A Search and Learning Model of Export Dynamics

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Abstract

1 Introduction

Transactions-level trade data reveal several key features of Colombian exporter behavior. First, in any one year, one-third to one-half of these exporters are shipping very small amounts abroad. Second, most of these small-scale exporters disappear from foreign markets within a year after their appearance. Third, however, those that do not disappear show very rapid growth during their early years of export market participation, often expanding at rates five times as fast as aggregate exports. Fourth, these successful young exporters grow partly by increasing their shipments to their initial buyers, and partly by adding buyers to their portfolio of clients. We develop a search and learning model of exporter behavior that captures all of these stylized facts, and we report simulations that demonstrate its properties.

The paper is organized into two remaining sections. The first presents transactions-level evidence on Colombian firms' exports to the United States. Some of the patterns we present resemble findings in Eaton et al. (2008), but others are new, and describe patterns of matching with particular U.S. importers. The second section presents a dynamic stochastic search-theoretic model of matching between exporters and importers that accords with basic features of the data, and reports numerical simulations that demonstrate its properties.

2 Firm-Level Trade: Transaction Level Evidence

We look at evidence from two sources. We begin with data on the export transactions of Colombian firms from Colombian customs over the period 1996-2005. We then turn to data that links these export transactions with information about the U.S. buyer from U.S. Census.

2.1 Evidence from Colombian Export Transactions to the United States

To explore the nature of trade barriers at this level of detail we look at all export transactions by Colombian firms between 1996 and 2005. Each transaction is recorded separately. A transaction record includes the firm's tax ID (which serves as a time-invariant identifier), a product code, the value of the transaction in US dollars, and the country of destination. Because we use the same data that are used for official statistics, the merchandise exports in our data set aggregate to within one percent of total merchandise exports reported by the Colombian Bureau of Statistics (Departamento Administrativo Nacional de Estadística or DANE).[1]

The Table below, following Brooks (2006) and Eaton et al. (2008), looks at various annual measures of Colombian exports to the United States for the years 1996-2007. In the first columns firms are separated according to when they began exporting. Since we don't know the history of firms before 1996, the 1996 "cohort" consists of all firms present that year regardless of when they began exporting. For subsequent years we can separate firms that entered since 1996 according to when they started exporting. The first page of the Table reports number of exporters total exports, and exports per firm.

Table 1 here

[1]The deviation is due to mistakes in the records of tax identifiers. Since following firms over time is central to our analysis, our database includes only records of transactions in which the tax identifier has the appropriate format. Not satisfying this requirement is a clear indication that the firm is not correctly identified in the record.

The column on the far right aggregates across cohorts. Looking at these aggregates first, note that the number of firms selling in the United States fell substantially in the first two years of the period and then recovered in the second half of the period. Total export sales are fairly stable at the beginning and then rise substantially in the last four years. Hence sales per firm are quite volatile, rising substantially at the beginning of the period, falling back down and then rising again to about twice their initial level.

Firms can drop out and reappear, which is why the number of firms in a cohort occasionally rises. But usually the number falls. Note that there is substantial attrition the first year, with at least half and up to three-fourths of firms dropping out. Conditional on surviving the first year the survival probability is much higher, however, with an attrition rate typically below 10 percent. Thus, in terms of numbers, the most recent cohort is always larger than any previous one (except, in a couple of the early years, the 1996 cohort). Note that by the end of the period firms that were around in 1996 constitute only about one in seven of firms exporting to the United States.

Despite the decline in the number of firms, the total sales of a cohort tends to rise over time, although quite unevenly. By the end of the period the 1996 cohort contributes about 76 percent of total sales, despite their relatively small number. The 2005 cohort contributes the second largest share.

The decline in number of firms per cohort along with their increasing contribution to total sales means, of course, that sales per firm are growing substantially. By the end of the period sales per firm remain very much higher for the 1996 cohort than for any subsequent one. More recent cohorts tend to sell less per firm. The 2005 cohort appears very robust both in terms

of number of exporters and exports per firm, with 2006 weak by comparison.

The second page of the table looks at export transactions, reporting the total number, the number per firm and the average value per transaction. Note from the far-right column that the number of transactions grew every year, even years in which the value of exports and the number of exporters fell. The average number of transactions per firm more than doubled, while, as with total Colombian exports, the average transaction size tended to fall.

Looking at individual cohorts, the average number of transactions among entrants in the first year is small, but it rises substantially after a year and tends to continue rising after that. Nevertheless, even at the end of the period older cohorts have substantially more transactions on average than more recent ones. For a given cohort, growth in average transaction size is more modest than growth in the number of transactions.

2.2 Evidence on Colombian-U.S. Relationships

Individual buyers and sellers are identified in the transaction level data collected by the United States Census Bureau. Accordingly, it is possible to keep track of how many buyers each Colombian exporter is shipping to, and to see when buyers are dropped or added. We next use these data to characterize the buyer-seller matchings that took place during our sample period of 1992-2005. The Table below provides some summary statistics:

Table 2

	Colombian Exporters	U.S. Importers	Exporter-Importer Pairs
start	3742	1265	5297
end	5297	2214	8046

For example, the number of Colombian exporters appearing in the sample in 1992 was 3742, which grew to 5297 in 2005, a growth of 3.5 while the number of U.S. firms grew by 4.4 percent. The number of Colombian exporter-U.S. importer pairs (representing at least one transaction between them in a year) grew at an annual rate of 3.3 percent. A typical Colombian exporter was involved in around 1.4 relationships with U.S. firms while a U.S. buyer was involved in around 4, with both declining slightly over the period.

Of the pairs, only 85 endure (are present every year) throughout the period. Most relationships are very short-lived. Of those that existed at the beginning of the period 47 percent didn't make it to the 1993. But of those that survived into that year, almost 70 percent made it into the next year. Similarly, of the relationships that existed in 2005, 48 percent started that year, but of those that started the previous year, 65 percent had been around at least 3 years before.

2.2.1 Transition Probabilities

The following Table reports the probability with which a Colombian firm participating in certain number of relationships with buyers transits into different number of relationships the following year. This table reports the annual average for 1992-1997 across all industries. Numbers for later periods are very similar. Thus, of firms not exporting to the United States at all in year t but that do export in year $t+1$, 92.5 percent sell to only one U.S. firm, etc. Of those that cell to one U.S. buyer in a year, 63 percent don't export the next year,while only about 6 percent go on to establish a larger number of relationships. For firms with two relationships in a year, about 14 percent enter into a larger number of relationships, etc. Hence there is an enormous amount of churning at the lower end. Even for firms with a large

number of relationships the most likely outcome is to have fewer the next year.

(table 3 here)

We can ask what this pattern of entry and growth implies about the ergodic distribution of relationships. If we assume that the number of entrants in a year replace exiters to the extent that the overall number of firms rises by 3.5 percent a year, the ergodic distribution implied by this transition matrix is given by:

Table 4

	1	2	3	4	5	6 to 10	11 to 25
ergodic	.809	.109	.039	.019	.010	.013	.002
period average	.800	.114	.041	.020	.010	.012	.003

For purposes of comparison the average annual share of Colombian firms in each group is reported as well in the period is reported as well. Note that the ergodic distribution implied by the transition matrix is very close to the distribution in the data.

