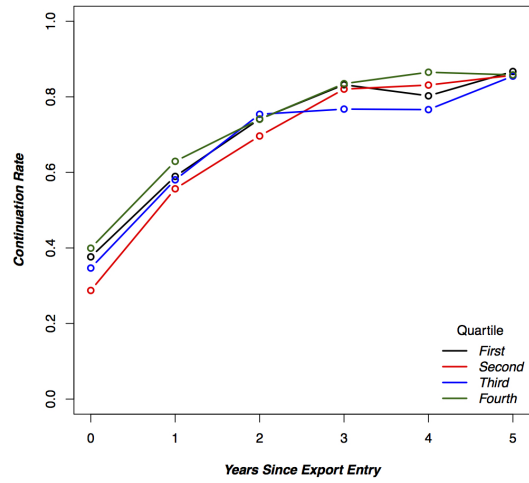
[2015].⁸ Sectoral financial vulnerability proxies for the sensitivity of a firm to the availability of outside capital. Of particular relevance are two measures of financial vulnerability: (i) *external finance dependence* which is the share of capital expenditures not financed with cash flows from operations and that identifies outside funding needs required for long-term investments such as the payment of upfront fixed costs; and (ii) *asset tangibility* which denotes availability of assets that can be pledged as collateral. Both of these measures relate to a firm's exposure and ability to overcome financial frictions. In addition, I also consider two other measures of financial vulnerability: the *inventory ratio* which proxies for the duration of the production cycle and the liquidity needed to maintain inventories and meet demand, and *trade credit intensity* which uses the ratio of changes in accounts payable to changes in total assets to characterize the availability and frequency of trade credit in an industry. Further details regarding these measures of sectoral financial vulnerability can be found in Manova et al. [2015].

Figures 2.4 and 2.5 show the dynamics of export entrants by quartiles of sectoral financial

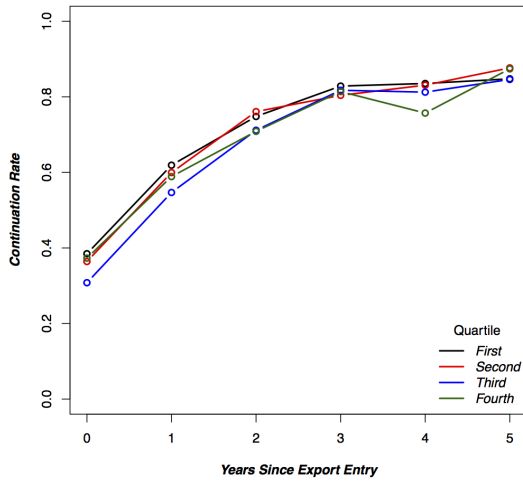
⁸The sectoral financial vulnerability data is classified according to the ISIC rev2 3-digit categories, while the firm-level data is classified at the HS 6-digit classification. To classify firms by industries, first I assign a firm to an HS6 industry according to the industry of its bestselling export product in the initial year. Then, to determine the sectoral financial vulnerability corresponding to the firm I map the HS 6-digit product categories to the ISIC 3-digit categories using the concordance available at WITS-concordance.



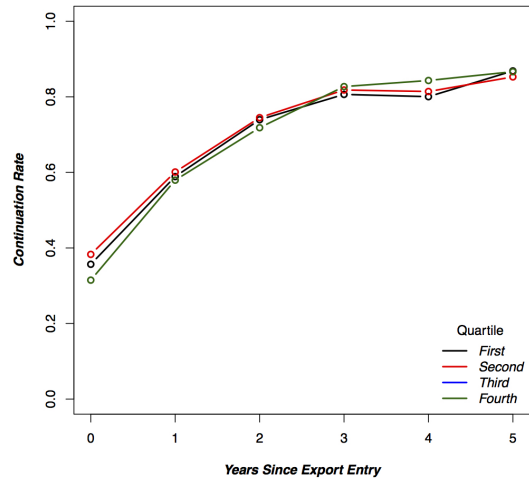
(a) External finance dependence



(b) Asset tangibility



(c) Inventory Ratio



(d) Trade credit intensity

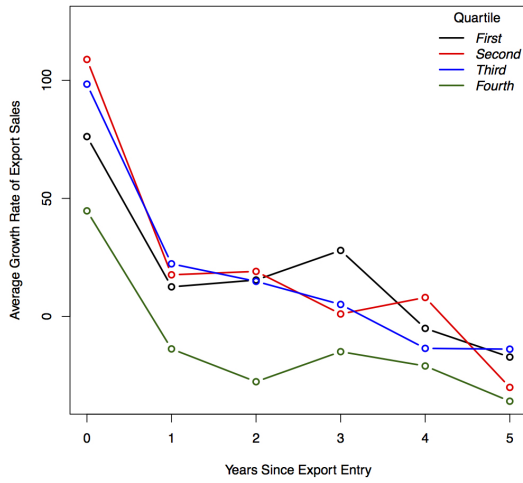
$x - axis$: Years since export entry. $y - axis$: Continuation rate.

Source: Author's own calculations using Mexican firm-level export data from the World Bank's Exporter Dynamics Database and the sector classification of Manova et al. [2015].

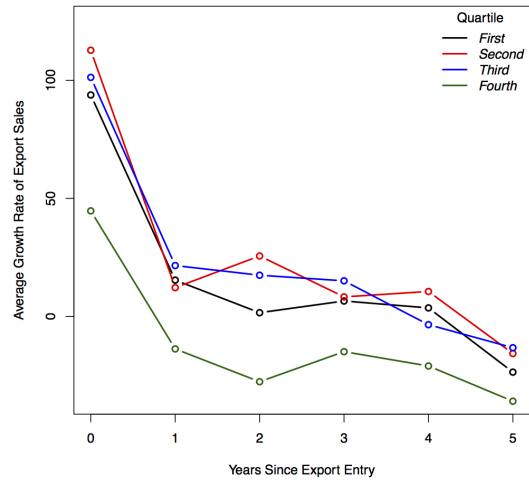
Figure 2.4: Survival and Financial Vulnerability

vulnerability.⁹ It can be seen from these figures that for all measures and for all quartiles of financial vulnerability the adjustment dynamics of Figure 2.1 are still present. I explore

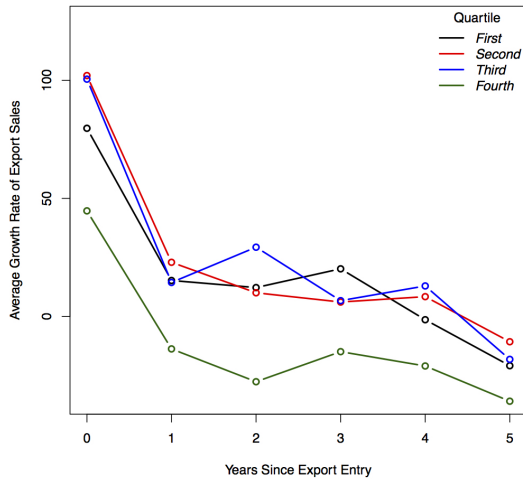
⁹For trade credit intensity only three quartiles are shown since both 50% and 75% of observations are below the percentile 0.8.



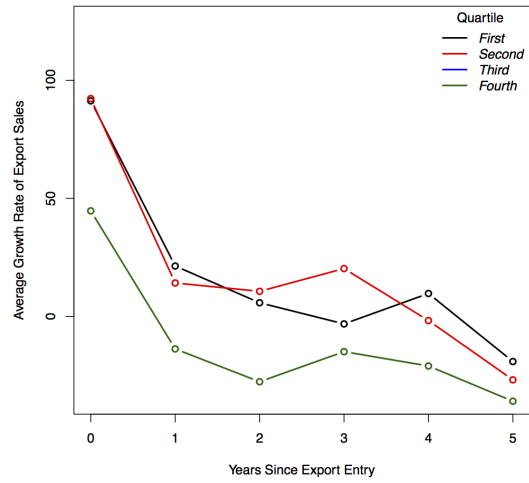
(a) External finance dependence



(b) Asset tangibility



(c) Inventory Ratio



(d) Trade credit intensity

x - axis : Years since export entry. y - axis : Average growth of Export sales.

Source: Author's own calculations using Mexican firm-level export data from the World Bank's Exporter Dynamics Database and the sector classification of Manova et al. [2015].

Figure 2.5: Growth and Financial Vulnerability

these results further through an econometric specification analogous to that behind the results reported in Table 1, but where here I replace Q_{it-1}^k with Q_{ij}^k that is a dummy variable for whether sector j , to which firm i belongs to, belongs to the k th quartile of a measure of financial vulnerability. The results reported in Tables 2 and 2.5 confirm that there is no

statistically significant difference in the relation of tenure, growth and survival across sectors which are differentially exposed to the need and availability of outside capital. These results are consistent with the findings of Albornoz et al. [2012] and show that financial frictions alone cannot account for the gradual internationalization process that new exporters undergo. Figure 2.3 also suggests that financial frictions alone cannot explain the gradual adjustment firms upon entry into the export market since even the top quartile of long-term survivors, which themselves are already at the top of the size distribution upon entry, display these dynamics and these large firms are the least likely to be financially constrained.¹⁰ Furthermore, in their calibrated model Kohn et al. [2015] show that financial frictions can account for the positive relationship between tenure and continuation rates and the negative relationship between tenure and growth rates, but in both cases the relationship is nearly linear while in the data there is a clear non-linear relationship between tenure, growth and survival. As I will show in sections 3 and 4, the estimated learning model of this paper can account for both the positive (negative) relationship between tenure and continuation (growth) rates *and* the diminishing effect of tenure on growth and survival.

	Ext.Fin.Dep.	Asset Tang.	Invt. Ratio	Trade Crd. Int.
<i>Tenure</i>	0.24*** (0.06)	0.16** (0.05)	0.23*** (0.06)	0.21*** (0.05)
<i>Quartile₂ × Tenure</i>	0.01 (0.08)	0.10 (0.08)	-0.02 (0.08)	0.01 (0.07)
<i>Quartile₃ × Tenure</i>	-0.02 (0.13)	0.15 (0.08)	0.01 (0.08)	
<i>Quartile₄ × Tenure</i>	-0.07 (-0.08)	0.06 (0.08)	-0.03 (0.01)	0.05 (0.08)
<i>Tenure²</i>	-0.02* (0.01)	-0.00 (0.01)	-0.01 (0.01)	-0.01 (0.01)
<i>Quartile₂ × Tenure²</i>	0.00 (0.01)	-0.01 (0.01)	0.00 (0.01)	-0.00 (0.01)
<i>Quartile₃ × Tenure²</i>	0.01 (0.02)	-0.02 (0.01)	-0.00 (0.01)	
<i>Quartile₄ × Tenure²</i>	0.01 (0.01)	-0.01 (0.01)	0.00 (0.01)	-0.01 (0.01)
<i>R²</i>	0.15	0.15	0.15	0.15
No. Obs.	21344	21344	21344	21344

OLS regression. Standard errors in parentheses (clustered at the firm level).

Significance codes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 2: Survival and Financial Vulnerability

Finally, it is often argued that entrant firms may differ significantly across product character-

¹⁰Using a firm-level size-stratified survey of 4000 firms in 54 countries, Beck et al. [2005] find that the activities and growth of large firms are largely unaffected by financial frictions and financial underdevelopment.

	Ext.Fin.Dep.	Asset Tang.	Invt. Ratio	Trade Crd. Int.
<i>Tenure</i>	-0.23 (0.23)	-0.98** (0.31)	-1.40** (0.51)	-0.25 (0.32)
<i>Quartile₂ × Tenure</i>	0.02 (0.18)	0.16 (0.18)	1.14* (0.53)	0.45 (0.48)
<i>Quartile₃ × Tenure</i>	-0.69* (0.32)	0.28 (0.21)	0.71* (0.30)	
<i>Quartile₄ × Tenure</i>	-0.21 (0.30)	-0.42 (0.31)	0.42 (0.31)	-0.69* (0.32)
<i>Tenure²</i>	-0.02 (0.04)	0.10* (0.04)	0.22* (0.10)	-0.02 (0.05)
<i>Quartile₂ × Tenure²</i>	0.01 (0.04)	-0.03 (0.03)	-0.26* (0.12)	-0.06 (0.09)
<i>Quartile₃ × Tenure²</i>	0.19* (0.09)	-0.07 (0.04)	-0.17* (0.08)	
<i>Quartile₄ × Tenure²</i>	0.09 (0.06)	0.12 (0.09)	-0.12 (0.09)	0.19* (0.09)
<i>R²</i>	0.10	0.10	0.10	0.10
No. Obs.	4992	4992	4992	4992

OLS regression. Standard errors in parentheses (clustered at the firm level).

Significance codes: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3: Growth and Financial Vulnerability

istics and that these differences can be related to the importance that learning about foreign market conditions has on shaping firm dynamics in the foreign market. In particular, Pedersen and Petersen [2002] argue that producers of customized or differentiated products are involved in more extended learning processes than are producers of standardized products. Using the product classification provided by Rauch [1999], column 4 in Table 4 reports the fraction of HS6 digit products classified as differentiated amongst all HS6 products exported by Mexican firms and columns 5-7 report the fraction of firms whose main source of export revenue comes from differentiated products.¹¹ Table 4 shows that differentiated products, that according to Pedersen and Petersen are the products for which learning in foreign markets is most important, are ubiquitous in Mexican trade. If producers of standardized products do not have much need for learning in foreign markets, we should expect these firms to exhibit higher continuation rates than producers of differentiated products and lower growth rates of

¹¹In Rauch [1999] industries are classified according to the SITC rev2. classification, which I map to the HS6 digit classification using the concordance available at WITS-concordance. For each year in the sample, between 43 and 45 percent of the HS product categories exported by Mexican firms can be classified according to Rauch's classification. In turn, this implies that roughly 33% of the firms in the sample can be classified as standardized or differentiated. Firms are classified as differentiated according to the following criterion: for the HS6 digit products that can be classified as differentiated or standardized I calculate the share of firm export revenues that accrue to differentiated products and classify a firm as differentiated if this share is larger than X percent, where X can be 50, 70 or 90 in turn.

export sales as learning does not lead to much adjustment in their scale of operation in the foreign market. Figure 2.6 displays new exporter dynamics for producers of differentiated and standardized products. Figure 2.6a shows that as expected, producers of standardized products have higher continuation rates than producers of differentiated products. On the other hand, Figure 2.6b shows that there is a negative relationship between tenure and growth for producers of differentiated products, but no discernible relationship between tenure and growth for producers of standardized products. In addition, it is not clear that producers of differentiated products exhibit higher growth rates of export sales than exporters of standardized products. These results remain even after controlling for sector specific aggregate shocks. However, the results are not statistically significant due to the small sample size of new exporters classified as producers of standardized products.

