Convexities, Nonconvexities, and Firm Export Behavior*

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May 2008

Preliminary & Incomplete

Abstract

Models of heterogeneous firms making decisions about entering foreign markets in the face of sunk entry costs have become standard tools for understanding the firm exporting decision. These models induce a discrete choice between exporting and only serving the domestic market. In this paper we study how well these discrete choice models account for the data on new export entrants. We document the employment responses of Colombian plants that enter the export market and find that, though there is a discrete nature to employment adjustment and exports, there is also a substantial amount of adjustment that continues after entry, which is contrary to a standard model with frictionless markets. We construct a dynamic discrete choice model of exporting that includes costs of adjusting labor inputs. We use simulation based methods to structurally estimate the parameters of the model and find that convex costs of labor adjustment are crucial for replicating the observed patterns of adjustment in the data. Our estimations also recover values for the entry costs that exporters face, adding to the small amount of evidence on the scale of these costs. The estimates of export entry costs increase by 21 percent when adjustment frictions are not accounted for, suggesting that entry cost estimates are sensitive to the model environment.

*We would like to thank Mark Roberts and Jim Tybout for allowing us access to the data used here. We are grateful to George Alessandria, Russell Cooper, and Dean Corbae for helpful comments. Thanks also to seminar participants at Columbia University, the University of Michigan, the University of British Colombia, the Federal Reserve International System Committee Meeting and the 2008 Midwest Macro Conference. This work was undertaken with the support of the National Science Foundation under grant SES-0536970.

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1 Introduction

Models of heterogeneous firms making decisions about entering foreign markets in the face of sunk entry costs have become increasingly used by economists interested in international trade. These models initially focused on steady state analysis, as in Melitz (2003), but have recently been incorporated into stochastic general equilibrium models. The key innovation in the dynamic models is the idea that firms enter and exit the foreign market is responses to changes in relative prices and productivity. For example, Melitz and Ghironi (2005) and Alessandria and Choi (2007) use these types of models to study how the inclusion of firm exporting decisions affects real exchange rate and net export dynamics and Ruhl (2004) demonstrates how export entry can produce asymmetric responses to temporary and permanent changes in expected export profits. These models have focused on the aggregate implications of export entry and exit. In this paper, we focus on the ability of this class of models to reproduce the patterns of plant level dynamics that we document using a data set on manufacturing plants in Colombia. In particular, we document the extent to which new exporters act as if they are making a discrete decision to enter the export market, and to what extent the standard heterogeneous firm model can replicate these patterns.

Using data on plants that enter the export market in our sample (1981-1991) we find that entering plants do seem to adjust in a discrete manner; upon entry, a plant's employment growth rates and export volumes adjust in discrete ways. The employment growth rates, however, do not adjust quickly, but continue at higher levels for several periods after entry. The employment growth rates of these plants are small in absolute value as well, averaging about 3.5 percent over the 4 years following entry. These finding suggest that while there is a discrete nature to the export decision, there is also slow adjustment.

To understand the role of fixed (and sunk) costs of exporting in conjunction with slow employment adjustment, we specify a structural model of plant export decisions in which there are also fixed and convex costs of labor adjustment. We find, as is well established,

that export entry costs are important in replicating plant behavior. A novel finding is that convex costs of labor adjustment are crucial in replicating the employment dynamics of new exporters. Our estimates suggest that the implicit barriers to entry from paying adjustment costs are about 13.8 percent of the estimated entry costs.

A good deal of work has been done establishing that sunk entry costs are relevant for export decisions. Early models, such as Baldwin (1988) and Baldwin and Krugman (1989) focused on the hysteresis implied by the sunk nature of the entry costs. Empirically, much of the evidence of sunk export entry costs came from reduced form specifications such as Roberts and Tybout (1997) and Bernard and Jensen (2004), which established that entry costs were important in accounting for the persistent nature of a plant's export status, but these reduced form models could not estimate the magnitudes of such costs.

Our work is closely related to that of Das, Roberts and Tybout (2007) who also estimate a structural model of plant export decisions using Colombian data. An advantage of the structural nature of their model and ours is that we can recover estimates of the size of the export entry costs. Our estimates of entry costs are about half the size of those found in Das et al. (2007), but direct comparisons should be made with caution, as their model includes unobserved shocks to the entry costs, so costs actually paid in there model are likely to be much lower.