2.2.2 Transactions and Buyers

To what extent does the number of buyers increase with the number of transactions. For Colombian exporters that made only one sale to the United States in a year, the number of buyers is necessarily one. But for firms that made two sales, the mean number of buyers was only 1.15. The mean number of buyers hits two only for firms that made 14 sales. Even firms that made 20 sales only had, on average, 2.33 buyers.

A regression of the number of buyers against the number of transactions (both in logs) gives an elasticity of .22. Hence as a firm engages in more export transactions, 80 percent of

the time this increase means more purchases by the same buyer. This "monogamous" pattern of exporting appears in terms of changes as well. Most year-to-year changes in transactions reflect changes in the number of sales to the same buyer, not adding or dropping buyers. However, these averages mask the fact that a small set of exporters has many buyers, and accounts for a large fraction of total sales.

3 A Model of Exporting at the Transactions Level

The measures above look at exports from a very different perspective than the standard one. Rather than considering exports as a flow over some interval of time, we are observing individual sales by single firms as discrete events. Existing trade models, including those emanating from the emerging literature on export activity by individual firms, model sales as flows to specific markets rather than as a discrete set of sales.

We propose a model that explains firm-specific export adjustments on three margins: clients (buyers) per destination market, transactions per client, and sales volume per transaction.

The model is consistent with several key stylized facts from transactions level export data: (1) many new exporting firms appear each period; (2) most new exporters sell tiny amounts and disappear from export markets in the following period; (3) those exporters who survive expand their export volume very rapidly over the following period, often accumulating additional buyers; (4) firms that sell more initially are more likely to survive into the following period.[2]

[2]See EEKT (2008).

The model builds on existing models of firm heterogeneity and exporting. As in Melitz (2003) and Bernard et al. (2003), firms are heterogeneous in terms of their underlying efficiency, with more efficient firms having greater incentive to overcome trade costs to sell in foreign markets. As in Das et al. (2007) and Irarrazabal and Opromolla (2007) firms experience shocks to their efficiency that lead them to switch into or out of exporting. As in Arkolakis (2008), by incurring a larger fixed cost a firm can increase the number of buyers it can reach. Finally, as in Rauch and Watson (2003), firms are initially uncertain about how their product will be received in an export market.

What we add to these models is the following structure of decision making and learning. Suppose that before it enters an export market a firm is unsure of the appeal that its product has to buyers there. However, the firm can invest in activities that bring its product to the attention of individual buyers, such as advertising, participation in trade fairs, and maintenance of a foreign sales office. The more a firm spends on these activities, the more likely it will encounter a foreign buyer per unit of time. And when a match does occur, its sale not only generates a profit for the firm, it conveys information to the firm about its product's appeal in that market. On the basis of this information the firm updates its beliefs about its product's ultimate chances for success in that market. Good news means that future matches are likely to be more profitable, so it strengthens its efforts to encounter buyers, while bad news discourages the firm from putting in so much effort.

3.1 Profits

To characterize the profit flow, consider firm j with an efficiency φ_{jt} (taking into account transport costs) at time t. This efficiency is known to the firm and evolves over time with idiosyncratic shocks. Given that it pays a wage (or more generally, unit input price) w_t it can produce at cost w_t/φ_{jt} in terms of local currency. If the exchange rate is e_t, its unit cost in the foreign market is $e_t w_t/\varphi_{jt}$. So assuming that all foreign buyers have Dixit-Stiglitz preferences with known demand elasticity η, seller j offers price:

$$p_{ijt} = \frac{\eta}{\eta - 1} \frac{e_t w_t}{\varphi_{jt}} \tag{1}$$

to any foreign buyer i with whom it matches.[3]

If potential buyer i is confronted with an opportunity to purchase firm j's product, that is, if j matches with i, j's period t sales to i are:

$$X_{ijt} = \exp(z_j + \epsilon_{ij}) \left(\frac{p_{ijt}}{P_t} \right)^{1-\eta} \overline{X_t}. \tag{2}$$

Here z_j is a product appeal index that is common to all foreign buyers but is initially unknown to the firm. Whatever its true product appeal we assume that every firm starts out with a prior that is distributed $N(0, \sigma_z^2)$. The term ϵ_{ij} is an idiosyncratic appeal/spending shock that is distributed i.i.d. $N(0, \sigma_\epsilon^2)$ across foreign buyers, $\overline{X_t}$ is the average spending level among potential buyers, and P_t is the relevant price index for all competing products in the export

[3] For simplicity we assume that the firm makes a take-it-or-leave-it price offer. An alternative specification would introduce bilateral bargaining between buyer and seller, although the seller's uncertainty about the buyer's evaluation of the product renders this second approach substantially more complicated.

market.[4] The flow profit in exporter currency implied by (1) and (2) is:

$$\pi(P_t, P_{Ct}, e_t, z_j, \epsilon_{ij}, \varphi_{jt}) = c\frac{1}{\eta}\frac{1}{e_t P_{Ct}} \exp(z_j + \epsilon_{ij}) \left(\frac{e_t w_t \eta/(\eta-1)}{\varphi_{jt} P_t} \right)^{1-\eta}, \tag{3}$$

where P_{Ct} is the price level in the home country. Or, combining all the aggregate variables and constants:

$$\pi(X_t, z_j, \epsilon_{ij}, \varphi_{jt}) = cX_t \exp(z_j + \epsilon_{ij}) \varphi_{jt}^{\eta-1} \tag{4}$$

where:

$$X_t = \frac{1}{\eta}\frac{1}{e_t P_{Ct}} \left(\frac{e_t w_t \eta/(\eta-1)}{P_t} \right)^{1-\eta}.$$

(Here c is simply a parameter that scales profit which is useful in our numerical analysis.) The term X_t summarizes all the macroeconomic information about the export market (i.e., information that applies to any seller j when matched to any buyer i). We can thus characterize the aggregate state of demand in the export market with X_t. We assume that X and φ evolve over time according to a Markov process, so that given (X_t, φ_{jt}) in period t the period $t+1$ values have a joint distribution $G(X', \varphi' | X_t, \varphi_{jt})$. The difference between X and φ is that the first applies to all firms while the second is idiosyncratic to a specific firm. Hence the first generates behavior that is correlated across firms while the second is independent.