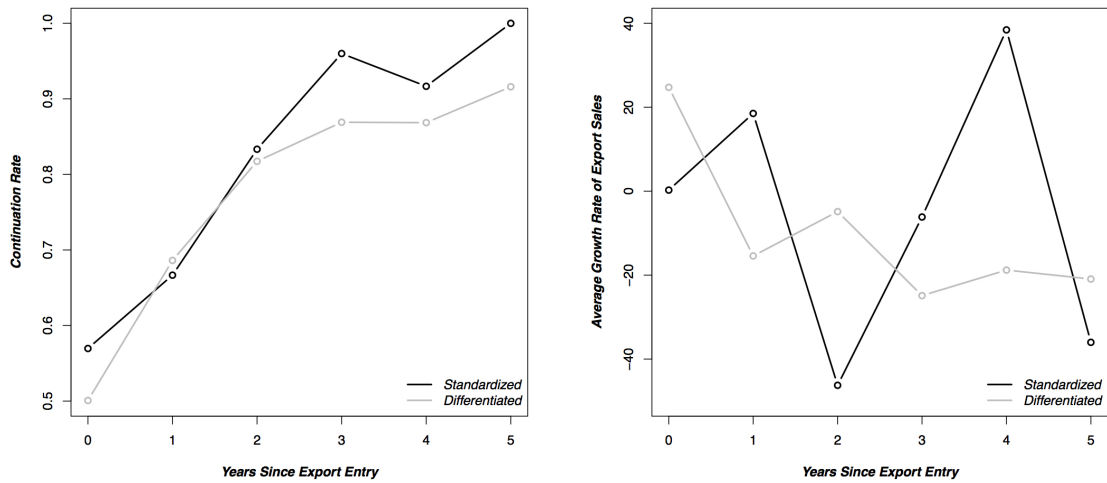
Year	Share of Export Value that can be classified as Standardized or Differentiated	Share of Export Value that can be classified as Differentiated	Proportion of Products Classified as Differentiated*	Proportion Differentiated Product Firms (>50%)*	Proportion Differentiated Product Firms (>70%)*	Proportion Differentiated Product Firms (>90%)*
2000	57%	47%	0.70	0.87	0.86	0.85
2001	59%	49%	0.70	0.87	0.87	0.86
2002	59%	49%	0.70	0.87	0.86	0.85
2003	58%	46%	0.70	0.87	0.86	0.85
2004	59%	45%	0.70	0.87	0.86	0.85
2005	59%	44%	0.70	0.87	0.86	0.85
2006	61%	45%	0.70	0.87	0.86	0.84
2007	54%	38%	0.70	0.87	0.86	0.84

*Conditional on being classified as standardized or differentiated.

Source: Author's own calculations using Mexican firm-level export data from the World Bank's Exporter Dynamics Database and the sector classification of Rauch [1999].

Table 4: Participation of Differentiated Products in Mexican Trade

The results presented here show that new exporters experience a substantial risk of failure early in their export tenure, but that conditional on survival they undergo a period of gradual adjustment in the export market. This gradual internationalization process is shared by export entrants of all sizes and cannot be fully accounted for by financial frictions constraining the foreign market presence of new export entrants. In what follows I show that introducing self-discovery into an otherwise standard model of export supply goes a long way in explaining



(a) Continuation Rates

(b) Growth Dynamics

x – axis : Years since export entry. y – axis : Continuation rate (panel *a*); Average growth of Export sales (panel *b*).

Source: Author’s own calculations using Mexican firm-level export data from the World Bank’s Exporter Dynamics Database and the secto classification of Rauch [1999].

Figure 2.6: New Exporter Dynamics: Differentiated vs Standardized Products

the features of the data presented in Figure 2.1.¹² I use my estimated model to quantify the importance of learning in the export supply decisions of new exporters and to study the impact of export promotion policies.

3 An empirical model of export supply with self-discovery

In this section I present a model of export supply that introduces firm learning into an otherwise standard trade model in a way that is both tractable and amenable to estimation. As such, the model will rely heavily on several key assumptions. First, I start with what has become by now a standard framework for studying the export supply decision (see Melitz [2003]). The domestic and export markets are assumed to be segmented and monopolistically competitive.

¹²Figure 2.6b suggest that the new exporter dynamics reported in Figure 2.1 are driven by the dynamics of producers of differentiated products, for who it is argued learning about its potential to “match” with the foreign market is most important.

On the demand side, I assume that the economy is described by CES preferences

$$C = \left(\int_{\Omega} \varepsilon(\omega) c(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\frac{\sigma}{\sigma-1}},$$

where $\sigma > 1$ is the elasticity of substitution across varieties $\omega \in \Omega$, $c(\omega)$ is consumption of variety ω and $\varepsilon(\omega)$ are consumer preferences for this variety. Given CES preferences, and the assumption that firms meet the demand for their product, the revenues for a producer of variety ω are given by

$$r(\omega) = \varepsilon(\omega) PC^{\frac{1}{\sigma}} q(\omega)^{\frac{\sigma-1}{\sigma}},$$

where P is the CES ideal price index and C is aggregate consumption.¹³ Notice that the term $PC^{\frac{1}{\sigma}}$ acts as a demand shifter common to producers of all varieties, while $\varepsilon(\omega)$ acts as a demand shifter specific to the producer of that variety.

For simplicity I will assume that in the domestic market firms face no aggregate or idiosyncratic uncertainty and normalize the demand shifter in that market to unity.¹⁴ In the export market I assume that all the uncertainty faced by the firm is regarding idiosyncratic preferences for their product and that these preferences depend on a underlying variable θ_t which is unknown to the firm. In what follows I assume that the demand shifter capturing the strength of demand for the firm's product in the foreign market is given by $h(\theta_t)$, which captures both aggregate $\left(PC^{\frac{1}{\sigma}}\right)$ and idiosyncratic (ε) determinants of the demand for the firm's product in the foreign market. These assumptions imply that the firm faces the following revenue functions

$$\begin{aligned} \text{(Domestic Revenues)} & : r(q_t) = q_t^{\frac{\sigma-1}{\sigma}} \\ \text{(Export Revenues)} & : r^*(q_t^*) = h(\theta_t) q_t^{*\frac{\sigma-1}{\sigma}}. \end{aligned}$$

The analysis here focuses on the micro-economic foundations of the dynamic behavior of firm level export supply decisions. Thus, I abstract from general equilibrium effects by focusing on the firm level export supply decision taking the demand shifter in the foreign market as given.¹⁵

¹³A firm is a producer of one of the differentiated varieties available for consumption in the economy.

¹⁴This simplification highlights that the focus here is on domestically established firms that have the potential to export, but have not yet started to do so.

¹⁵The function $h : \mathbb{R} \rightarrow \mathbb{R}_+$ is assumed to be continuous and bounded. The representation of the firm's dynamic optimization problem through the functional equation defined by the Bellman operator necessitates the period return function to be bounded in the firm's state variables. Restricting $h(\cdot)$ to be bounded guarantees that

I assume that

$$\theta_t = \theta + \varepsilon_t,$$

where $\varepsilon_t \stackrel{i.i.d.}{\sim} N(0, v_\varepsilon)$ are firm specific shocks, independent over time and across firms. θ is the firm's "fundamental export profitability", a persistent component affecting foreign market revenues. This specification for the stochastic process $\{\theta_t\}$ provides a tractable way to introduce transitory and permanent, but unknown, components that affect firm revenues into a standard model of export supply.

The distribution of "fundamental export profitabilities" among the potential entrants is known to all (common prior), but no firm knows what its true export profitability is. That is, an export entrant only knows that θ is a random draw from a normal distribution with mean μ_θ and precision v_θ .¹⁶ A firm also knows the variance of ε , as well as the exact functional form of $h(\cdot)$ so that this "prior" distribution is updated as evidence comes in.

3.1 Firm's static profit maximization problem

In this section I describe the firm's static profit maximization problem. Conditional on θ_t and the firm's export status, total firm revenues are given by

$$r_t = y_t^{\frac{\sigma-1}{\sigma}} + d_t h(\theta_t) y_t^* \frac{\sigma-1}{\sigma},$$

where

$$d_t = \begin{cases} 1 & \text{if the firm exports in period } t \\ 0 & \text{otherwise,} \end{cases}$$

and y_t and y_t^* are the quantities supplied (and sold) by the firm in the domestic and foreign markets, respectively.

Conditional on export status, profit maximizing firms will equate marginal revenues at home and abroad:

$$y_t^* = d_t [h(\theta_t)]^\sigma y_t.$$

I define $\tilde{y}_t = y_t + y_t^*$, the firm's total output. Then, total output can be expressed as $\tilde{y}_t =$

the firm's period return function is bounded in the relevant state variables.

¹⁶For convenience when studying the firm's signal extraction problem I parametrize ε and θ in terms of their "precision" rather than their standard deviation. That is, $v_\varepsilon = 1/\sigma_\varepsilon^2$ and $v_\theta = 1/\sigma_\theta^2$, where σ_ε^2 is the standard deviation for ε and σ_θ^2 is the standard deviation of the distribution characterizing the (common) prior beliefs of firms.

$[1 + d_t (h(\theta_t))^\sigma] y_t$, and I can write the firm's revenues in terms of its scale of operation as

$$r_t = (1 + d_t (h(\theta_t))^\sigma)^{\frac{1}{\sigma}} \tilde{y}_t^{\frac{\sigma-1}{\sigma}}.$$

Let f denote the fixed costs of production (paid in units of domestic output) and let f_x denote the fixed costs of exporting. Conditional on θ_t and the firm's export status, firm's choose their optimal scale of operation to maximize profits:

$$\max_{\tilde{y}_t} \left\{ (1 + d_t (h(\theta_t))^\sigma)^{\frac{1}{\sigma}} \tilde{y}_t^{\frac{\sigma-1}{\sigma}} - (f + d_t f_x + \tilde{y}_t) \right\}.$$

The CES assumption on the demand side allows me to assume that there are no productivity differences between firms and that all heterogeneity is captured through heterogeneity in the underlying "export profitability" of firms (i.e. heterogeneity in θ , under the CES assumption, is isomorphic to productivity heterogeneity).¹⁷ Firms face a constant marginal cost of production (normalized to unity so that the numeraire is the cost of one unit of output), which implies that the decision to serve each market is separable on the cost side. Therefore, the firm's profit maximizing scale of operation, conditional on θ_t and the firm's export status, is given by

$$\tilde{y}_t = \left(\frac{\sigma-1}{\sigma} \right)^\sigma (1 + d_t (h(\theta_t))^\sigma).$$

Using this expression for the optimal scale of operation I can express firm profits, conditional on θ_t and export status, as

$$\Pi(d_t|\theta_t) = \underbrace{\left(\frac{1}{\sigma} \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} - f \right)}_{\text{Domestic Profits}} + d_t \underbrace{\left(\frac{1}{\sigma} \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} [h(\theta_t)]^\sigma - f_x \right)}_{\text{Export Profits}}.$$

Taking the expectation over the conditional distribution of θ_t , the firm's expected profits are given by

$$\Pi(d_t) = \left(\frac{1}{\sigma} \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} - f \right) + d_t \left(\frac{1}{\sigma} \left(\frac{\sigma-1}{\sigma} \right)^{\sigma-1} \mathbb{E} [(h(\theta_t))^\sigma | \mathcal{I}_t] - f_x \right),$$

where \mathcal{I}_t denotes the firm's information set at the outset of period t .

¹⁷However, one key feature of demand as opposed to productivity is that it is likely to be market specific. This is relevant here as I am looking at the decision of domestic firms to enter a second market (the export market).

In what follows it will prove useful to define $A_t := (\mathbb{E} [(h(\theta_t))^\sigma | \mathcal{I}_t])^{\frac{1}{\sigma}}$. Using this notation it can be shown that a modified *certainty-equivalence* result holds: the firm's optimal export status decision and optimal scale of operation is the same as that of a firm which replaces the unknown $h(\theta_t)$ by its *adjusted expected value* A_t and then proceeds as if there were no uncertainty.

With this notation I can express the firm's optimal scale of operation in the export market and export intensity as

$$\begin{aligned} y_t^* &= d_t \left(\frac{\sigma - 1}{\sigma} \right)^\sigma A_t^\sigma \\ \frac{y_t^*}{\tilde{y}_t} &= d_t \left(\frac{1}{1 + A_t^{-\sigma}} \right) \end{aligned}$$

which displays how both the firm's optimal export status decision *and* its scale of operation in the foreign market depends on its beliefs regarding export profitability. Notice that, conditional on survival, the firm's export intensity would grow over time as the firm receives positive information regarding its export profitability that would lead to upward revisions in the statistic A . This evolution of the export intensity of new exporters, conditional on survival, is consistent with the findings of Ruhl and Willis [2015] for Colombian exporters and of Kohn et al. [2015] for Chilean exporters.¹⁸

3.2 Exporting and self-discovery

In this section I describe the self-discovery process of firms. The timing of events is as follows: at the beginning of the period the firm makes a quantity decision based on the information it has accumulated up to that point. After the firm makes its quantity decision demand uncertainty is realized (i.e. θ_t is realized). The market clearing price for the firm's output provides a signal that can be used by the firm to update its beliefs. That is, a firm's revision of its export profitability depends on how realized revenues r_t compare to expected revenues r_t^e :

$$r_t - r_t^e \propto (h(\theta_t) - A_t).$$

If a firm's revenues at t are large compared to what it expected, it means that θ_t was unusually high and this induces an upward revision of "export profitability". Through updating of the

¹⁸This pattern is not documented in section 2 using the Mexican firm-level data because the data set only contains information regarding the export activity of firms.

statistic A , today's high revenues are transformed into growth as firms use newly acquired information to increase their scale of operation in the foreign market in the next period.

Firms use these signals to update their beliefs in a Bayesian manner. In this setting, exporting is a pure “experience good”: the signals θ_t are revealed only *after* the firm has made the decision to export. I could consider situations in which signals regarding export profitability are realized before the firm decides its export status. For example, exogenous signals, such as the export success of previous exporters, could represent a secondary source of information regarding export profitability that is available to the firm before it decides whether to export or not (i.e. exporting could also be an “inspection good”, whose quality can be learned by the firm without necessarily engaging in the activity itself). However, as long as potential exporters cannot learn everything they need to know through external sources of information, there would still be a role for self-discovery through exporting. For the sake of simplicity, here I abstract from such secondary sources of learning for the firm.

I study the firm's signal extraction problem and Bayesian updating by utilizing the Kalman Filter.¹⁹ Let $z_t = \theta$, which I interpret as the hidden value of “export profitability”. Then, the firm's learning problem can be posed in the state-space representation of the Kalman Filter:

$$\begin{aligned} \text{(Evolution of Unobserved State)} & : z_{t+1} = z_t \\ \text{(Observation Equation)} & : \theta_t = z_t + \varepsilon_t; \varepsilon_t \sim i.i.d. \mathcal{N}(0, v_\varepsilon) \\ & z_0 = \theta \sim \mathcal{N}(\mu_\theta, v_\theta), \end{aligned}$$

where $v_\varepsilon = 1/\sigma_\varepsilon^2$ and $v_\theta = 1/\sigma_\theta^2$.

It will be convenient to define $\mu_t \equiv \mathbb{E}[\theta | \theta^{t-1}]$ and $\sigma_t^2 = \mathbb{E}[(\theta - \mu_t)^2 | \theta^{t-1}]$, which capture the firm's current beliefs about its true “export profitability” θ . Then, the Kalman Filter implies that μ_t and $v_t = 1/\sigma_t^2$ evolve according to a controlled first-order Markov process, with transition equations for the mean and precision given by

$$\begin{aligned} \mu_{t+1} & = \mu_t + d_t \left(\frac{v_\varepsilon}{v_t + v_\varepsilon} \right) (\theta_t - \mu_t) \\ v_{t+1} & = v_t + d_t v_\varepsilon \\ \mu_0 & = \mu_\theta, v_0 = v_\theta \text{ given.} \end{aligned}$$

¹⁹DeGroot [1970] and Ljungqvist and Sargent [2012] provide a comprehensive discussion of the theoretical relationship between Bayesian updating and the use of the Kalman filter as a device for signal extraction.

Additionally, the Kalman Filter implies the following conditional distributions

$$\begin{aligned}\mu_{t+1}|\theta^{t-1} &\sim \mathcal{N}\left(\mu_t, \frac{v_\varepsilon}{v_t(v_t + v_\varepsilon)}\right) \\ \theta_t|\theta^{t-1} &\sim \mathcal{N}\left(\mu_t, \frac{1}{v_t} + \frac{1}{v_\varepsilon}\right).\end{aligned}$$

The firm's level of uncertainty, as captured by the precision v_t , evolves independently of the realization of signals: it only depends on the fact that a signal was received. This will offer a key simplification to the solution of the firm's dynamic optimization problem. On the other hand, the evolution of the prior mean μ_t will depend on the realization of signals since the new information revealed through observation of the signal, $(\theta_t - \mu_t)$, will determine the direction in which the firm updates its beliefs regarding the mean of "export profitability".

The pair (μ, v) are sufficient statistics for the firm's information (i.e. beliefs regarding export profitability). Since v_t evolves deterministically, the transition equation for v readily implies that

$$v_t = v_\theta + n_t v_\varepsilon \quad \forall t \geq 0,$$

where $n_t = \sum_{i=0}^{t-1} d_i$ is equal to the total number of periods on which the firm has decided to export *before* period t . That is, tenure in the export market is a sufficient statistic for the precision of the firm's beliefs regarding its export profitability.

Because I am interested in the relationship between export tenure, growth and survival as new exporters enter and exit from the foreign market, it proves useful to replace v_t with n_t , the firm's "export tenure", as a state variable, with n evolving according to $n_{t+1} = n_t + d_t$. This implies that the adjusted expected value of $h(\theta_t)$ is a function of (μ, n) alone: $A_t = A(\mu_t, n_t)$. Since the statistic A is key to understanding the dynamics of export participation of new exporters, it proves useful to decompose its evolution as

$$A_{t+1}^\sigma = A_t^\sigma + d_t \left\{ \underbrace{\sigma \int_{-\infty}^{\infty} [\Phi(\theta; \mu_t, n_{t+1}) - \Phi(\theta; \mu_{t+1}, n_{t+1})] \tilde{h}(\theta) d\theta}_{\text{Effect of "new" information}} + \underbrace{\sigma \int_0^{\infty} \Delta_F(\tilde{\theta}) [\tilde{h}(\mu_t - \tilde{\theta}) - \tilde{h}(\tilde{\theta} + \mu_t)] d\tilde{\theta}}_{\text{Effect of more precise information}} \right\},$$

where $\Phi(\cdot; \mu, n)$ is the cdf of a normal distribution with mean μ and standard deviation defined by n , $\tilde{h}(\theta) = [h(\theta)]^{\sigma-1} h'(\theta)$, and $\Delta_F(\tilde{\theta}) = \Phi(\tilde{\theta} + \mu_t; \mu_t, n_{t+1}) - \Phi(\tilde{\theta} + \mu_t; \mu_t, n_t)$ for $\tilde{\theta} \geq 0$.²⁰

When a firm decides to serve the foreign market the information gathered through its ex-

²⁰The details of this derivation can be found in the online appendix.

perience has two effects: “new” information, revealed through the observation of the signal $(\theta_t - \mu_t)$, leads to an updating of μ . Since $\Phi(\theta; \mu_t, n_{t+1})$ and $\Phi(\theta; \mu_{t+1}, n_{t+1})$ have the same variance, either $\Phi(\theta; \mu_t, n_{t+1})$ will first-order stochastically dominate $\Phi(\theta; \mu_{t+1}, n_{t+1})$ or the other way around depending on the direction in which μ was updated. Thus, the effect of new information will be to increase (decrease) A if “new” information leads to an upwards (downwards) revision of μ . On the other hand, even when no “new” information has been revealed to the firm (i.e. $\theta_t - \mu_t = 0$), experience in the foreign market leads to more precise information for the firm regarding its export profitability (i.e. v increases regardless of the “new” information revealed to the firm and the conditional distribution $\theta_t | \theta^{t-1}$ compresses about the mean). The effect of more precise information on the updating of A is ambiguous as it depends on (i) the current state of beliefs regarding export profitability (μ_t), and (ii) the behavior of $h(\cdot)$ in the neighborhood of μ_t . The compression in the conditional distribution for θ_t implies that the firm deems extreme values for $h(\theta_t)$ as less likely, both at the high and low end. The decreased likelihood of extremely low values for $h(\theta_t)$ would have a positive effect on the calculation of A , but the decreased likelihood of extremely high values for $h(\theta_t)$ would have the opposite effect. Thus, the behavior of $h(\cdot)$ about the current state of beliefs μ_t will determine the relative strength of these two effects and the ultimate effect of more precise information on the updating of the statistic A .

Given that the statistic A is a function of (μ, n) alone, I may write the (expected) export profits as $\pi(d, \mu, n) = d\tilde{\pi}(\mu, n)$, where

$$\tilde{\pi}(\mu, n) = \left(\frac{1}{\sigma} \left(\frac{\sigma - 1}{\sigma} \right)^{\sigma - 1} [A(\mu, n)]^\sigma - f_x \right).$$

With $h(\cdot)$ bounded, $A(\cdot, \cdot)$ is also bounded and so are per period (expected) export profits $\tilde{\pi}(\mu, n)$ for any $(\mu, n) \in \mathbb{R} \times \mathbb{R}_+$. It is clear that (expected) export profits are increasing in A , but given the preceding discussion regarding the effects of “new” and more precise information on the updating of this statistic we know that as a function of (μ, n) per-period expected profits are non-decreasing in μ and that the effect of increasing n is ambiguous.

Firm uncertainty regarding export profitability means that past experience in the export market will affect a firm’s information set, which in turn will affect their current choices. The dependence of information sets on export tenure will generate state dependence. The state dependence generated through the process of self-discovery gives the model an interesting dynamic component with firms adjusting their presence in the foreign market gradually as information comes in and in which export tenure is an important determinant of firm growth

in the foreign market.

3.3 The export market participation rule: firm's dynamic optimization problem

Firms will optimally choose to serve the export market depending on: (a) their beliefs regarding their export profitability, and (b) the fixed costs associated with maintaining a presence in foreign markets. Absent any additional sources of uncertainty the firm's problem would be an *optimal stopping problem*: given current state variables, if the firm decided to stop exporting it would never re-enter the export market. The *stopping property* results from the fact that, without any additional sources of uncertainty, there is no reason for the firm to re-enter the foreign market once it has decided to exit.²¹

In the data firms are constantly observed to be coming in and out of exporting. To address the model's capability to rationalize the entry-exit behavior of exporters observed in the data, I assume that fixed costs of exporting at time t are given by

$$f_{xt} = f_x + \zeta \varepsilon_t,$$

where $\zeta > 0$, and where f_x denotes the observable component of fixed costs and $\varepsilon_t = \varepsilon_{1t} - \varepsilon_{0t}$ denotes unobserved (by the econometrician) state variables that may affect the decision to export. These fixed costs of serving the foreign market are faced every year and are independent of previous exporting history. I assume that ε_{ti} are i.i.d. Extreme Value with shape parameter γ equal to the Euler-Mascheroni constant (this implies $\mathbb{E}[\varepsilon_{ti}] = 0$), and independent of the other state variables (μ_t, n_t) . The distribution of ε_t is approximately Normal, but modeling this unobserved state variable as the difference of Extreme Value distributions offers important computational advantages in terms of solving the firm's dynamic optimization problem.

Prior to making the export decision, firms observe the current realization of ε_t . Thus, the firm's state vector is given by $s_t = (\mu_t, n_t, \varepsilon_t)$. Let ϑ denote the vector of parameters of the model. The dynamic programming problem characterizing the firm's optimal export partici-

²¹Unless there was a secular change in the fundamentals of the foreign market which would change the profitability of exporting, such as changes in market size or trade costs.

pation choice is given by

$$\mathcal{V}_\vartheta(\mu, n, \varepsilon) = \max_{d \in D} \{d(\tilde{\pi}(\mu, n; \vartheta) + \zeta \varepsilon) + \beta \mathbb{E}[\mathcal{V}_\vartheta(\mu', n', \varepsilon') | \mu, n, d]\},$$

subject to the constraints on the evolution of the state variables given in section 3.2. Further details regarding the firm's dynamic optimization problem can be found in the appendix.

Firms solve a dynamic program with discrete controls: the decision to export or not. Since firms are assumed to be forward-looking, firms make decisions today not only looking at current period payoffs, but also on the effect that choices today have on tomorrow's information set. Recall that the focus here is on domestically established firms that have the potential to export, but have not yet done so, and their dynamics after export entry. Thus, by the way in which the firm's value function \mathcal{V}_ϑ is defined it can be interpreted as the value to the firm of having the option to serve the foreign market.

It will be convenient to define

$$\begin{aligned} W_0(n, \mu; \vartheta) &\equiv \beta \mathbb{E}[\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 0] \\ W_1(n, \mu; \vartheta) &\equiv \tilde{\pi}(n, \mu; \vartheta) + \beta \mathbb{E}[\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 1], \end{aligned}$$

which are commonly referred to as the “alternative specific” value functions in the discrete choice literature.

Then, I can write the firm's dynamic optimization problem more compactly as

$$\mathcal{V}_\vartheta(n, \mu, \varepsilon) = \max_{d \in D} \{W_d(n, \mu; \vartheta) + \zeta \varepsilon_d\}.$$

I define the “exporter premia” as the difference between the alternative specific value functions: $\delta(n, \mu; \vartheta) \equiv W_1(n, \mu; \vartheta) - W_0(n, \mu; \vartheta)$. With this notation the optimal policy rule for the firm can be expressed as

$$d_t^* = d(n_t, \mu_t, \varepsilon_t; \vartheta) = \mathbb{I}[\delta(n_t, \mu_t; \vartheta) + \zeta \varepsilon_t > 0],$$

where $\mathbb{I}[\cdot]$ is an indicator function.

The exporter premia is given by

$$\delta(n, \mu; \vartheta) = \tilde{\pi}(n, \mu; \vartheta) + \beta [\mathbb{E}[\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 1] - \mathbb{E}[\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 0]].$$

This model based definition of the exporter premia differs from that commonly estimated in reduced form regressions. In particular, this definition crucially includes the *option value* created for the firm from the advantage that additional information can have on deciding tomorrow’s optimal scale of operation in the foreign market and optimal export market participation decision. Thus, the premium to becoming an exporter is composed of two terms: (i) $\tilde{\pi}(n, \mu; \vartheta)$ the current period (expected) payoff from serving the foreign market; and (ii) the “gains from trial”:

$$G(n, \mu; \vartheta) \equiv \beta \left[\mathbb{E} [\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 1] - \mathbb{E} [\mathcal{V}_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 0] \right].$$

The “gains from trial” arise from the fact that by exporting the firm receives information that allows it to decrease the amount of uncertainty regarding export profitability. This option value arises from the forward-looking nature of the firm’s optimal export status decision and the state dependence that self-discovery induces in the firm’s information set. This results in a key difference in relation to static models of export supply a la Melitz [2003]. The “gains from trial” are akin to the option value of exporting that arises in models with sunk entry costs (see, for example, Das et al. [2007]): by not exporting the firm forgoes a (possibly positive) stream of profits in the foreign market. However, by exporting today, even possibly at a loss, the firm acquires the option to not export tomorrow based on more precise information regarding the payoffs from serving the export market.

The “gains from trial” are approximately given by

$$G(n, \mu; \vartheta) \simeq W_0(n + 1, \mu; \vartheta) - W_0(n, \mu; \vartheta),$$

the change in the value of not exporting when this decision is made with more precise information regarding the firms true export profitability.²²

4 Estimation

In this section I describe the parametrization and estimation of the model outlined in section 3. The structural parameters are estimated using simulation methods. Within the estimation procedure, the dynamic programming problem defining the firm’s optimal policy rule is

²²Further details concerning the firm’s dynamic optimization problem and its numerical solution can be found in the online appendix.

solved for each guess of the parameter vector. Using this parameter vector and corresponding policy rule, an artificial data set is simulated from which moments are computed for a moment matching exercise. The following sections discuss these points in detail.

4.1 Parametrization

For the purposes of estimation I need to specify a functional form for the function $h(\cdot)$. Here I assume that h takes the form $h(z) = \kappa \exp(-\lambda \exp(-gz))$, where $\kappa > 0$ and $\lambda, g > 0$. Under this functional form assumption:

1. $h(z) \geq 0$ for all $z \geq 0$.
2. $h(\cdot)$ is continuous, differentiable, and monotone increasing.
3. $h(\cdot)$ satisfies

$$\begin{aligned} \lim_{z \rightarrow \infty} h(z) &= \kappa \\ \lim_{z \rightarrow -\infty} h(z) &= 0. \end{aligned}$$

This functional form assumption imposes the boundedness condition assumed in section 3, while allowing for flexibility in the shape that $h(\cdot)$ can take on its domain.²³ The parameter κ controls the upper bound for $h(\cdot)$, while λ and g affect the growth rate of $h(\cdot)$. Notice that the parameter κ is related to the aggregate demand shifter that is common to all firms and that the maximum foreign market revenues attainable for any firm (at the optimal scale of operation) are entirely determined by κ and σ : $r^{\max} = \kappa^\sigma ((\sigma - 1)/\sigma)^{\sigma-1}$.

I assume that β , the time discount factor, and σ , the CES elasticity of substitution, are known and set $\beta = 0.96$ and $\sigma = 5$. This value for the time discount factor is standard in the literature and it is the one used by Alessandria et al. [2013]. The choice for σ draws on various sources. Alessandria et al. set $\sigma = 5$ to generate a 25% markup for firms; Broda and Weinstein report that for the period 1990-2001 the average elasticity of substitution was 8 for 10-digit (HTS) goods and 4 within 3-digit goods. Furthermore, Lai and Trefler (2002) report an estimated elasticity of substitution of approximately 5 for various econometric specifications considered

²³Because this is a bounded, positive and monotone function, $h(\cdot)$ must be ‘‘S-shaped’’ on this domain. However, the parameters λ and g provide flexibility in terms of the displacement along the x – axis and growth rate, respectively.

by the authors. In particular, their maximum likelihood estimate of σ is 5.25. Based on these disparate sources of evidence I set $\sigma = 5$.²⁴

4.2 Estimation procedure

Since the model outlined in section 3 involves unobserved state variables, I estimate the remaining parameters $\vartheta = (v_\varepsilon, \mu_\theta, v_\theta, f_x, \lambda, g, \kappa, \zeta)$ using *indirect inference* methods as discussed in Gouriéroux and Monfort [2002]. In particular, I use the moment-matching simulation estimator:

$$\hat{\vartheta}(\Omega) = \operatorname{argmin}_{\vartheta} (\hat{m}_d - \hat{m}(\vartheta))' \Omega (\hat{m}_d - \hat{m}(\vartheta)),$$

where \hat{m}_d is a vector of data moments, $\hat{m}(\vartheta)$ are the corresponding simulated moments for parameter vector ϑ , and Ω the weighting matrix defining a metric for the distance between the data and the simulated moments.²⁵

The estimate $\hat{\vartheta}$ is the result of an iterative procedure: for an initial guess $\hat{\vartheta}_1$ I calculate the optimal weighting matrix $\hat{\Omega}_1$ and use this to calculate $\hat{\vartheta}_2 = \hat{\vartheta}(\hat{\Omega}_1)$. This process is repeated until the estimates for $\hat{\vartheta}_j$ converge, yielding the moment-matching simulation estimator $\hat{\vartheta}$. Details of the estimation procedure can be found in the appendix.