For purposes of the dynamic optimization problem to be introduced below, it will be convenient to define $\widetilde{\pi}(X_t, z_j, \varphi_{jt})$ as the expected present value of firm j's entire profit profit stream associated with a match as perceived at time t. That is, $\widetilde{\pi}(X_t, z_j, \varphi_{jt})$ is the discounted

[4] Not all buyers necessarily face the same range of goods and hence the same aggregate price index P_t. We treat idiosyncratic components of the price index as P_t as reflected in ϵ_{ijt}.

expected future value of the $\pi(X_t, z_j, \epsilon_{ij}, \varphi_{jt})$ trajectory, with expectations taken over ϵ_{ij} and the future trajectory of (X_t, φ_{jt}). The value of $\widetilde{\pi}(X_t, z_j, \varphi_{jt})$ depends on the firm's discount rate r and the hazard of separating from a particular buyer, which we treat as occurring at the exogenous rate δ. Thus $\widetilde{\pi}(X_t, z_j, \varphi_{jt})$ solves:

$$\widetilde{\pi}(X, z_j, \varphi_j) = X_t E_\epsilon \left[\exp(z_j + \epsilon_{ij})\right] \varphi_j^{\eta-1} + \frac{1}{r+\delta} \int_{X'.} \int_{\varphi'} \widetilde{\pi}(X', z_j, \varphi') dG(X', \varphi' | X_t, \varphi_{jt}). \quad (5)$$

This expression thus gives the value to firm j of meeting up with a buyer with idiosyncratic evaluation ϵ_{ij}. Note that our assumptions imply that having met this buyer there is nothing more to learn from her about product appeal, and the firm has no further decisions to make that affect its sales to this buyer. Nevertheless sales could change due to macroeconomic shocks X or shocks to the firm's efficiency φ.

3.2 Information about product appeal

Firm j knows neither z_j nor ϵ_{ij} individually, but each time the firm matches with another buyer it learns more about z_j. That is, knowing the macro state $(\overline{X}_t)$, the price index (P_t) and its own price (p_{ijt}), firm j can compute the signal:

$$s_{ij} = z_j + \epsilon_{ij}.$$

of its product appeal in foreign markets. Combining this signal with the signals it inferred from earlier matches, and with the prior beliefs $N(0, \sigma_z^2)$ it held about z_j before any matches occurred, firm j calculates the posterior distribution of z_j to be $N(\widehat{z}_j^n, \sigma_n^2)$, where:

$$\widehat{z}_j^n = z_j^0 \frac{\sigma_z^{-2}}{\sigma_z^{-2} + n\sigma_\varepsilon^{-2}} + \overline{s}_j^n \frac{n\sigma_\epsilon^{-2}}{\sigma_z^{-2} + n\sigma_\epsilon^{-2}}, \quad (6)$$

and:

$$\sigma_n = \left(\sigma_z^{-2} + n\sigma_\epsilon^{-2}\right)^{-1/2}, \tag{7}$$

n is the number of matches the firm has experienced, and $\overline{s}_j^n = n^{-1}\sum_{i=1}^n s_{ij}$.

This characterization of Bayesian learning generalizes to allow for correlation between a firm's product appeal in the foreign market and (1) its product appeal at home (d), or (2) the average appeal of rival (domestically-based) firms' products in the foreign market (y). To do the first, one can incorporate signals from domestic sales, $s_{jt}^d = \beta_d z_j + \epsilon_t^x$, where $t = 1, ...T$ indexes the periods that the firm has been in operation. To do the second one can incorporate signals from the foreign sales of rival firms in the same industry $s_{kt}^y = \beta_y z_j + \epsilon_{jkt}^y$, where $k = 1, ...n_{yt}$ indexes the number of such rival matches that the firm has observed as of time t. These modifications lead to straightforward generalizations of (6) and (7). Among other things, they generate learning spillovers that accelerate aggregate export responses to positive early experiences in new foreign markets.

3.3 Search intensity

As information accrues to a seller about foreign buyers' demand for its product, it adjusts the intensity with which it searches for new buyers. Let the firm experience new matches with hazard λ when it spends $e(\lambda)$ on search activities, where $e(\cdot)$ is increasing and convex.[5]

[5]Following Arkolakis (2008), if we think that the market has M potential buyers and sampling occurs without replacement we can generalize the hazard rate to be $\widetilde{\lambda} = \lambda \cdot h(n)$ where $h(n)$ is decreasing in n, bounded on [0,1], and $h(M) = 0$. For example, if the probability of a match is proportional to the pool of potential buyers who have not yet been visited, this function might take the form: $h(n) = \frac{M-n}{M}$. Working

Then if the firm has received an average signal of $\overline{s}_n$ after n encounters, the value of continued searching in the foreign market is $V(\widehat{z}_j^n, n, X_t, \varphi_{jt})$, where:

$$\begin{aligned} & V(\widehat{z}_j^n, n, X_t, \varphi_{jt}) \qquad (8) \\ = & \max_{\lambda} \left\{ -e(\lambda) + \lambda \int_z \widetilde{\pi}(X_t, z, \varphi_{jt}) dF(z|\widehat{z}_n, n) \right. \\ & \left. + \frac{1}{1+r} \int_{X'.} \int_{\varphi'} \left[(1-\lambda) V(\widehat{z}_j^n, n, X', \varphi') + \lambda \int_{\widehat{z}'} V(\widehat{z}', n+1, X', \varphi') d\Phi(\widehat{z}'|\widehat{z}_j^n) \right] dG(X', \varphi'|X_t, \varphi_{jt}) \right\}. \end{aligned}$$

Here r is the discount rate, $F(z|\widehat{z}_n, n)$ is the posterior distribution for z after the n^{th} match, and $\Phi(\widehat{z}'|\widehat{z}_j^n) = N(\widehat{z}_j^n, \sigma_{n+1})$ is the posterior distribution for z that the firm expects to prevail after the $n+1^{st}$ match, given $\widehat{z}_n$.

Three margins of firm-level export response are characterized by this value function. First, average sales per foreign transaction at time t ($\overline{X}_{jt}$) are determined by product appeal (z_j), productivity (φ_{jt}), and macro conditions ($\overline{X}_t$). Second, buyers per firm are governed by the search intensity, λ, which responds to sales history (X_{ijt-n}). (The case of zero buyers corresponds to non-participation in export markets, of course, but it does not imply $\lambda = 0$.).

3.4 Stationary State

We consider an environment where firms are buffeted by shocks to their macroeconomic environment and to their own productivity, and in which the start out ignorant of their product appeal on a market and learn about it over time. Hence our situation is a highly nonstationary

against this effect is the possibility that as matches accumulate, a firm's reputation grows, and it becomes *less* costly to reach new custumers. Hence a general expression for $h(n)$ that does not impose a sign on its derivative may be the most appropriate formulation. If this function is identified, it provides a test of Arkolakis (2008).

one which in not amenable to an analytic solution and we pursue numerical techniques. Nevertheless it is useful to consider what happens in a stable environment in which all learning has taken place.