4.3 Specifying moments

For a candidate value ϑ , I simulate the export sales and dynamics of 20,000 firms using the model outlined in section 3. Out of these 20,000 firms I choose the subset of firms which exported in the initial period and track the outcomes of these firms over time in analogy to the cohort of exporters analyzed in section 2. In the data, the 2001 cohort of Mexican exporters is comprised of approximately 13,000 firms.²⁶ By simulating 20,000 firms I obtain

²⁴The results reported in this section are robust to alternative choices of β and σ . Considering low and high values of β of 0.93 and 0.975 and low and high values of σ of 4.75 and 5.25 leave the results reported in this section largely unchanged.

²⁵I do not estimate the model via maximum likelihood because constructing the likelihood for this model imposes a greater computational burden than simulating moments. In particular, the probability of observing a particular export history $d = (d_1, \dots, d_T)'$, which is required to evaluate the likelihood, must be constructed by integration over *all* histories μ that are consistent with d since $\{\mu_t\}_{t=1}^T$ is an *unobserved state variable*. This high-dimensional integral does not have a closed form solution and must be approximated by simulation. These high dimensional integrals have to be approximated for all unique export histories that are observed in the data. Doing so to evaluate the likelihood increases the computational burden relative to the moment matching approach taken here.

²⁶Exporting cohorts for 2002-2007 are of a similar size.

new exporting cohorts of roughly the same size as those seen in the data. For the artificial data I compute a vector of moments $\hat{m}(\vartheta)$ analogous to particular moments \hat{m}_d in the data. The set of moments that I use for estimation are:

1. Mean log Sales (conditional on exporting) for the first three period of the cohort.²⁷
2. Continuations rates for $n = 0, 1, \dots, 5$, where n denotes years since export entry.
3. Average export tenure.

In total I use 10 moments to identify 8 parameters. The first-year mean log sales will contain information about the initial scale of operation of firms, and thus about the initial beliefs regarding export profitability μ_θ and v_θ . Together, the set of moments concerning mean log sales will also provide information relating to the revenue function parameters κ , λ , and g . The continuation rates and average export tenure will provide information about the entry-exit behavior of firms which will be informative about the parameters that affect the optimal export status decision of firms such as the fixed costs f_x , the rate of learning v_ε , and the size of the idiosyncratic shocks to fixed costs ζ .

4.4 Estimation results and in-sample model performance

The best fit is achieved at the parameter values reported in Table 5 below. Table 6 reports the data moments used in estimation and their counterparts in the model for the estimated parameter values. Compared to the data, in the model firms live (on average) for slightly longer and start out smaller. The fact that firms start smaller in the model but in their second year reach export sales similar to those observed in the data means that the model will over-predict the first year average growth rate of firms (conditional on survival).

In order to generate the large attrition rate of firms after the first year that is observed in the data the model needs to generate a large mass of firms with relatively low export sales (which is the signal that would tell firms that they are unprofitable exporters) which drags down the mean export sales of the first year in the model. In simulation exercises, attempts to push these two simulated moments closer to their empirical counterparts resulted in a higher discrepancy between the data and simulated moments for second and third year mean log

²⁷Due to partial year effects (see Bernard et al. [2014]), I make an adjustment to the data moment corresponding to the first year mean log sales by assuming that export entrants and their revenues are uniformly distributed over the calendar year.

sales. The first-year continuation rate and the first year mean log sales cannot be simultaneously pushed closer to their data counterparts without affecting the value of other matched moments because *all parameters* jointly determine *all moments*.

Parameter	v_ε	μ_θ	v_θ	f_x^*	λ	g	κ	ζ
Estimate	7.93	0.09	1.92	4	2.64	2.69	1.2	0.02

* hundreds of thousands of dollars

Table 5: Estimation Results

Moment	Data	Model
Avg. Export Tenure	2.4	2.8

Continuation Rates

$n = 0$	0.36	0.30
$n = 1$	0.58	0.50
$n = 2$	0.71	0.71
$n = 3$	0.8	0.83
$n = 4$	0.84	0.88
$n = 5$	0.88	0.91

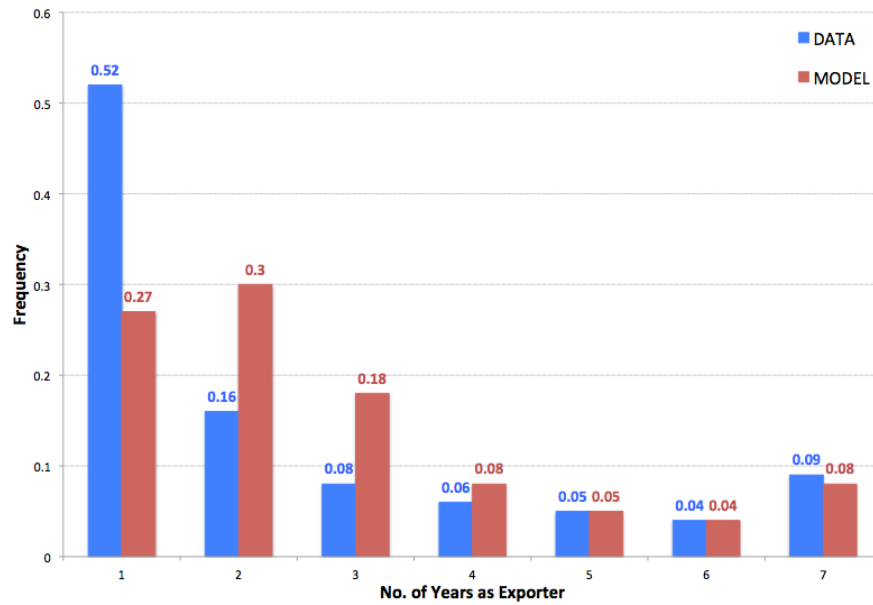
Mean log Sales*

Year 1	-5.70	-7.2
Year 2	-5.29	-5.25
Year 3	-5.06	-5.16

* Mean log Sales are in tens of millions of U.S. dollars.

Table 6: Matched Moments

Figure 4.1 serves as a check for over-identification as it compares the predictions of the estimated model for some non-targeted data moments. Figure 4.1 presents the distribution of export tenures (no. of years as an exporter). The model does a good job matching the tail of this distribution: for 4 or more years as an exporter the data and model frequencies are a good match. However, the model implies that after the large attrition rate of the first year firms are subsequently more likely to re-enter the export market than what is observed in the data. This implies that the model over-predicts the likelihood of 2 and 3 year tenures and under-predicts the likelihood of single-year exporters. That is, in the model, even after receiving a very bad signal about export profitability in the initial period, firms are likely to re-enter the export market after receiving a good enough idiosyncratic shock to their fixed costs of serving the foreign market.



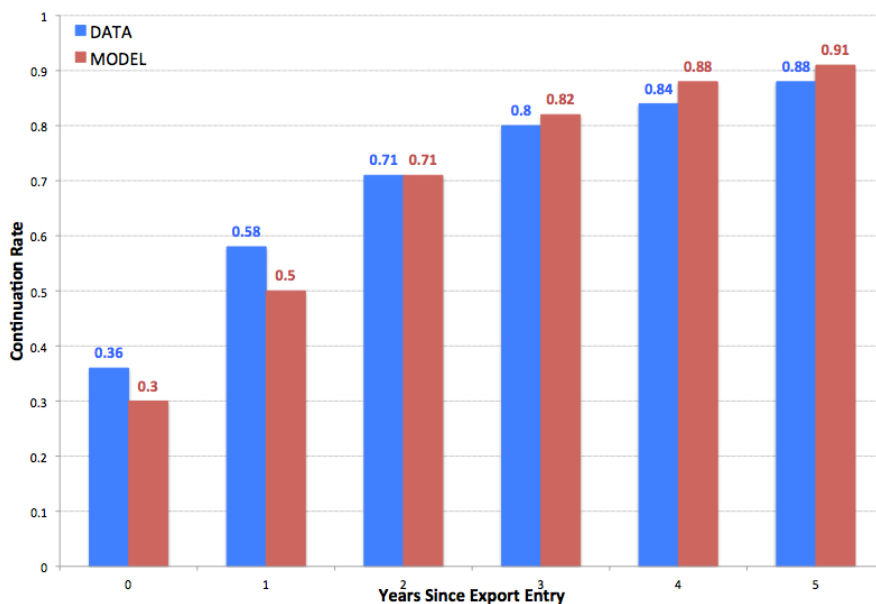
Source: Mexican firm-level export data from the World Bank’s Exporter Dynamics Database.

Figure 4.1: Distribution of Export Tenures

Figure 4.2 graphically depicts the continuation rates presented in Table 6 to more clearly show that the estimated model is able to provide a good fit to continuation rates that are increasing with export tenure as observed in the data. Figure 4.3 presents the growth dynamics of “long-term” survivors. As mentioned above, the large first year attrition rate is generated by the model at the cost of relatively low (average) first year export sales, which results in over-predicting the first-year growth rate. This stands in contrast to models of exporter dynamics based on financial frictions such as Kohn et al. [2015] where first-year growth rates are under-predicted. However, the model with self-discovery does generate the growth dynamics observed in the data: very strong average sales growth in the first year, followed by rapidly decaying growth rates.²⁸

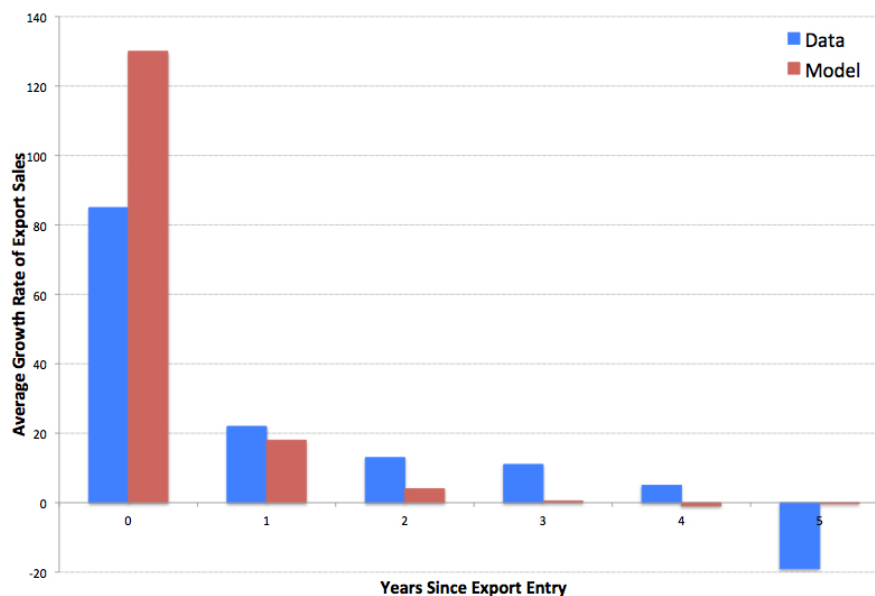
The evidence presented here shows that the estimated model gives rise to entry-exit behavior

²⁸In the midpoint of the sample, 2004, there appears to be a generalized increase in all export activity from Mexican exporters (see Cebreros [2015]). Exports as a share of GDP averaged 24.5% between 2001 and 2004, and increased to an average of 27.6% between 2005 and 2009. This increase in the share of exports in GDP coincides with a 7% reduction in the weighted average tariff index for industrial production and an elimination of effectively applied tariffs with Canada and a gradual elimination of these same tariffs with the USA, Mexico’s two largest trading partners (see the World Bank’s World Integrated Trade Solution <http://wits.worldbank.org/default.aspx>). This suggests that the growth dynamics of long-term survivors observed in the data decayed more slowly than they otherwise would have as firms adjusted to this trade liberalization. Additionally, in the data there is a large drop in export sales towards the end of the sample due to the 2007 financial crisis.



Source: Mexican firm-level export data from the World Bank's Exporter Dynamics Database.

Figure 4.2: Exporter Continuation Rate: Conditional Survival Probabilities



Source: Mexican firm-level export data from the World Bank's Exporter Dynamics Database.

Figure 4.3: Growth Dynamics of Long-Term Survivors

and growth that is consistent with the data. In particular, Figures 4.2 and 4.3 show that the model with self-discovery can *qualitatively* and *quantitatively* succeed in explaining the gradual adjustment of new exporters observed in the data, a feat not achieved by the standard

sunk entry cost model with productivity heterogeneity (see Ruhl and Willis [2015]).

5 Implications of self-discovery for export supply: profits, option values, and the effects of tenure

In this section I use the parameter estimates of section 4 to calculate option values, probabilities, and scales of operation. These objects will be useful to understand the dynamic adjustment of export supply as firms transition from new to mature exporters. In particular, I will be interested in quantifying the role that self-discovery plays in the export supply decisions of new exporters and the length of time in the export market necessary for firms to uncover their true export profitability.

5.1 Option values: quantifying the gains from trial

In section 3 it was argued that the “gains from trial” represent a crucial component of the exporter premia which shapes the export supply decision of firms. I use the estimated model to quantify the importance of this option value for the dynamics of new exporters and to show how the dynamic model differs from a static model of export supply.

To gain further insights into how the exporter premia and the “gains from trial” evolve as a cohort of new exporters matures I will define the “term structure” of the “gains from trial”, conditional on survival. Let δ_t and G_t be the average export premia and average gains from trial, where the average is taken over the set of firms that export in both t and $t + 1$ (i.e. the “continuers”). Figure 5.1 presents the evolution of the share of the “gains from trial” G_t in the exporter premia δ_t :

$$s_{G_t} = \frac{G_t}{G_t + \delta_t}.$$

If $s_{G_t} > 1$, then the export premia δ_t is negative and since G_t is non-negative this implies that expected export profits must be negative. Similarly to Alessandria et al. [2013], I find that new exporters will, on average, earn negative profits on entry. For first time exporters the value they attach to the information gained through serving the export market is the most important component to the value from serving the foreign market. With no previous export experience, the “gains from trial” compensate new entrants for their expected losses to the

point of leaving them indifferent between entering the export market or not. Entry of new exporters is driven by temporary below average fixed costs of entering the export market.

Figure 5.1 shows that the initial export period provides a crucial learning experience for first-time exporters and that following the initial participation in the foreign market there there is a very quick and sharp drop in the contribution of the “gains from trial” in the exporter premia. However, Figure 5.1 also shows that there is a positive value to learning over the first four years of the firm’s tenure in the export market. That is, export profitability is not entirely uncovered by the firm in its first year serving the export market. It is only after the discovery stage that the export premia is entirely comprised of expected export profits and learning about the foreign market ceases to have any value for the firm.

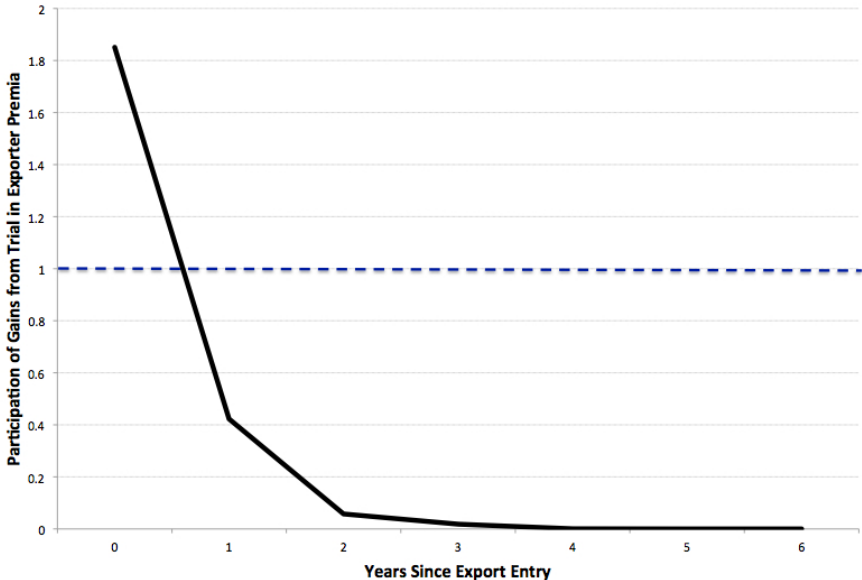


Figure 5.1: Evolution of the Gains from Trial as Share of the Exporter Premia

To further understand the role of the gains from trial in shaping the export supply decision of firms it is also interesting to understand how the forward-looking behavior of firms affects entry-exit decisions. To do so I simulate a myopic version of the model ($\beta = 0$) and compare this to the forward-looking model ($\beta > 0$). Myopic firms will learn their export profitability in the same way that forward-looking firms do, the only difference is that the export supply decision of myopic firms is entirely shaped by the expected profits in the foreign market (i.e. myopic firms do not place any value on how serving the foreign market can affect their information sets). Figure 5.2 depicts the difference in continuation values between the forward-looking and myopic models. In the first three years of tenure in the export market the “gains from trial” has a non negligible effect on the export supply decision of firms, resulting

in higher continuation rates for forward-looking firms relative to their myopic counterparts. After this discovery stage, the difference in continuation rates is negligible or non-existing since firms have mostly uncovered their true export profitability and thus the gains from trial play an inconsequential role in determining the firm's export supply decision.

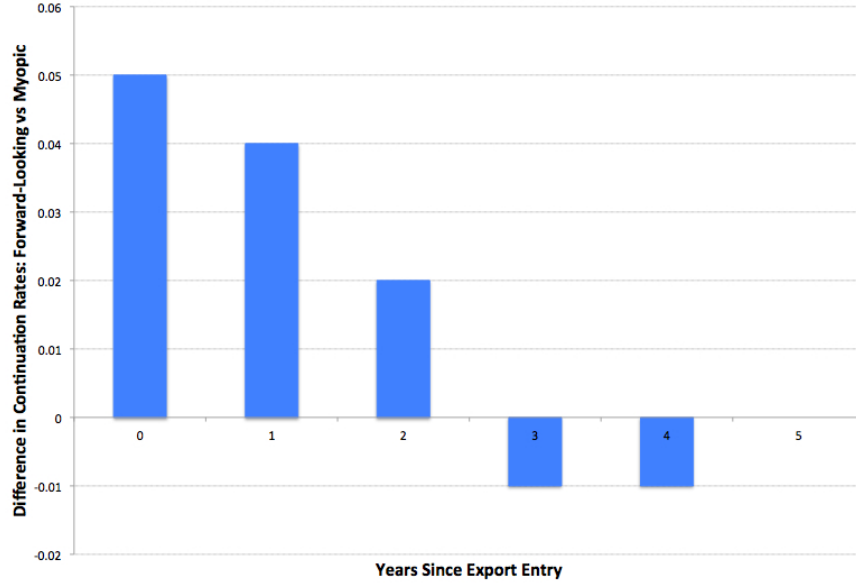


Figure 5.2: Exporter Continuation Rates: Forward-Looking vs Myopic Model

5.2 The Effects of Tenure on Export Status

How does the probability of serving the foreign market change with export tenure? In section 3 it was shown that tenure is a sufficient statistic for the precision of the firm's information. Here I quantify how tenure affects the decision to serve the export market. Given the distributional assumptions of section 3, the ex-ante probability of exporting²⁹ given state variables (μ, n) is given by

$$\Pr(d = 1 | \mu, n) = \left(1 + \exp \left(-\frac{\delta(\mu, n; \hat{\vartheta})}{\zeta} \right) \right)^{-1}.$$

²⁹By ex-ante probability of exporting I mean the probability of serving the foreign market before the firm observes the idiosyncratic shock to its fixed export costs.

Since this probability depends on the unobserved state variable μ , I define

$$P_t := \left(1 + \exp \left(-\frac{\tilde{\delta}_t}{\zeta} \right) \right)^{-1},$$

where $\tilde{\delta}_t := H_t^{-1} \sum_{h=1}^{H_t} \delta(n_t^h, \mu_t^h; \hat{\nu})$. Here H_t denotes the number of firms that have exported every period through $t - 1$ (i.e. conditional on survival, H_t is the set of *potential exporters* in period t).

Table 7 presents the effects of tenure on the probability of being an exporter. The first row shows how this probability evolves, while the second row shows the evolution of this probability relative to the probability of serving the foreign market for a firm with no previous experience in the export market. To better understand these results, the third row of Table 7 shows the evolution in the (average) export premia of potential exporters. Changes in these rewards to exporting are the driving force behind changes in the likelihood of serving the foreign market. The first thing that can be gleaned from Table 7 is that after the first year there is a large drop in the likelihood of serving the export market. The reason behind this result is a powerful *selection effect* that affects *first-time exporters*. Recall that H_t is the set of, conditional on survival, *potential exporters* at time t . By definition of the exporting cohort and of H_t , the set of exporters in $t = 0$ and of potential exporters at $t = 1$ is the same. The initial exporting period reveals a lot of information to export entrants, and during their first venture into the export market many members of the initial cohort of exporters will receive unfavorable information regarding their export profitability. The third row of Table 7 demonstrates how the revelation of unfavorable information regarding export profitability that drives the high first-year exit rate entails a drop in the average exporter premia for the set of potential second-year exporters. After the sharp attrition rate that occurs during the first year, this selection is dominated by the increase in the export premia of continuing firms and we observe that the exporter premia of the average potential exporter gradually increases giving rise to a positive, but diminishing, effect of tenure on the probability of being an exporter.

	$t = 0$	$t = 1$	$t = 2$	$t = 3$	$t = 4$	$t = 5$	$t = 6$
P_t	0.41	0.28	0.58	0.86	0.94	0.96	0.97
P_t/P_0	1	0.68	1.41	2.10	2.29	2.34	2.37
$\tilde{\delta}_t$	-0.01	-0.02	0.01	0.04	0.06	0.07	0.08

Table 7: Effect of Tenure on the (ex-ante) Probability of Exporting

After a firm has maintained a continuous export presence for 7 years, the (ex-ante) probability

that it will serve the foreign market in the current period increases by 137%. During this same time span, “long-term” survivors see their export premia grow by approximately 900% as they develop from new to established exporters. Conditional on survival, the increase in the ex-ante probability of serving the foreign market is concentrated in the first four years of tenure: after the 4th year the ex-ante probability of serving the foreign market has already experienced 95% of its long-term adjustment. These numbers reveal that valuable rewards are available to those firms lucky enough to discover that they can profitably serve the foreign market.

The model of export supply with self-discovery leads to a theory of “noisy” selection in which exporters, through a bit of luck, are able to gradually learn their true export profitability. This process of noisy selection can account for the gradual thinning of active firms in the export market that is observed in the data, and continuation rates that are increasing with export tenure. To further understand how tenure and selection work in the model, I define the “export cutoff” $\mu^* = \mu(n)$ by

$$\mu(n) = \inf \{ \mu : \delta(\mu, n; \hat{\vartheta}) > 0 \}.$$

Figure 5.3 plots the evolution of the cutoff for export entry μ^* . In contrast to the static model of Melitz [2003], where the cutoff for export entry is fixed and only responds to changes in fixed costs and/or changes in the distribution of production heterogeneity, here the cutoff for export entry changes with tenure. At any finite t , the threshold for exporting is more lax than the zero-profit cutoff “at infinity”.³⁰ As was discussed in section 5.1, early in the firm’s tenure the entry decision is mostly driven by the gains from trial so firms are willing to export even at an expected loss because of the value they attach to gathering information. As information comes in which allows exporters to decrease the amount of uncertainty regarding their true profitability in the export market, firms are able to set export cutoffs more accurately.

The cutoffs for export entry converge from below to the zero-profit cutoff “at infinity” as the value to gathering information decreases over time. Notice, specially, that after the initial year there is a substantial adjustment in the cutoff for export entry. This sharp increase in the cutoff for export entry after the initial year accounts for the large attrition rate of first-time exporters. Figure 5.3 also shows that not all adjustment occurs after the first period: export cutoffs continue to adjust after the first year of tenure in the export market, with 90 percent of the adjustment occurring in the first four years of tenure in the foreign market.

³⁰The zero-profit cutoff “at infinity” is the cutoff for export entry once firms have learned their true export profitability, which is equivalent to the zero-profit cutoff in the static Melitz model.

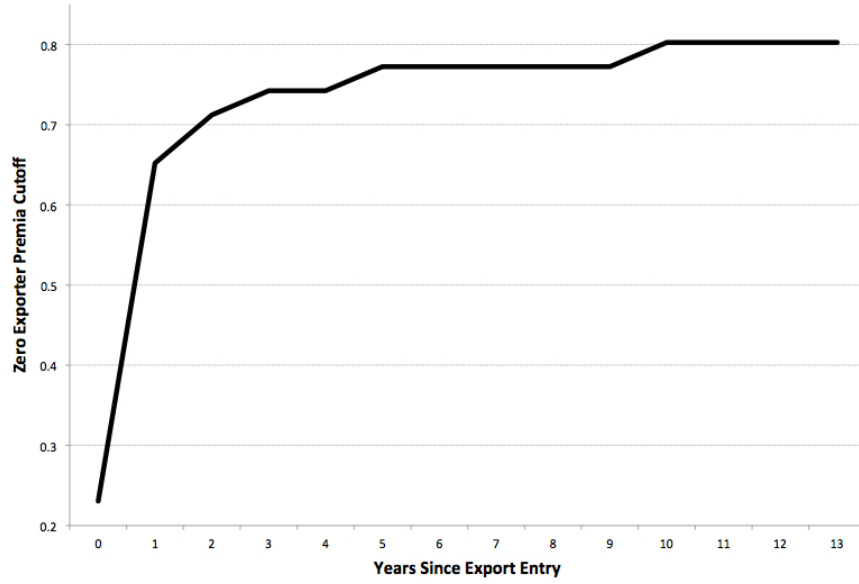


Figure 5.3: Cutoffs for Export Entry

5.3 Implications for the intensive margin

Besedes and Prusa [2011] argue that the “deepening” of export relationships is key to understanding the contribution to export growth of export entrants. Cebreros [2015] documents that the growth in export sales of new exporters is driven by the introduction of new products into markets the firms already served and, more importantly, by expansions along the intensive margin. Thus, the transition from new to established exporters is driven by the “deepening” of the firm’s export relationships. In this subsection I use the estimated model to investigate how self-discovery affects the adjustment of the firm’s optimal scale of operation in the foreign market.

In section 3 it was shown that the firm’s optimal scale of operation in the foreign market was given by

$$y_t^* = \left(\frac{\sigma - 1}{\sigma} \right)^\sigma A_t^\sigma,$$

where A_t was the adjusted expected value of $h(\theta_t)$. Here I write $A_t^\sigma = I(\mu_t, n_t; \hat{\vartheta})$, and decompose the adjustment in the firm’s scale of operation into the effect of receiving more (less) favorable information and the effect of obtaining more precise information as

$$\log y_{i,t+1}^* - \log y_{i,t}^* = \underbrace{\log I(\mu_{t+1}^i, n_{t+1}^i; \hat{\vartheta}) - \log I(\mu_t^i, n_{t+1}^i; \hat{\vartheta})}_{\text{effect of change in beliefs regarding mean export profitability}} + \underbrace{\log I(\mu_t^i, n_{t+1}^i; \hat{\vartheta}) - \log I(\mu_t^i, n_t^i; \hat{\vartheta})}_{\text{effect of more precise information}}.$$

Table 8 presents the results of this decomposition for the set of long-term survivors. The first column presents the (average) growth in the intensive margin, while columns two and three decompose this growth into the effect of a change in the beliefs about mean export profitability and the effects of more precise information, respectively. The first three years are particularly meaningful since mean log sales for the first three years of the cohort were part of the targeted moments used for estimation in Section 4. Table 8 shows that the growth in the foreign market presence of long-term survivors is driven by the effect of the change in beliefs regarding the mean of export profitability: positive information regarding export profitability translates into growth as newly acquired information is used to adjust the optimal scale of operation in the foreign market.

On the other hand, Table 8 reports that the effect of more precise information is to contract the firm's foreign market presence. When the firm receives information that does not lead to a change in its beliefs regarding mean export profitability, the only effect of this additional information is to compress the conditional distribution of θ_t about its current mean. The third column in Table 8 shows that for the estimated model, the dominating effect that arises from the acquisition of more precise information stems from the firm's perception of a decreased likelihood for very high values of the demand shifter that results in a downsizing of the firm's foreign market scale of operation. The results in Table 8 also show that, conditional on survival, the first-year of tenure in the export market reveals a large amount of information to firms which results in high first-year growth rates for continuing firms. Table 8 also shows that during the first four years of tenure in the export market there are non-negligible adjustments along the intensive margin: full adjustment in the firm's foreign market presence is not attained immediately after surviving the first period.

To summarize, I have shown that: (i) first-time exporters expect to incur losses by serving the foreign market; the option value generated by the acquisition of more precise information regarding export profitability compensates inexperienced exporters for their losses and entry is driven by below average costs of serving the foreign market; (ii) the "gains from trial" as

	Growth	Δ Beliefs Mean	\uparrow Precision of Information
$t + 1$	179.00	499.36	-320.36
$t + 2$	16.53	17.41	-0.88
$t + 3$	3.79	3.84	-0.05
$t + 4$	0.90	1.22	-0.32
$t + 5$	0.05	0.42	-0.37
$t + 6$	-0.04	0.26	-0.30

Table 8: Decomposing the Intensive Margin of Firm Adjustment: Long-Term Survivors

a share of the export premium remains positive for the first four years of tenure in the export market, after this initial discovery stage the export premia is entirely comprise of expected export profits; *(iii)* long-term survivors observe a 137% increase in their ex ante probability of serving the foreign market and a 900% increase in their (average) export premia as they transition from new to mature exporters; 95% of the long-term adjustment in the ex ante probability of being an exporter is attained during the first four years of tenure in the export market; *(iv)* self-discovery leads to a theory of noisy selection with the cutoff for serving the foreign market converging from below to that static full-information export cutoff; 90% of the adjustment in the cutoff for exporting is realized in the first four years of export tenure, and *(v)* the growth in the foreign market presence of long-term survivors is led by growth in the intensive margin, where most growth occurs after the initial revelation of information regarding export profitability. However, full adjustment is not attained after surviving the first year, adjustments along the intensive margin continues during the first four years of tenure in the export market. More precise information regarding export profitability leads to a downsizing in the scale of operation of firms. Positive growth for long-term survivors is the result of above expected performance in the export market which is a source of positive information regarding the mean of export profitability.