We thus ask what happens if $(X_t, \varphi_{jt}) = (X', \varphi')$ and $n \to \infty$ so that $\overline{s}_n \to z$ and new matches convey no further information. Asymptotically, the distinction between $V(\widehat{z}_n^j, n, X', \varphi')$ and $V(\widehat{z}', n+1, X', \varphi')$ disappears, and the problem becomes $rV(z) = \max_\lambda \left\{-e(\lambda) + \lambda \widetilde{\pi}(X, z, \varphi_j)\right\}$. The solution is:

$$V(z) = \frac{-e(\lambda^*) + \lambda^* \widetilde{\pi}(X, z, \varphi_j)}{r},$$

where λ^* solves $e'(\lambda^*) = \widetilde{\pi}(X, z_j, \varphi_j)$. So, not surprisingly, steady state search efforts and the present value of participating in foreign markets are monotonically increasing in the payoff to a successful match. As in Arkolakis (2008), more efficient firms (with higher φ_j) are going to undertake more search effort and encounter more buyers. A difference is that firms accumulate and shed buyers over time. In a stationary situation a firm will have an average number of buyers $n(j)$ that satisfies $\delta n(j) = e(\lambda^*)$.

3.5 Specification for Numerical Solution

To solve the problem numerically we parameterize the cost of matching as:

$$e(\lambda) = b\left(\frac{\lambda}{1-\lambda}\right)^2 + f \cdot 1\left[\lambda > 0\right], \quad \lambda \epsilon [0, 1) \tag{9}$$

where f is the fixed cost of maintaining positive levels of search. Finally, we (arbitrarily) choose parameter values to be as indicated in Table 1. We treat shocks to efficiency and

macroeconomic shocks as following independent first-order autoregressive processes, so that:

$$\begin{aligned} \varphi_{jt+1} &= \psi\varphi_{jt} + \epsilon_t^{\varphi} \\ X_{t+1} &= \phi X_t + \epsilon_t^{X} \end{aligned} \tag{10}$$

where:

$$\begin{aligned} \ln \epsilon_t^{\varphi} \tilde{} N(0, \sigma_{\varphi}^2) \\ \ln \epsilon_t^{X} \tilde{} N(0, \sigma_{X}^2). \end{aligned} \tag{11}$$

The model thus has four sources of variance: each firm's underlying true product appeal z, which is drawn from $N(0, \sigma_z^2)$, the noise around true product appeal associated with each match, which is drawn from $N(0, \sigma_\epsilon^2)$, the shocks to productivity, and the macroeconomic shock, both given in (11).

The model is fully described by the expression for profit (3), from which we can calculate, using (10), the expected value of a relationship (5), the equation for updating beliefs about product appeal (6), the value function (8) and the cost function (9). The complete set of parameters of the model are given in the following Table:

Table: Parameters for Simulations

Parameter		*base value*
rate of time preference	r	0.05
rate of separation	δ	0.20
search cost function scale parameter	b	0.20
profit function scale parameter	c	0.05
fixed cost of searching	f	0.02
standard deviation of noisy signal	σ_ϵ^2	0.30
standard deviation of product appeal	σ_z^2	0.30
root of efficiency process	ϕ	0.90
root of macro process	φ	0.80
standard deviation of efficiency innovation	σ_φ^2	0.10
standard deviation of macro innovation	σ_X^2	0.16

where we indicate the values we place on them in our baseline simulation.

3.6 Numerical Procedure

Our numerical solution proceeds in four steps.

3.6.1 Markov transition matrices for signals

With our parameterization learning occurs very fast. After encountering twenty buyers the seller's uncertainty about its product's true appeal has dwindled, according to (7), to having a standard deviation of .07. Hence we limit the number or encounters to twenty and treat the seller as fully informed about its own product appeal at that point. For transitions across the first twenty periods we discretize the space of noisy signals into 50 signals evenly across 3 standard deviations, and calculate the Markov transition matrices across each possible pair, using (7).

3.6.2 Markov transition matrices for macroeconomic and efficiency processes

We follow a similar procedure of discretizing efficiency levels into 20 possible values and the macroeconomic states into 8 possible values. We then calculate the Markov transition probabilities across them.

3.6.3 Discretization of Effort

We allow for 50 possible effort levels across $[0, 1]$.

3.6.4 Value Function Iteration

We solve for the value function V and associated policy function for λ that solves (8) for different numbers of meetings n, profit signals i, efficiencies k, and macroeconomic shocks m.

3.7 Policy functions

The first panel of figure 1 above shows the value of access to foreign buyers that firms perceive after one signal, as a function of the signal they have received. Not surprisingly, there is a positive relationship, and firms that receive better signals choose to search more intensively. The second panel of this figure shows how values and search intensities have changed after 5 signals have accrued. (The horizontal axis is the posterior mean after 5 signals, $\widehat{z}^5$.) Note that the value of search has fallen relative to its value after one signal for those firms with low average signals because these signals become increasing precise as experience accumulates. (When, five buyers tell you they don't care for your product, there is a good chance that your product has poor market potential.) The last two panels of figure 1 translate search values into match probabilities, and tell the same qualitative story. Below some threshold signal, the return to search is less than the associated fixed cost (f), and so no search takes place. If f were to increase, this cutoff would shift to the right (not pictured).

Figure 2 shows how the policy function characterized in figure 1 translates into behavior for a simulated set of 1,000 firms. Here the horizontal axis is true z value rather than signal. The first panel describes match hazards for a new cohort of firms, none of which has received any signals yet. Since all firms share the same priors at this point there is no relationship between z values and search intensity. However, some firms don't search at all because their current productivity level is low. After 5 periods, a relationship between z and search intensity emerges, but heterogeneity in behavior remains, given z. (Refer to the bottom panel.) This reflects both productivity differences and differences in the idiosyncratic features of the buyers (ϵ's) that the exporters have randomly matched with.

Figure 3 depicts match probabilities as functions of exporters' productivity levels and the macro state. Not surprisingly, improvements in either encourage search. The shape of the function changes over time, however, as seen in figures 1 and 2. In particular, after 5 matches have accrued, those firms with relatively low productivity have been convinced to stop looking for buyers, and the truncation point is particularly high when the macro state (i.e., the real exchange rate) is poor. Thus macro conditions may explain the cross-cohort variation in export market participation seen in Table 1 above.

3.8 Export Trajectories

To link this model back to export flows, we need simply keep track of match patterns, random productivity shocks, and random separation patterns for a simulated set of 1,000 firms. Figure 4 shows clients per exporter and total exports for a new market that appears in year 0. (Imagine a Caribbean island dismantling prohibitive trade barriers, and the population of Colombian producers commencing to learn about the islanders' demand for their products.) Note that, although the number of exporters falls over time (not pictured), clients per surviving exporter and total exporters both rise. They climb particularly rapidly in the early years because the firms which have received positive signals tend to (1) be exporting relatively more, and (2) intensify their search as these signals accrue. Eventually firms learn their true z values and settle into a stable search intensity. This translates into a stable number of clients per firm.

Figure 5 shows the five year transition densities for numbers of clients, providing a simulated analog to Table 3 above. The top panel describes transitions between year 1 and year 5,

when firms are in their early learning stages. Because they have not yet built their clientele, most of the action involves movement between 0, 1 and 2 clients. After 5 periods have elapsed, many firms that have low product appeal have dropped out, and the remaining firms have built larger client bases (bottom panel).

The export aggregates associated with this new market exploration are depicted in the panels of figure 6. To see how exchange rates figure in, these are graphed in each quadrant as the lower line.[6] The first panel indicates that during the early years, exchange rate effects are dominated by learning effects, but eventually, exports start to track the exchange rate– both because shipment values depend upon the exchange rate and because search intensities increase when the Colombian peso depreciates (second panel and fourth panel). The number of exporters is not very sensitive to the exchange rate because matches last for multiple periods, and exporters have no incentive to terminate clients when appreciation occurs. These features of the model induce a kind of hysteresis in trade flows. However, instead of attributing irreversibilities to one-time market entry costs, as in the existing literature, we attribute irreversibilities to the fact that devaluation induces learning but appreciation does not induce forgetting.

Table 1 above defined the year t cohort to consist of all firms who exported in period t but did not export in period t-1. Applying this definition to our simulated data, we obtain figure 7. The four panels correspond to the cohorts that enter in years 2, 3, 4 and 5. Consistent with table 1, our model shows that membership in each cohort drops off rapidly after its first year. (Refer to the lower line each graph.) However, total exports go through a growth period as

[6]Note that the units differ across graphs. The exchange rate process used in this experiment is obtained by fitting a simple AR1 to real Colombian peso-dollar rate (1982-2007).

those cohort members who survive add to their client base, and thus exports per suriviving cohort member climb rapidly in the early years of each cohort's existence. This, too, matches up well to the actual data.

4 Econometric estimation (to come)

5 Conclusions (to come)

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Table 1: Firms that exported to the United States by initial export year cohorts, 1996-2007

Number of firms

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total Number of firms
1996	3129	0	0	0	0	0	0	0	0	0	0	0	3129
1997	1390	1646	0	0	0	0	0	0	0	0	0	0	3036
1998	1034	257	978	0	0	0	0	0	0	0	0	0	2269
1999	896	169	309	834	0	0	0	0	0	0	0	0	2208
2000	848	159	238	317	991	0	0	0	0	0	0	0	2553
2001	769	151	216	253	356	1128	0	0	0	0	0	0	2873
2002	743	133	187	218	266	403	1253	0	0	0	0	0	3203
2003	744	135	170	191	246	335	419	1635	0	0	0	0	3875
2004	700	129	148	191	221	262	343	491	1894	0	0	0	4379
2005	672	114	112	142	180	219	239	316	416	2218	0	0	4628
2006	620	116	113	145	160	178	206	265	300	551	1727	0	4381
2007	572	102	87	130	148	152	170	211	246	413	369	1358	3958

Value of exports (US$ Millions)

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total Value of exports
1996	4145	0	0	0	0	0	0	0	0	0	0	0	4145
1997	4115	147	0	0	0	0	0	0	0	0	0	0	4262
1998	3685	196	169	0	0	0	0	0	0	0	0	0	4049
1999	5083	299	135	98	0	0	0	0	0	0	0	0	5615
2000	5934	269	92	170	63	0	0	0	0	0	0	0	6527
2001	4637	211	87	133	117	69	0	0	0	0	0	0	5254
2002	4576	153	75	115	84	97	52	0	0	0	0	0	5151
2003	4813	296	88	101	124	99	90	167	0	0	0	0	5779
2004	5437	264	107	136	140	104	92	183	135	0	0	0	6598
2005	6529	206	122	155	191	163	115	177	240	581	0	0	8480
2006	7670	279	122	141	220	175	123	148	220	499	54	0	9650
2007	7883	233	107	153	255	177	119	167	208	560	45	466	10373

Exports per firm (US$ Thousands)

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total Exports per firm
1996	1325	0	0	0	0	0	0	0	0	0	0	0	1325
1997	2961	89	0	0	0	0	0	0	0	0	0	0	1404
1998	3563	761	173	0	0	0	0	0	0	0	0	0	1785
1999	5673	1768	438	117	0	0	0	0	0	0	0	0	2543
2000	6997	1691	386	536	64	0	0	0	0	0	0	0	2557
2001	6030	1395	402	527	330	61	0	0	0	0	0	0	1829
2002	6159	1149	399	529	316	240	41	0	0	0	0	0	1608
2003	6470	2189	520	530	502	296	216	102	0	0	0	0	1491
2004	7767	2048	722	710	633	398	270	373	71	0	0	0	1507
2005	9716	1805	1093	1095	1059	744	483	560	577	262	0	0	1832
2006	12370	2405	1083	970	1373	985	595	557	735	906	31	0	2203
2007	13782	2288	1235	1177	1723	1163	703	791	844	1357	121	343	2621

Number of Transactions

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total Number of transactions
1996	54001	0	0	0	0	0	0	0	0	0	0	0	54001
1997	49243	5624	0	0	0	0	0	0	0	0	0	0	54867
1998	47759	6045	5335	0	0	0	0	0	0	0	0	0	59139
1999	48994	5614	5234	4604	0	0	0	0	0	0	0	0	64446
2000	50854	6284	4149	5760	4694	0	0	0	0	0	0	0	71741
2001	52701	6276	4207	5116	5309	6854	0	0	0	0	0	0	80463
2002	53439	4511	4146	4815	4569	8144	5140	0	0	0	0	0	84764
2003	82886	6364	5344	6762	6366	8024	7933	8774	0	0	0	0	132453
2004	79122	7254	4929	7264	7190	6807	8229	7736	8822	0	0	0	137353
2005	98822	11052	5148	8575	7196	8283	8995	9014	9750	15344	0	0	182179
2006	101616	12862	4547	8370	6251	6647	8966	7533	10171	15670	6563	0	189196
2007	104549	11993	4165	8458	5709	6848	8860	7144	8801	16574	6544	4999	194644

Transactions Per Firm

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average Transactions/Firm
1996	17.3												17.3
1997	35.4	3.4											18.1
1998	46.2	23.5	5.5										26.1
1999	54.7	33.2	16.9	5.5									29.2
2000	60.0	39.5	17.4	18.2	4.7								28.1
2001	68.5	41.6	19.5	20.2	14.9	6.1							28.0
2002	71.9	33.9	22.2	22.1	17.2	20.2	4.1						26.5
2003	111.4	47.1	31.4	35.4	25.9	24.0	18.9	5.4					34.2
2004	113.0	56.2	33.3	38.0	32.5	26.0	24.0	15.8	4.7				31.4
2005	147.1	96.9	46.0	60.4	40.0	37.8	37.6	28.5	23.4	6.9			39.4
2006	163.9	110.9	40.2	57.7	39.1	37.3	43.5	28.4	33.9	28.4	3.8		43.2
2007	182.8	117.6	47.9	65.1	38.6	45.1	52.1	33.9	35.8	40.1	17.7	3.7	49.2

Transaction Size (US$)

First year of report between 1996 and 2007

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average Size
1996	76764												76764
1997	83575	26053											77679
1998	77149	32352	31664										68467
1999	103756	53210	25868	21263									87134
2000	116683	42786	22163	29489	13409								90986
2001	87995	33570	20643	26044	22100	10042							65302
2002	85630	33883	17979	23971	18387	11882	10044						60771
2003	58071	46444	16542	14967	19418	12375	11399	19086					43633
2004	68712	36421	21668	18666	19453	15328	11237	23661	15263				48034
2005	66067	18622	23777	18130	26499	19664	12821	19620	24623	37885			46546
2006	75477	21687	26917	16800	35155	26372	13669	19582	21678	31843	8232		51007
2007	75401	19463	25800	18088	44669	25819	13481	23356	23582	33807	6814	93168	53293

Notes: this table classifies firms exporting each year to the United States according to the first year in which they reported exporting in our sample period (1996-2007) . Total number of Firms, Value of Exports and Number of Transactions represented by these firms are reported for each entry cohort.