Using the estimated model I find that, while the first year of tenure in the export market provides a crucial learning experience for firms, export profitability is not uncovered after the first year serving the foreign market. The results of this section suggest that the discovery stage last approximately four years. This result contrasts with the reduced formed evidence presented by Albornoz et al. [2012], who find that uncovering export profitability is attained in the firm's first year as an exporter. The fact that export profitability is not fully uncovered in the first year implies that, conditional on survival, firm's will not fully adjust their foreign market presence immediately. Adjustment continues for a number of periods as firms gradually uncover export profitability, and it is this gradual learning that leads to the firm dynamics

that is observed in the data concerning growth and survival of new exporters.

6 Counterfactual analysis: the speed of learning, export promotion and implications for aggregate trade

In this section I use the estimated model of sections 3 and 4 to assess the export supply consequences of the learning environment faced by firms and to broach two important questions concerning the export supply of new exporters: 1. How does the speed of learning affect export dynamics? and 2. How effective are export promotion policies?

6.1 The speed of learning

In section 3 it was shown that the firm's signal extraction problem and Bayesian updating implies that the precision of the firm's beliefs regarding its unknown export profitability evolves as

$$v_{t+1} = v_t + d_t v_\varepsilon,$$

where v_ε is the precision of the revenue (demand) shocks faced by firms in the foreign market. The rate at which firms increase the precision of their information (i.e. the speed of learning) is entirely determined by the parameter v_ε : the more variability there is in the demand shocks faced by the firm, the less information it can extract from its signals.

Firms may face different learning environments if, for example, learning is destination and/or industry specific. In particular, it is often argued that entrant firms may differ significantly on product characteristics and that producers of customized products are involved in more extended learning processes than are producers of standardized products (see Pedersen and Petersen [2003]). Figure 2.6a from section 2 was suggestive of this fact, as producers of standardized product exhibited higher continuation rates in the foreign market than producers of differentiated products. Data limitations prevent me from splitting the sample and estimating the model separately for producers of differentiated products and producers of standardized products since the sample size of the latter is too small (see Table 4). Nevertheless, Waller et al. [1999] document that demand variability ranges widely, with basic consumer products exhibiting low demand variability, while more differentiated products such as electronics exhibit significantly higher demand variabilities. In the context of the present model, these

differences in demand variability across industries can be interpreted as differences in the parameter v_ϵ that result in differences in the learning environment faced by firms in different industries.

In this section, I study the export supply consequences of the learning environment faced by firms by considering a counterfactual environment where learning happens more slowly by reducing v_ϵ to 25% of its benchmark value. Figure 6.1 shows the evolution of the gains from trial as a share of the exporter premia for both the benchmark and slow learning case. In the slow learning environment the value that firms attach to the option value of making future choice using more precise information is greater as reflected by the higher participation of the gains from trial in the exporter premia. Additionally, the firm’s discovery stage is 50% longer in the slow learning environment relative to the benchmark. This speaks to the point that producers of customized products (where demand is more volatile) undergo learning processes that are more prolonged than those experienced by producers of standardized products.

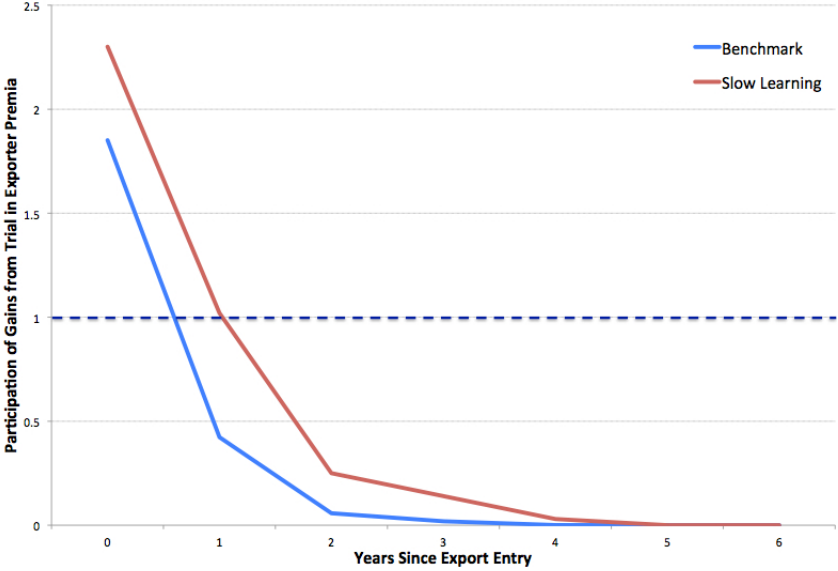


Figure 6.1: The Effects of Slow Learning on the Gains from Trial

Figure 6.2 presents the effect of a slower learning environment on continuation rates. When it takes more time for firms to uncover their export profitability they are less likely to continue serving the export market. Figure 6.2 shows that in the slow learning environment continuation rates are uniformly lower than in the benchmark case: even when firms receive a very positive signal θ_t , the amount of information they are able to extract about θ , their “fundamental export profitability”, is small since the signal contains a lot of noise. Thus, firm’s beliefs regarding their export profitability adjust slowly which results in less firms deciding

to continue serving the export market. If, as suggested by Waller et al., producers of standardized products experience less variability on the idiosyncratic component of demand, then Figure 6.2 shows that the learning model of section 3 can account for the pattern depicted in Figure 2.6a of section 2.

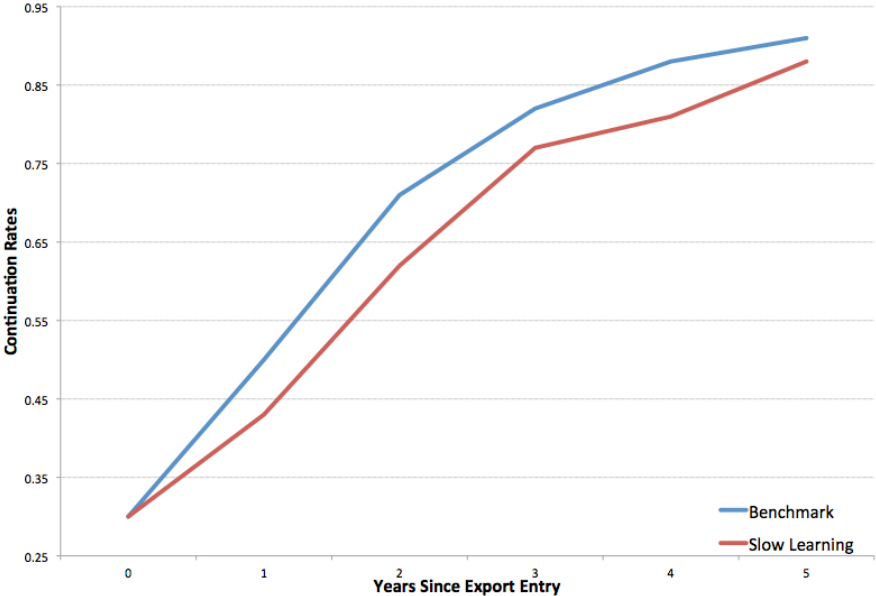


Figure 6.2: Effect of Slow Learning on Continuation Rates

6.2 Export promotion and aggregate trade

Over the last two decades national export promotion agencies (EPAs) have tripled and have had a strong and statistically significant impact on aggregate export volumes (see Lederman et al. [2010]). The case for export promotion is, however, contentious (see Grossman [1998]). Nevertheless, given the popularity of export promotion policies in developing nations and the prominence given to these by policymakers as an integral part of a nations development strategy (see Bhagwati [1988]) it is of interest to investigate the impact of these policies on aggregate trade. Here the focus is not normative, it is a positive evaluation of the type of export promotion policies typically carried out by policymakers and EPA’s (see, for example, OECD [2009]). The objective is as in Roberts and Tybout [1997] and Das et al. [2007]: to understand how micro-founded firm level export dynamics affect aggregate exports in response to changes in the economic environment that effect the profitability of serving the

foreign market.³¹ Arkolakis et al. [2015] explore the welfare implications of such policies and find that these can be welfare enhancing since they preclude the early exit of young firms who provide additional varieties for consumption to consumers.

The type of export promotion policy I consider here are direct subsidies to the fixed costs associated with maintaining a foreign market presence.³² Policy makers justify these type of export assistance programs under the guise that there are exporting firms that would increase their foreign market presence and non-exporters that would start to export, but do not do so because they lack crucial information about foreign markets (see Pursell [2000]). In the current setup, export promotion policies would help firms overcome the key piece of information they are missing: knowledge about persistent demand components affecting foreign market revenues.

I simulate the effects of a temporary export subsidy to the fixed costs of exporting of 50, 75 and 100 percent of the benchmark value. From the date at which the EPA makes the subsidy available it lasts for three years (i.e. if the EPA announces the subsidy program at t the subsidy is available until $t + 2$). I also consider the impact of these trade policies in a counterfactually slow learning environment.

Figure 6.3 shows that even temporary export subsidies can have long-term consequences on aggregate trade when new exporters need to acquire information regarding the value of their match with the foreign market. The temporarily low cost of serving the export market implies that some unprofitable exporters will remain in the export market longer than they should, but it also means that profitable exporters who are unlucky at the outset of their export tenure can remain in the export market long enough to uncover that they can profitably serve the export market. It is precisely these firms which account for the long term increase in trade volumes in response to temporary subsidies.

Figure 6.4 shows the effects of the speed of learning on the impact of export promotion. The simulation results presented in Figure 6.4 suggest that in the long-run there are no consequences for aggregate trade volumes: in response to a temporary subsidy to the fixed costs of exporting, aggregate trade volumes converge to the same value regardless of the speed of

³¹Roberts and Tybout (1997) write “Export supply responsiveness is of central concern to the World Bank and its client countries...Unfortunately, export supply responses are not well understood...Seemingly similar reform packages have generated a large range of export responses in different countries and time periods. Policymakers have faced substantial uncertainty whether a given reform package will, for their country, generate the needed response.”

³²For example, in Australia the Export Market Development Grants scheme reimburses up to 50% of eligible export promotion expenses which are above a given threshold.

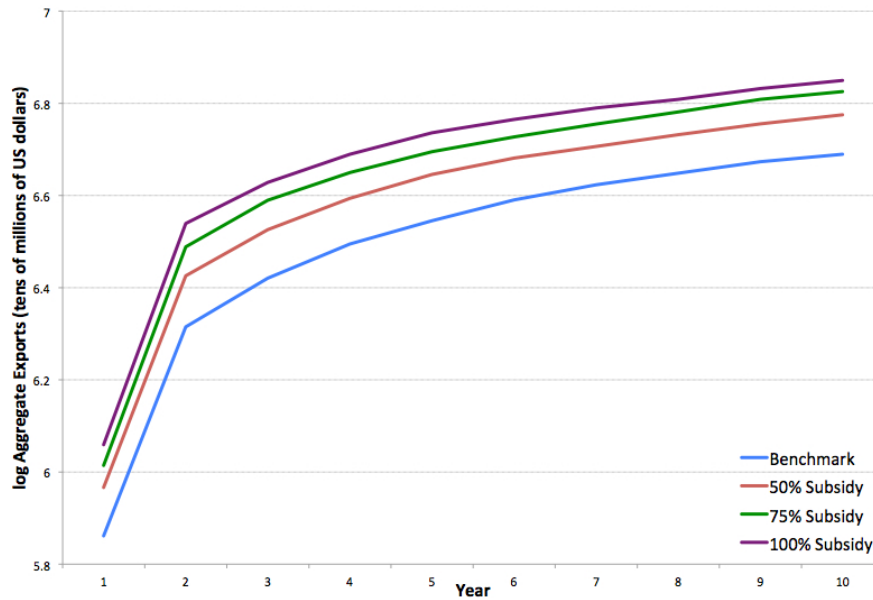


Figure 6.3: Temporary Export Subsidies and Aggregate Trade

learning. As is clear from this figure, it is during the transition that the speed of learning can affect the influence of export promotion. Over a 15 year horizon, the net present value of the trade that is “lost” under the counterfactually slower learning environment is in the order of 13.6 billion U.S. dollars for a policy which temporarily subsidizes 75% of the fixed costs of exporting.³³ Thus, the effectiveness of temporary export subsidies, in terms of engineering aggregate trade growth, is critically affected by the speed at which firms are able to learn their way out of the uncertainty they face in the foreign market.

7 Conclusions

I have developed and estimated a quantitative model of export dynamics featuring self-discovery. The estimated model accounts well for the pattern of export dynamics of new exporters that is observed in the data. In particular, the model is able to qualitatively and quantitatively account for the relationship between growth, survival, and tenure in the export market that is observed in the data: (a) continuation rates that are increasing with export tenure, and (b) high initial and subsequent gradual growth of export sales of new exporters.

The model provides a framework that can be used to quantify the role of learning dynamics

³³I use the same discount factor used by firms in section 3, which is equivalent to discounting at a 4% annual real rate of interest.

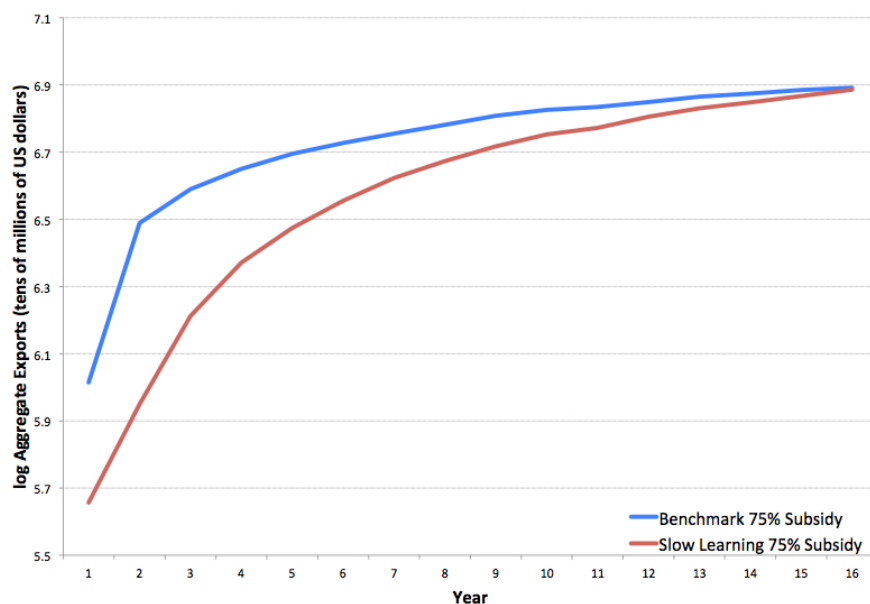


Figure 6.4: The Impact of the Speed of Learning on Export Promotion

in shaping the firm level export decision and its consequences for the effects of trade liberalization on micro and macro export growth. The main results that I obtain from the estimated model and counterfactuals are: (i) first-time exporters expect to incur losses by serving the foreign market; the option value generated by the acquisition of more precise information regarding export profitability compensates inexperienced exporters for their losses and entry is driven by below average costs of serving the foreign market; (ii) while the first-year serving the foreign market provides a crucial learning experience for new exporters, the discovery stage is more prolonged: the value of learning remains positive for the first four years of tenure in the export market. During the discovery stage, the export cutoff experiences 90% of its long-term adjustment and the (ex-ante) probability of serving the foreign market for long-term survivors realizes 95% of its long-term adjustment; (iii) in the transition from new to established exporters, long-term survivors observe a 137% increase in their ex-ante probability of serving the foreign market and a 900% increase in their (average) export premia, and (iv) temporary shocks to the profitability of serving the export market can have long-lived effects on aggregate trade volumes. In particular, export promotion policies that temporarily subsidize the fixed costs of maintaining a presence in the foreign market can result in long-term increases in aggregate trade volumes. However, the short-run impact of these types of policies on trade volumes crucially depends on the speed at which firms are able to uncover their export profitability.