Table 3: Colombian Firms Participation in Relationships

Transition Probability Matrix (All Sectors)

(Annual Average: 1992-1997)

		cell in year t							
		0	1	2	3	4	5	6 to 10	11 to 25
	0		0.630	0.265	0.153	0.050	0.024	0.039	0.000
	1	0.925	0.310	0.344	0.246	0.131	0.079	0.039	0.000
cell in	2	0.056	0.046	0.244	0.222	0.202	0.211	0.087	0.000
year	3	0.012	0.010	0.096	0.186	0.223	0.168	0.082	0.000
t+1	4	0.004	0.003	0.031	0.116	0.165	0.184	0.117	0.000
	5	0.002	0.000	0.012	0.045	0.108	0.105	0.169	0.380
	6 to 10	0.002	0.000	0.004	0.016	0.113	0.205	0.429	0.620
	11 to 25	0.000	0.000	0.004	0.016	0.009	0.024	0.039	0.000
	TOTAL	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
			0.800357	0.114037	0.04081	0.019985	0.009966	0.012117	0.002728	1
		10558	15258	2174	778	381	190	231	52	19064

Some figures are interpolated for reasons of confidentiality

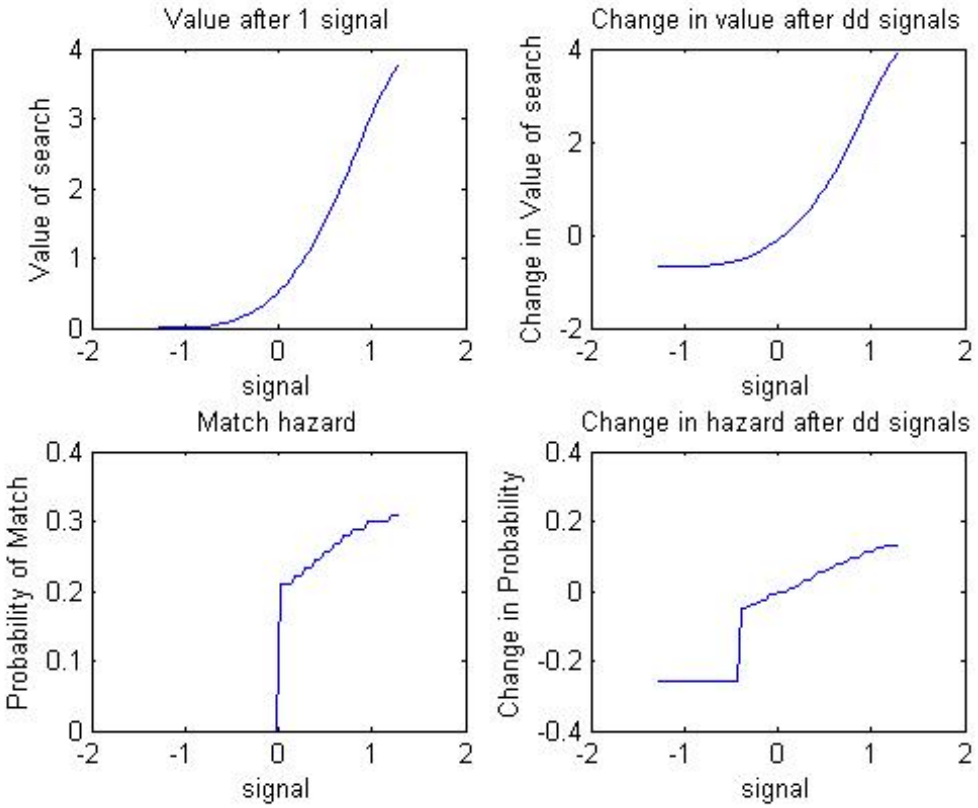

Figure 1:

Signal, value, match hazard, and learning

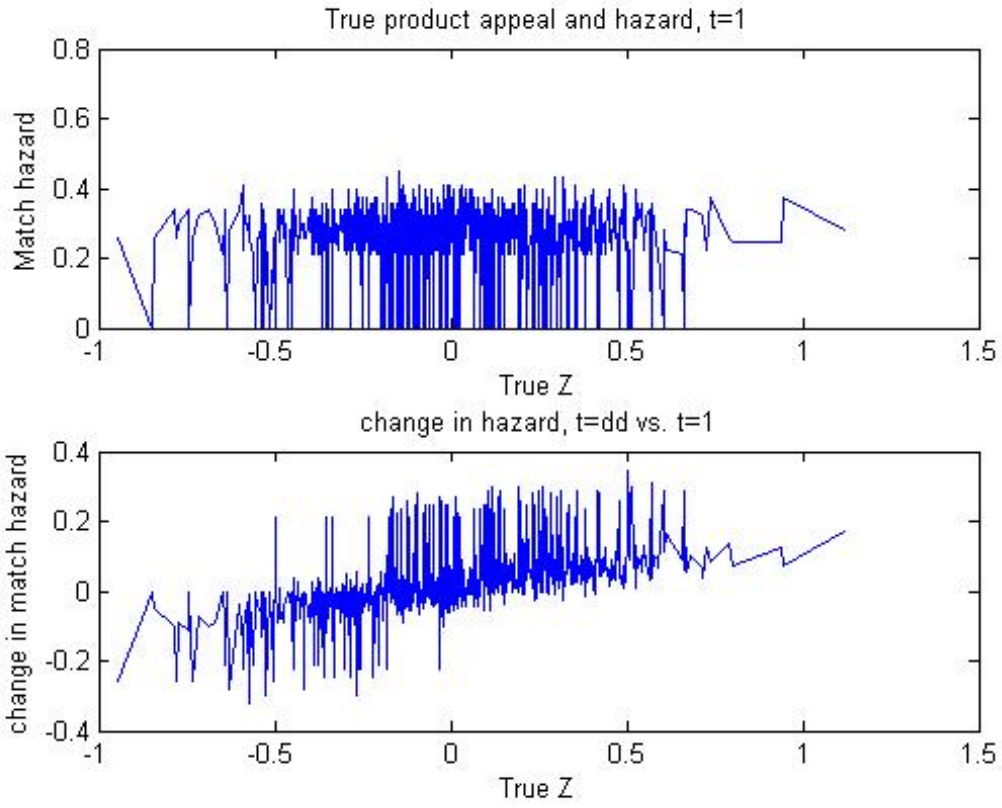

Figure 2:

True product appeal and match hazard: initial and change after 5 signals

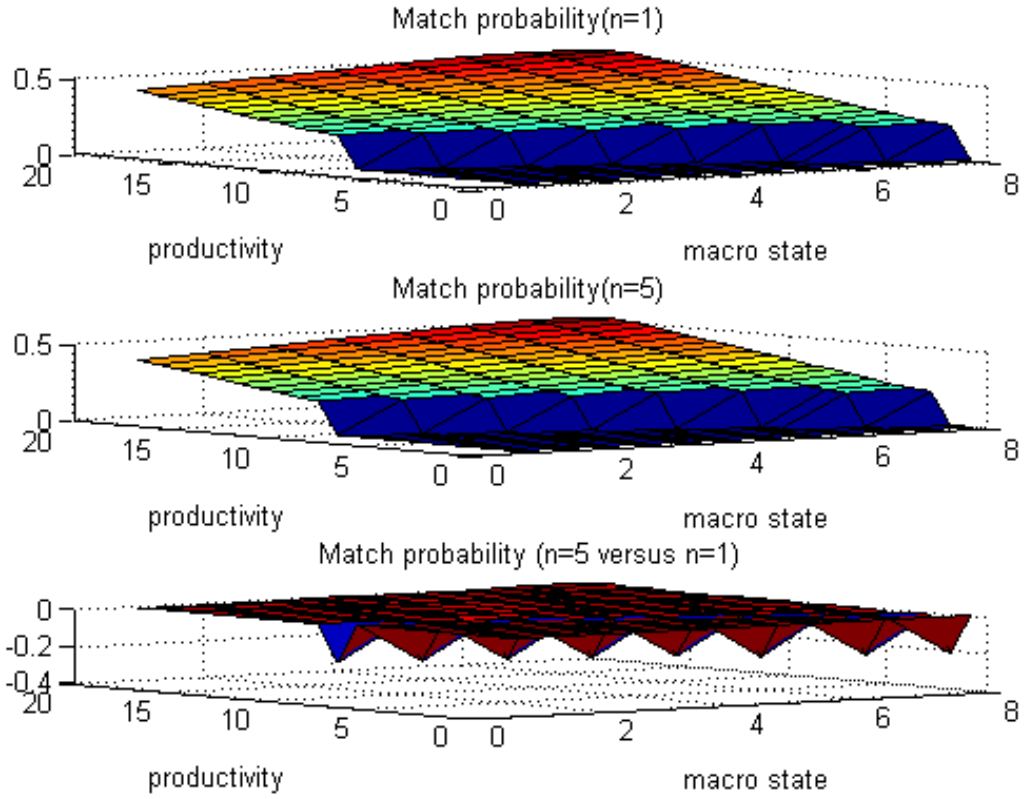

Figure 3:

Match Probabilities, firm productivity, and macro state

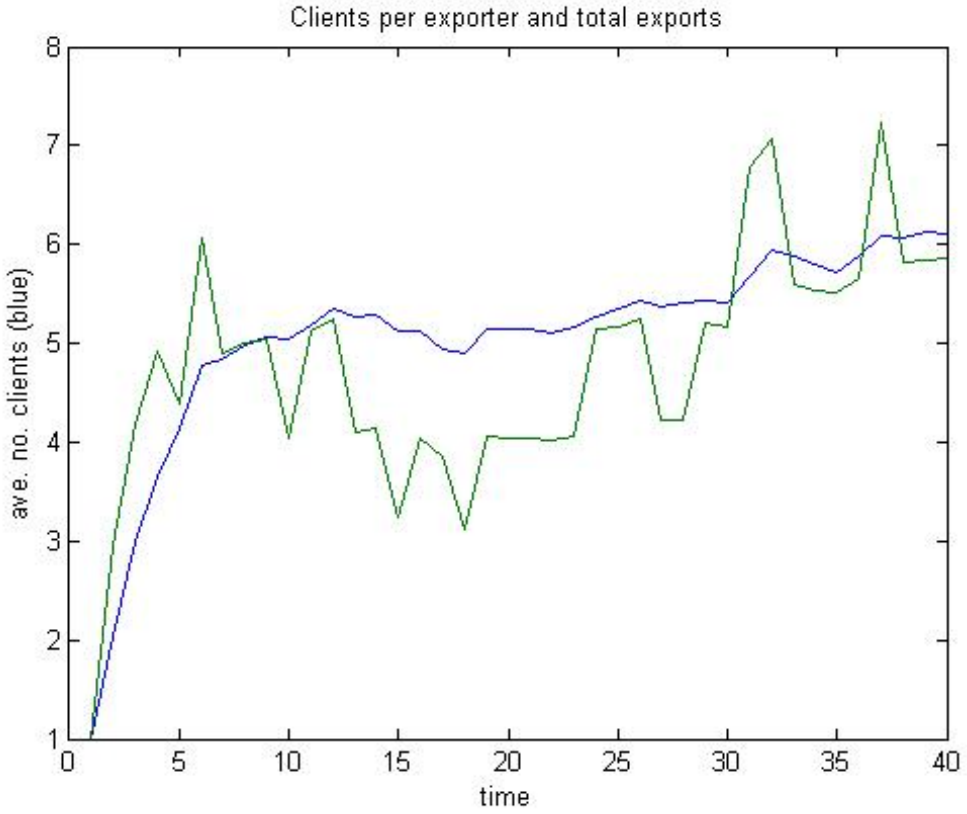

Figure 4:

Clients per exporter and total exports: new cohort through time

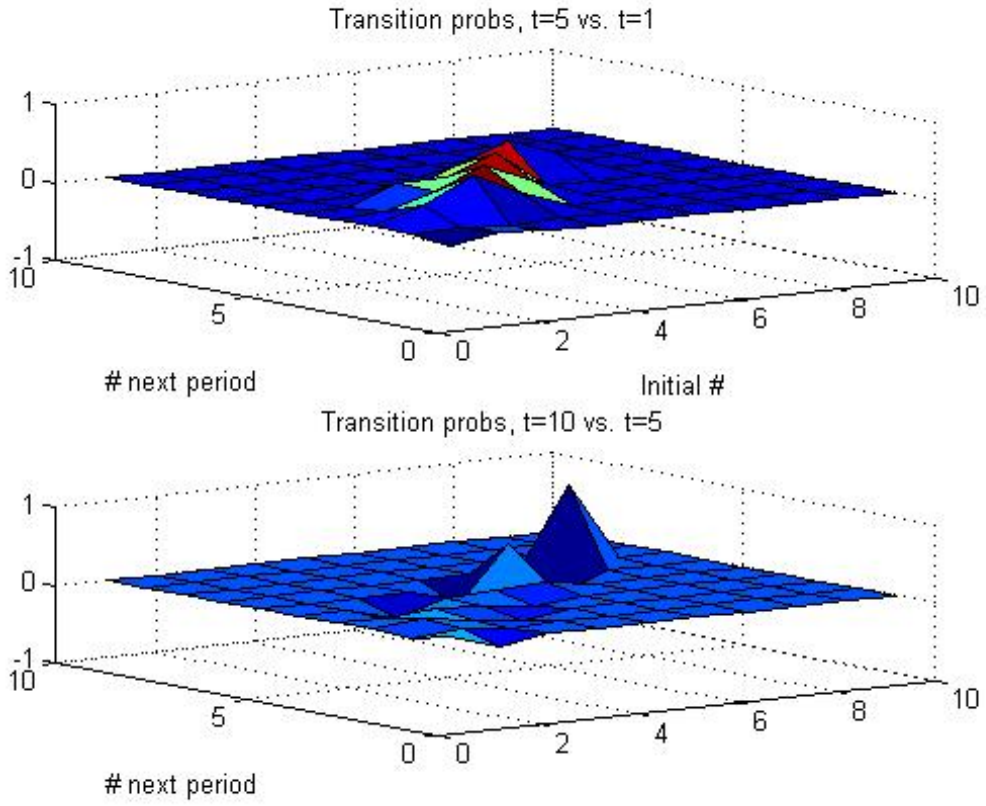

Figure 5:

5-period transition probabilities (conditional densities)

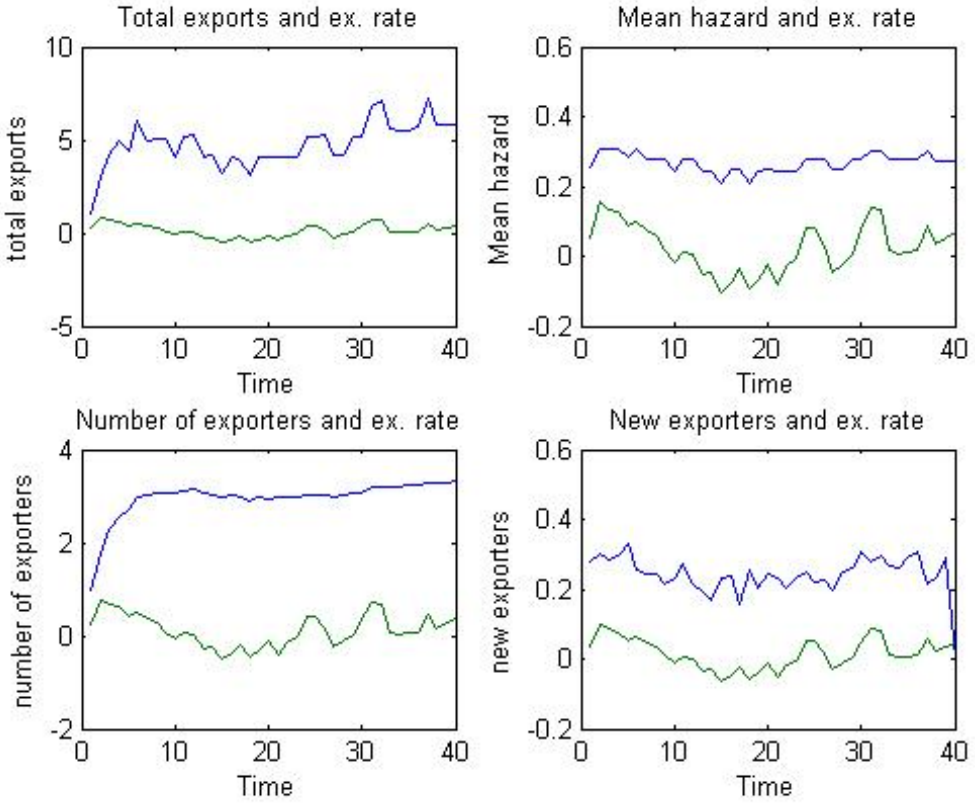

Figure 6:

Export aggregates and the real exchange rate (new cohort)

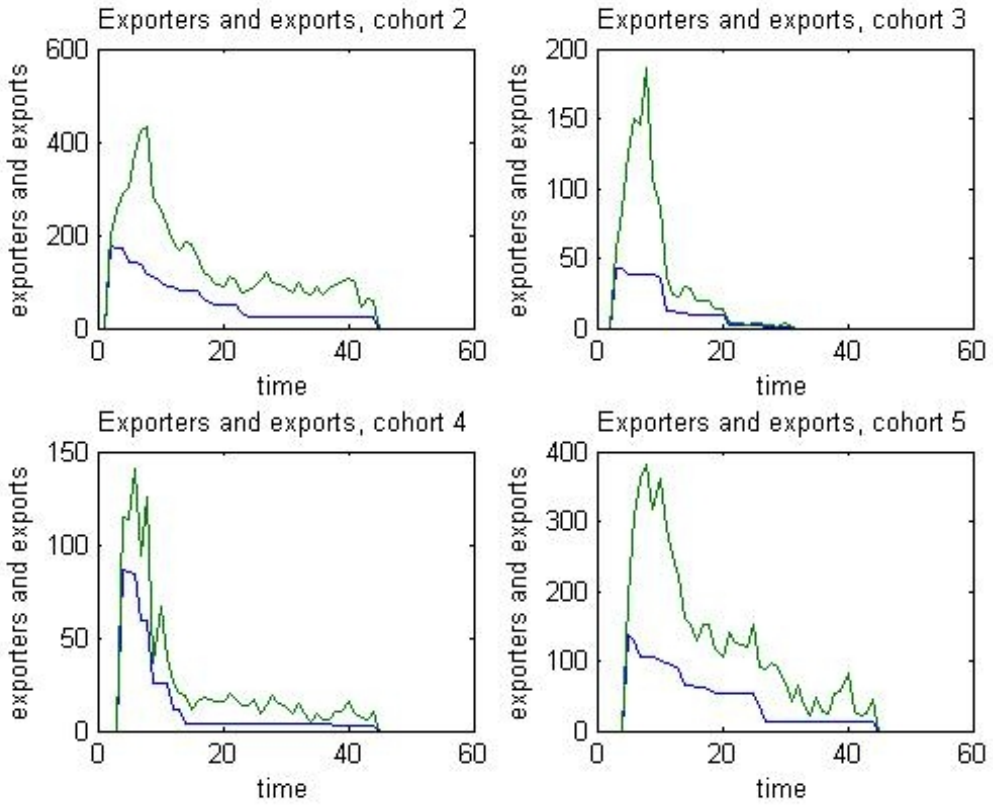

Figure 7: Cohort-specific exports and exporters