In contrast to the evidence on learning and export dynamics afforded by reduced form specifications such as those considered by Albornoz et al. [2012], by developing and estimating a structural model of export supply featuring self-discovery I was able to quantify the role of learning in shaping the export supply decision of firms. By doing so I found that export profitability is not fully uncovered in the first year as suggested by these authors: the discovery stage lasts for approximately four years. Conditional on survival, firm's will not fully adjust their foreign market presence immediately. Adjustment continues for a number of periods as firms gradually uncover export profitability, and it is this gradual learning that leads to the firm level export dynamics that is observed for the growth and survival of new export entrants.

In order to highlight the role that self-discovery plays in explaining the relationship between export tenure, growth and survival, the model has abstracted from certain aspects that may be important in shaping the internationalization process of new exporters. Secondary sources of learning have been omitted from the discussion. There is some evidence that incumbent exporters provide informational spillovers for new export entrants (see Roberts and Tybout [1997] and Cadot et al. [2013]) and it would be interesting to include such secondary sources of firm learning to assess the role of private and public sources of information in shaping firm dynamics in the foreign market. Additionally, these informational spillovers would enrich the normative analysis of export promotion (see Arkolakis et al. [2015]) since there would be a case for policy interventions that compensate exporters for the information externalities they generate.

Other extensions of the basic setup considered here would also be of interest to further understand the dynamics of firm level exports and the internationalization process of new exporters. For example, while the decision to acquire information is endogenous in the model presented here, the amount of information acquired is not: all firms learn at the same rate. Figure 2.3 in section 2 suggests that the duration of the firm's learning period is inversely related with size on entry: firms that start out bigger undergo a quicker adjustment period in the foreign market. It would be interesting to incorporate self-discovery into the market penetration cost framework of Arkolakis [2010]. There, the endogenous choice of number of consumers reached by the firm can be linked to the amount of information acquired by the firm if it is assumed that each consumer provides an independent signal regarding the firm's export profitability (see Akhmetova and Mitaritonna [2013] for an approach along these lines).

Finally, the extensive margin of number of destinations served is abstracted from. When export profitability is a persistent component that is global in scope, self-discovery could

lead to a pattern of sequential expansion in export markets where the magnitude of first-year growth in export sales in a given destination depends on the time in the firm's export tenure when that market was reached for the first time: first-year growth in export sales is stronger in destinations which are reached earlier on in the firm's tenure in the export market. Cebberos [2015] documents that: (i) export entrants reach new destinations gradually according to a "pecking order" defined by the barriers to breaching foreign destinations; (ii) new exporters become increasingly likely to reach more destinations as time goes by, but the magnitude of adjustment in the number of destinations served is greater earlier on in the firm's export tenure, and (iii) growth rates of export sales for destinations further down in the entry process of firms are smaller than for the initial destinations reached. These dynamics would be consistent with firm learning about persistent demand components that are global in scope. This pattern of sequential exporting is also discussed and documented in Albornoz et al. [2012] for Argentinian exporters. These and other extensions are left for future work.

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Appendix A: dynamics of the sufficient statistic A_t

In this subsection I provide the details behind the expression for the dynamics of A_t^σ presented in the text. Recall that A_t^σ evolves according to

$$A_{t+1}^\sigma = A_t^\sigma + d_t \{ [A^\sigma(\mu_{t+1}, n_{t+1}) - A^\sigma(\mu_t, n_{t+1})] + [A^\sigma(\mu_t, n_{t+1}) - A^\sigma(\mu_t, n_t)] \},$$

where $A_t = A(\mu_t, n_t)$ and $d_t = 1$ if the firm export in period t and $d_t = 0$ otherwise.

To derive the desired result I make the additional assumption that $\lim_{\theta \rightarrow \infty} h(\theta)$ exists. Now, observe that

$$\begin{aligned} A^\sigma(\mu, n) &= \int_{-\infty}^{\infty} [h(\theta)]^\sigma d\Phi(\theta; \mu, n) \\ &= [(h(\theta))^\sigma \Phi(\theta; \mu, n)]_{-\infty}^{\infty} - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu, n) \tilde{h}(\theta) d\theta \\ &= \lim_{\theta \rightarrow \infty} h(\theta) \Phi(\theta; \mu, n) - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu, n) \tilde{h}(\theta) d\theta \\ &= \lim_{\theta \rightarrow \infty} h(\theta) - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu, n) \tilde{h}(\theta) d\theta = M - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu, n) \tilde{h}(\theta) d\theta, \end{aligned}$$

where $\Phi(\cdot; \mu, n)$ is the cdf of a normal distribution with mean μ and standard deviation defined by n , and $\tilde{h}(\theta) = [h(\theta)]^{\sigma-1} h'(\theta)$.

Using the above representation for $A^\sigma(\mu, n)$ we can write the effect of “new information” as

$$\begin{aligned} A^\sigma(\mu_{t+1}, n_{t+1}) - A^\sigma(\mu_t, n_{t+1}) &= M - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu_{t+1}, n_{t+1}) \tilde{h}(\theta) d\theta - \left(M - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu_t, n_{t+1}) \tilde{h}(\theta) d\theta \right) \\ &= \sigma \int_{-\infty}^{\infty} [\Phi(\theta; \mu_t, n_{t+1}) - \Phi(\theta; \mu_{t+1}, n_{t+1})] \tilde{h}(\theta) d\theta. \end{aligned}$$

For the case of more precise information we can write

$$\begin{aligned} A^\sigma(\mu_t, n_{t+1}) - A^\sigma(\mu_t, n_t) &= M - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu_t, n_{t+1}) \tilde{h}(\theta) d\theta - \left(M - \sigma \int_{-\infty}^{\infty} \Phi(\theta; \mu_t, n_t) \tilde{h}(\theta) d\theta \right) \\ &= \sigma \int_{-\infty}^{\infty} [\Phi(\theta; \mu_t, n_t) - \Phi(\theta; \mu_t, n_{t+1})] \tilde{h}(\theta) d\theta \\ &= \sigma \left\{ \int_{-\infty}^{\mu_t} [\Phi(\theta; \mu_t, n_t) - \Phi(\theta; \mu_t, n_{t+1})] \tilde{h}(\theta) d\theta + \int_{\mu_t}^{\infty} [\Phi(\theta; \mu_t, n_t) - \Phi(\theta; \mu_t, n_{t+1})] \tilde{h}(\theta) d\theta \right\} \end{aligned}$$

If $\sigma_1 > \sigma_2$ then for $x \geq 0$ we have

$$\begin{aligned}
\Phi(\mu + x; \mu, \sigma_1) - \Phi(\mu + x; \mu, \sigma_2) &= \left[1 - \Phi\left(-\frac{x}{\sigma_1}\right) \right] - \left[1 - \Phi\left(-\frac{x}{\sigma_2}\right) \right] \\
&= \Phi\left(-\frac{x}{\sigma_2}\right) - \Phi\left(-\frac{x}{\sigma_1}\right) \\
&= \Phi(\mu - x; \mu, \sigma_2) - \Phi(\mu - x; \mu, \sigma_1),
\end{aligned}$$

where $\Phi(\cdot)$ is the cdf of a standard normal distribution and in the first line I made use of the fact that the normal distribution is symmetric about its mean.

Define $\Delta_F(\tilde{\theta}) = \Phi(\tilde{\theta} + \mu_t; \mu_t, n_{t+1}) - \Phi(\tilde{\theta} + \mu_t; \mu_t, n_t)$ for $\tilde{\theta} \geq 0$. Since n_{t+1} implies a lower variance than n_t , normality implies that $\Delta_F(\tilde{\theta})$ is non-negative and non-decreasing. With this notation we may write

$$\begin{aligned}
\int_{\mu_t}^{\infty} [\Phi(\theta; \mu_t, n_t) - \Phi(\theta; \mu_t, n_{t+1})] \tilde{h}(\theta) d\theta &= \int_0^{\infty} [\Phi(\tilde{\theta} + \mu_t; \mu_t, n_t) - \Phi(\tilde{\theta} + \mu_t; \mu_t, n_{t+1})] \tilde{h}(\tilde{\theta} + \mu_t) d\tilde{\theta} \\
&= - \int_0^{\infty} [\Phi(\tilde{\theta} + \mu_t; \mu_t, n_{t+1}) - \Phi(\tilde{\theta} + \mu_t; \mu_t, n_t)] \tilde{h}(\tilde{\theta} + \mu_t) d\tilde{\theta} \\
&= - \int_0^{\infty} \Delta_F(\tilde{\theta}) \tilde{h}(\mu_t + \tilde{\theta}) d\tilde{\theta},
\end{aligned}$$

and

$$\int_{-\infty}^{\mu_t} [\Phi(\theta; \mu_t, n_t) - \Phi(\theta; \mu_t, n_{t+1})] \tilde{h}(\theta) d\theta = \int_0^{\infty} \Delta_F(\tilde{\theta}) \tilde{h}(\mu_t - \tilde{\theta}) d\tilde{\theta},$$

where I have used the symmetry of the normal distribution.

Thus, the effect of more precise information is given by

$$A^\sigma(\mu_t, n_{t+1}) - A^\sigma(\mu_t, n_t) = \sigma \int_0^{\infty} \Delta_F(\tilde{\theta}) [\tilde{h}(\mu_t - \tilde{\theta}) - \tilde{h}(\mu_t + \tilde{\theta})] d\tilde{\theta}.$$

Putting these results together delivers the expression for the dynamics of A_t^σ that is found in section 3 of the main text.

Appendix B: solving the firm's dynamic optimization problem

In this section I provide a more thorough characterization of the firm's dynamic optimization problem presented in section 3.3. It will be useful to work with a scaled version of the

dynamic programming problem that defines the firm's optimal policy. To that end, I define $v_{\vartheta} := \frac{1}{\zeta} \mathcal{V}_{\vartheta}$ and $w_d := \frac{1}{\zeta} W_d$ and study the dynamic programming problem

$$v_{\vartheta}(n, \mu, \varepsilon) = \max_{d \in D} \{w_d(n, \mu; \vartheta) + \varepsilon_d\}.$$

Under the assumptions presented in section 3 this dynamic optimization problem satisfies all of the assumptions of Theorem 3.1 in Rust [1988] (also see Rust [1994]), so the value function exists and is unique and the firm's optimal policy can be determined from the Bellman equation representing the firm's problem.

The assumptions made in section 3 allow for a more detailed characterization of the solution to the firm's dynamic programming problem. Under the assumption that the unobserved state variables ε are independent of the other state variables, the expected value function can be written as

$$\mathbb{E}[v_{\vartheta}(n', \mu', \varepsilon') | n, \mu, d] = \mathbb{E}_{\mu'} [\mathbb{E}_{\varepsilon'} [v_{\vartheta}(n + d, \mu', \varepsilon') | n, \mu, d]].$$

I define $\mathcal{W}_{\vartheta}(n', \mu') \equiv \mathbb{E}_{\varepsilon'} [v_{\vartheta}(n', \mu', \varepsilon')]$, which allows me to write the expected value function as

$$\mathbb{E}[v_{\vartheta}(n', \mu', \varepsilon') | n, \mu, d] = \mathbb{E}_{\mu'} [\mathcal{W}_{\vartheta}(n + d, \mu') | n, \mu, d].$$

Claim. Under the distributional assumption for ε , the expected value function $\mathcal{W}_{\vartheta}(n, \mu)$ can be expressed as

$$\mathcal{W}_{\vartheta}(n, \mu) = \ln [\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))],$$

where w_0 and w_1 are the alternative specific value functions.

Proof. I proof the claim in two steps. First, I proof that if $\varepsilon_i \stackrel{i.i.d}{\sim} F_{EV}(\cdot; \gamma)$, where $F_{EV}(x; \gamma) = \exp\{-\exp\{-(x + \gamma)\}\}$ is the CDF of an extreme value distribution with parameter γ equal to the Euler-Mascheroni constant ($\simeq 0.577$), and v_i are constants, then

$$\max_i \{v_i + \varepsilon_i\} \sim F_{EV} \left(\cdot; \gamma - \log \left[\sum_i \exp(v_i) \right] \right),$$

with $\mathbb{E}[\max_i \{v_i + \varepsilon_i\}] = \log [\sum_i \exp(v_i)]$.

Notice that

$$\begin{aligned}
\Pr\left(\max_i \{v_i + \varepsilon_i\} \leq x\right) &= \Pr(v_1 + \varepsilon_1 \leq x, \dots, v_I + \varepsilon_I \leq x) \\
&= \prod_i \Pr(v_i + \varepsilon_i \leq x) \quad (\text{by independence}) \\
&= \prod_i \exp\{-\exp\{-(x + \gamma - v_i)\}\} \\
&= \exp\left\{-\sum_i \exp\{-(x + \gamma - v_i)\}\right\} = \exp\{-\exp\{-(x + \xi)\}\}
\end{aligned}$$

where $\xi = \gamma - \log \sum_i e^{v_i}$. The last line is just the CDF for an extreme value distribution with parameter ξ .

Now, if $x \sim F_{EV}(\cdot; \gamma)$, then $\mathbb{E}[x] = \delta - \gamma$, where δ is the Euler-Mascheroni constant (thus, when γ is equal to the Euler-Mascheroni constant x has an expected value of zero). Applying this result to the random variable $\max_i \{v_i + \varepsilon_i\}$ we have that

$$\mathbb{E}\left[\max_i \{v_i + \varepsilon_i\}\right] = \delta - \xi = (\delta - \gamma) + \log\left[\sum_i \exp(v_i)\right] = \log\left[\sum_i \exp(v_i)\right],$$

since γ is assumed to be equal to δ .

Finally, recall from section 3.3 that $\mathcal{V}_\vartheta(n, \mu, \varepsilon) = \max_{d \in D} \{w_d(n, \mu; \vartheta) + \varepsilon_d\}$, so that applying this last result we have that

$$\begin{aligned}
\mathcal{V}_\vartheta(n, \mu) &= \mathbb{E}_\varepsilon[v_\vartheta(n, \mu, \varepsilon)] \\
&= \mathbb{E}_\varepsilon\left[\max_{d \in D} \{w_d(n, \mu; \vartheta) + \varepsilon_d\}\right] \\
&= \ln[\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))].
\end{aligned}$$

□

If the firm decides to not serve the foreign market, then its state variables will remain at their current levels. That is, if $d = 0$, then $n' = n$ and $\mu' = \mu$. Therefore, in the case in which the firm decides not to export, the expected value function is given by

$$\mathbb{E}[v_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 0] = \mathcal{V}_\vartheta(n, \mu),$$

which from the previous claim and the definition of the alternative specific value functions implies that the value of not exporting is given by

$$W_0(n, \mu; \vartheta) = \beta \ln [\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))],$$

which is just the discounted expected value of $\max_{d \in D} \{w_d(n, \mu; \vartheta) + \varepsilon_d\}$.

For the alternative in which the firm chooses to export, we have that the output from the Kalman Filter implies the following conditional distribution :

$$\mu' \sim N\left(\mu, \frac{\mathbf{v}_\varepsilon}{(\mathbf{v}_\theta + n\mathbf{v}_\varepsilon)(\mathbf{v}_\theta + (n+1)\mathbf{v}_\varepsilon)}\right).$$

Thus, in the case $d = 1$ the expected value function is given by

$$\begin{aligned} \mathbb{E}[v_\vartheta(n', \mu', \varepsilon') | n, \mu, d = 1] &= \mathbb{E}_{\mu'}[\mathcal{W}_\vartheta(n+d, \mu') | n, \mu, d = 1] \\ &= \int_{-\infty}^{\infty} \ln [\exp(w_0(n+1, \mu'; \vartheta)) + \exp(w_1(n+1, \mu'; \vartheta))] f_\vartheta(\mu' | n, \mu) d\mu', \end{aligned}$$

where $f_\vartheta(\mu' | n, \mu)$ is the density of a Gaussian distribution with mean and standard deviation given as above.

From the definition of the alternative specific value functions, we have that the value of choosing to serve the foreign market is given by

$$w_1(n, \mu; \vartheta) = \zeta^{-1} \tilde{\pi}(n, \mu; \vartheta) + \beta \int_{-\infty}^{\infty} \ln [\exp(w_0(n+1, \mu'; \vartheta)) + \exp(w_1(n+1, \mu'; \vartheta))] f_\vartheta(\mu' | n, \mu) d\mu',$$

the sum of expected current export profits and the discounted expected continuation value.

Therefore, the alternative specific value functions are the solution to the functional equations (FE):

$$\begin{aligned} w_0(n, \mu; \vartheta) &= \beta \ln [\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))] \\ w_1(n, \mu; \vartheta) &= \zeta^{-1} \tilde{\pi}(n, \mu; \vartheta) \\ &\quad + \beta \int_{-\infty}^{\infty} \ln [\exp(w_0(n+1, \mu'; \vartheta)) + \exp(w_1(n+1, \mu'; \vartheta))] f_\vartheta(\mu' | n, \mu) d\mu'. \end{aligned}$$

These functional equations define a contraction mapping which possess a unique fixed point for (w_0, w_1) as shown in Rust [1994]. The firm's optimal policy is given by

$$d^* = \mathbb{I}[\delta(n, \mu; \vartheta) + \zeta \varepsilon > 0],$$

where $\delta(n, \mu; \vartheta) = W_1(n, \mu; \vartheta) - W_0(n, \mu; \vartheta)$. Thus, to solve for the optimal policy function all that is required is to solve the above functional equations for the alternative specific functions (w_0, w_1) .

In section 3.3 it was shown that a crucial distinction between this dynamic model and static models of export supply is that the “exporter premia” in the dynamic model includes the “gains from trial”: the value that the firm attaches to gaining more precise information about its true profitability in the export market (information that can only be acquired by exporting). To further our intuition regarding the “gains from trial” or the option value of exporting, recall that for $d = 0$ the alternative specific value function was given by $w_0(n, \mu; \vartheta) = \beta \ln[\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))]$, thus I can re-write the above expression for w_1 as

$$w_1(n, \mu; \vartheta) = \zeta^{-1} \tilde{\pi}(n, \mu; \vartheta) + \int_{-\infty}^{\infty} w_0(n+1, \mu'; \vartheta) f_{\vartheta}(\mu'|n, \mu) d\mu',$$

which in turn implies that

$$\begin{aligned} w_1(n, \mu; \vartheta) - w_0(n, \mu; \vartheta) &= \zeta^{-1} \tilde{\pi}(n, \mu; \vartheta) \\ &+ \int_{-\infty}^{\infty} [w_0(n+1, \mu'; \vartheta) - w_0(n, \mu; \vartheta)] f_{\vartheta}(\mu'|n, \mu) d\mu'. \end{aligned}$$

Thus, the “exporter premia” can be expressed as

$$\delta(n, \mu; \vartheta) \equiv \tilde{\pi}(n, \mu; \vartheta) + \int_{-\infty}^{\infty} [W_0(n+1, \mu'; \vartheta) - W_0(n, \mu; \vartheta)] f_{\vartheta}(\mu'|n, \mu) d\mu',$$

from which we readily see that the “gains from trial” are given by

$$G(n, \mu; \vartheta) = \int_{-\infty}^{\infty} [W_0(n+1, \mu'; \vartheta) - W_0(n, \mu; \vartheta)] f_{\vartheta}(\mu'|n, \mu) d\mu'.$$

By Taylor’s Theorem there exists $R(\cdot)$, a real-valued function, such that

$$W_0(n+1, \mu'; \vartheta) = W_0(n+1, \mu; \vartheta) + W_{0,\mu}(n+1, \mu; \vartheta) (\mu' - \mu) + R(|\mu' - \mu|),$$

where

$$\lim_{\mu' \rightarrow \mu} R(|\mu' - \mu|) = 0.$$

Therefore, I can re-write the “gains from trial” as

$$\begin{aligned} G(n, \mu; \vartheta) &= \int_{-\infty}^{\infty} [W_0(n+1, \mu; \vartheta) + W_{0,\mu}(n+1, \mu; \vartheta)(\mu' - \mu) + R(|\mu' - \mu|) - W_0(n, \mu; \vartheta)] f_{\vartheta}(\mu'|n, \mu) d\mu' \\ &= [W_0(n+1, \mu; \vartheta) - W_0(n, \mu; \vartheta)] + W_{0,\mu}(n+1, \mu; \vartheta) \mathbb{E}_{f_{\vartheta}}[\mu' - \mu] + \mathbb{E}_{f_{\vartheta}}[R(|\mu' - \mu|)], \end{aligned}$$

where $\mathbb{E}_{f_{\vartheta}}[\cdot]$ denotes the expectation taken with respect to the density $f_{\vartheta}(\mu'|n, \mu)$.

Since μ' has mean μ under $f_{\vartheta}(\mu'|n, \mu)$, the third term in the above expression drops out, and $\mathbb{E}_{f_{\vartheta}}[R(|\mu' - \mu|)]$ is “small” since most of the mass of $f_{\vartheta}(\mu'|n, \mu)$ is concentrated around μ and in that neighborhood $R(|\mu' - \mu|)$ is close to zero. Thus, the “gains from trial” are approximately given by

$$G(n, \mu; \vartheta) \simeq W_0(n+1, \mu; \vartheta) - W_0(n, \mu; \vartheta).$$

This is the expression presented in section 3.3 of the main text.

7.0.1 B.1. Numerical solution to the firm’s dynamic programming problem

To characterize the optimal policy rule of the firm I need to solve for the alternative specific value functions w_0 and w_1 , which are the solution to the functional equations:

$$\begin{aligned} w_0(n, \mu; \vartheta) &= \beta \ln [\exp(w_0(n, \mu; \vartheta)) + \exp(w_1(n, \mu; \vartheta))] \\ w_1(n, \mu; \vartheta) &= \zeta^{-1} \tilde{\pi}(n, \mu; \vartheta) + \beta \mathbb{E} [\ln [\exp(w_0(n+1, \mu'; \vartheta)) + \exp(w_1(n+1, \mu'; \vartheta))] | n, \mu, d = 1], \end{aligned}$$

where $\mathbb{E}[\cdot | n, \mu, d = 1]$ denotes the expectation taken with respect to the density for

$$\mu' \sim N\left(\mu, \frac{\mathbf{v}_{\varepsilon}}{(\mathbf{v}_{\theta} + n\mathbf{v}_{\varepsilon})(\mathbf{v}_{\theta} + (n+1)\mathbf{v}_{\varepsilon})}\right),$$

which is the conditional distribution resulting from the signal extraction problem defined by the Kalman filter.

Observe that the functional equations defining w_0 and w_1 involve w at both n and $n+1$. Given that to solve for the exporter premium I will work with $N < \infty$, I need to make an assumption about the exporter premium at $N+1$. Since the underlying learning process implies that exporting will firms eventually learn their true export profitability, I impose that for sufficiently large N : $w(N, \mu; \vartheta) \simeq w(N+1, \mu; \vartheta)$. That is, I assume that for sufficiently large N exporters have gathered enough information such that an additional export episode does

not affect their perceived premium for exporting. Assumptions such as this are commonly used in the numerical solution of dynamic programming problems with unbounded state variables whose transition implies that the state variable must be non-decreasing. In practice I choose $N = 25$ to solve for the exporter premia.³⁴ The results are not significantly different for $N = 20$ or $N = 30$.

I solve for the exporter premia numerically as follows: Let $N = \{0, 1, \dots, N\} \subset \mathbb{N}$ and $G_\mu = \{-M, \dots, \mu_{-1}, \mu_0, \mu_1, \dots, M\} \subset \mathbb{R}$, where $\mu_0 = \mu_\theta$ and $M = \mu_\theta + 2.5\sigma_\theta$. The grid for the unobserved state variable μ defined by G_μ is such that I cover 99% of the mass for the initial prior distribution for the unknown export profitability θ . I discretize the distributions implied by the Kalman filter over the grid G_μ to define transition matrices as follows:

$$\begin{aligned} \Pr(\mu' = \mu_j | \mu = \mu_k, n, d = 0) &= \mathbb{I}\{j = k\} \\ \Pr(\mu' = \mu_j | \mu = \mu_k, n, d = 1) &= \zeta \left[\Phi\left(\frac{\Delta_{jk} + 0.5\Delta_j}{\sigma_n}\right) - \Phi\left(\frac{\Delta_{jk} - 0.5\Delta_{j-1}}{\sigma_n}\right) \right], \end{aligned}$$

where

$$\begin{aligned} \Delta_{jk} &\equiv \mu_j - \mu_k \\ \Delta_j &\equiv \mu_{j+1} - \mu_j \\ \sigma_n &\equiv \sqrt{\frac{v_\varepsilon}{(v_\theta + nv_\varepsilon)(v_\theta + (n+1)v_\varepsilon)}} \end{aligned}$$

and ζ is a normalizing constant such that $\sum_j P_{kj}^n = 1$.

Let $J = |G_\mu|$, the number of grid points on the grid for the state variable μ , and let $\pi(\vartheta)$ be an $N \times J$ matrix with typical element³⁵

$$\pi_{nj}(\vartheta) = \zeta^{-1} \tilde{\pi}(n-1, \mu_j; \vartheta).$$

The following algorithm solves numerically for the exporter premia:

Step 1 - Select an accuracy level $\varepsilon > 0$ and an initial guess $(w_0^0(\vartheta), w_1^0(\vartheta))$ which are $(N+1) \times J$ matrices.

³⁴What is important is that $N \gg T$, where T is the number of time periods for which data is available in the sample.

³⁵To calculate the per period profits of the firm I need to evaluate the integral $\mathbb{E}[(h(\theta_t))^\sigma | \mu_t, n_t]$ which defines the adjusted expected value of $h(\cdot)$. I calculate this integral using the Gauss-Hermite quadrature method (see Judd [1999] for details).

Step 2 - Functional equation step : use the functional equations defined above to solve for $(w_0^{m+1}(\vartheta), w_1^{m+1}(\vartheta))$.

For $k = 1, \dots, J$: For $n = 1, \dots, N$

$$\begin{aligned} w_{0,nk}^{m+1} &= \beta \ln \left[\exp(w_{0,nk}^m) + \exp(w_{1,nk}^m) \right] \\ w_{1,nk}^{m+1} &= \pi_{nk}(\vartheta) + \beta \sum_j P_{kj}^n \ln \left[\exp(w_{0,n+1j}^m) + \exp(w_{1,n+1j}^m) \right] \\ w_{0,N+1k}^{m+1} &= w_{0,Nk}^{m+1} \\ w_{1,N+1k}^{m+1} &= w_{1,Nk}^{m+1}. \end{aligned}$$

Step 3 - End of iteration: If

$$\max \left\{ \max \left| w_{0,nj}^{m+1}(\vartheta) - w_{0,nj}^m(\vartheta) \right|, \max \left| w_{1,nj}^{m+1}(\vartheta) - w_{1,nj}^m(\vartheta) \right| \right\} \leq \varepsilon$$

stop; else, increment m by 1 and return to step 2.

\mathbb{P}^n is the $J \times J$ transition matrix with typical element

$$P_{kj}^n = \Pr(\mu' = \mu_j | \mu = \mu_k, n-1, d=1) = \zeta \left[\Phi \left(\frac{\Delta_{jk} + 0.5\Delta_j}{\sigma_{n-1}} \right) - \Phi \left(\frac{\Delta_{jk} - 0.5\Delta_{j-1}}{\sigma_{n-1}} \right) \right],$$

as outlined above.

Let $(\tilde{w}_0(\vartheta), \tilde{w}_1(\vartheta))$ denote the result from the this algorithm. I use these matrices to construct the exporter premium by: $\delta(\vartheta) = [\delta_{nj}] = [\zeta(\tilde{w}_{1,nj} - \tilde{w}_{0,nj})]$.

Appendix C: estimation procedure - moment matching and indirect inference

I estimate the model's parameters using indirect inference as described in Gouriéroux and Monfort (2002). I use the iterative procedure described in Dejong and Dave (2007) which proceeds as follows:

Step 1 - Select an accuracy level $\varepsilon > 0$ and an initial guess $\hat{\vartheta}_0$.

Step 2 - Weighting matrix step: Use $\hat{\vartheta}_j$ to construct

$$\begin{aligned}\Sigma_j &= \frac{1}{S} \sum_{s=1}^S \left(m_s(\hat{\vartheta}_j) - \frac{1}{S} \sum_{s=1}^S m_s(\hat{\vartheta}_j) \right) \left(m_s(\hat{\vartheta}_j) - \frac{1}{S} \sum_{s=1}^S m_s(\hat{\vartheta}_j) \right)' \\ \Omega_j &= \Sigma_j^{-1},\end{aligned}$$

where $m_i(\hat{\vartheta}_j)$ is the i th of S realizations of model moments under the parameter vector $\hat{\vartheta}_j$. The matrix Ω_j is a symmetric non-negative matrix.

Step 3 - Minimization step: Find $\hat{\vartheta}_{j+1}$ as

$$\hat{\vartheta}_{j+1} = \arg \min_{\vartheta} (\hat{m}_d - \hat{m}(\vartheta))' \Omega_j (\hat{m}_d - \hat{m}(\vartheta)).$$

Step 4 - End of iteration: If $\|\hat{\vartheta}_{j+1} - \hat{\vartheta}_j\| < \varepsilon$, stop and set $\hat{\vartheta} = \hat{\vartheta}_{j+1}$; else, increment j by 1 and return to step 2.

For the minimization step I use a simulated annealing algorithm (see Judd [1999] for details).