Our findings suggest that, while there is a discrete nature to the export entry decision, there is also a substantial amount of adjustment that continues after the plant has entered the foreign market. Our model of employment adjustment costs is successful in limiting the size of the adjustment made by firms in the period of entry, but fails to produce enough adjustment in the subsequent periods; conditional on entering, plants still would like to adjust as quickly as possible. Our specification also implies that a new exporter's foreign sales grow too quickly after entry compared to that in the data. In these ways, our model is still "too discrete" relative to the data.

The behavior of new exporters that we document here could support other models of adjustment that we have not considered. An obvious candidate would combine a cost of entry, to induce the jump in export sales in the period of entry, with a model in which firms learn about their profitability from exporting through time, as in Jovanovic (1982). Market access costs used in a static setting in Arkolakis (2006) could also generate smooth adjustment in a dynamic model.

2 Data

We draw our data from an annual census of manufacturing plants in Colombia. The data were originally collected as a sequence of cross sections by the Departmento Administrativo Nacional de Estadística and were cleaned and linked into a panel as described in Roberts (1996). The census covers all manufacturing plants with 15 or more employees and includes variables about revenues, input costs, employment, and exporting revenue. We choose the period 1981-1991 as our sample. This choice is motivated by the experience in Colombia; as can be seen in Table 1, Colombia's real effective exchange rate had a small appreciation followed by a large and persistent depreciation. The depreciation was accompanied by a significant increase in the number of plants that exported, making it an ideal episode to study. This time period, and the data we are using, have been previously studied in Roberts and Tybout (1996), Roberts and Tybout (1997), and Das et al. (2007). In this paper we focus on the decision of an existing plant to enter the export market, so we balance the panel by dropping any plant that did not have at least 15 employees in each year of the sample.

2.1 Exporter Entry and Exit

We characterize a plant as an *exporter* in year t if export revenues for the plant are positive. A plant that enters the export market in year t, an *export starter*, is a plant that was not an exporter in year $t-1$ and is an exporter in year t. Analogously, an *export stopper* in

year t is a plant that exported in $t-1$ and does not export in year t. In Table 1 we list the fraction of plants that are exporters along with the starter and stopper rates for each year of the sample..

From 1981-1983 the real effective exchange rate (REER) slightly appreciated and the number of exporters stagnated: the fraction of plants that exported fell by 1.4 percentage points. The appreciation was followed by a depreciation of the Peso by more that 50 percent. This depreciation was accompanied by a boom in exporting. The fraction of the plants in our sample that export increased from 21.4 percent in 1984 to 33.9 percent in 1991. The increase in exporting plants comes from both a decrease in the rate of plants leaving the export market and and increase in the rate of plants entering the export market.

Table 1: Real effective exchange rate, export starter and export stopper rates (in percent)

	1981	**1982**	**1983**	**1984**	**1985**	**1986**	**1987**	**1988**	**1989**	**1990**	**1991**	**AVG**
REER	100	94.6	95.8	106.9	121.7	135.2	135.4	133.7	137.3	151.5	144.2	
Exporters	22.4	21.8	21.0	21.4	23.4	24.5	24.0	24.5	25.7	29.0	33.9	24.7
Start Rate	-	2.6	2.7	3.1	4.7	3.7	2.9	2.9	3.9	4.7	6.7	3.8
Stop Rate	-	3.2	3.4	2.8	2.7	2.6	3.3	2.5	2.6	1.4	1.7	2.6

2.2 Dynamics of New Exporter Growth

The purpose of this study is to evaluate how well heterogeneous firm models replicate the dynamics of the export decision. Here we focus on one aspect of the decision to export, the firm's decisions over how much to produce for the export market and how much labor to hire. The now "standard" models, based on Melitz (2003) feature a sunk cost of export entry, which induces a discrete decision regarding entry into the export market. As we show below, these types of models imply that when a firm enters the export market it immediately starts selling a large volume of exports and adjusts its labor force accordingly to the new level needed to produce these additional export goods.

In Figure 2 we plot the average export to sales ratio for new exporters in the Colombian data. For each plant in the panel that enters the export market, we compute the export to sales ratio of the plant for the year it entered—period 0 on the x-axis—and the years preceding and succeeding the entry, conditional on remaining in the export market. From the figure we see the discrete nature of the entry decision, as exports jump from zero to about 4 percent of total sales upon entry. The discrete jump is not the complete picture, though. Exports continue to grow over the 5 years subsequent to entry, increasing to nearly 12 percent of total sales. The dashed line in 2 is the average export to sales ratio for all exporting firms. Thus, it takes a new exporter about 5 years to reach the average export to sales ratio.

Figure 1 plots the response of the employment growth rates of new exporters in the Colombian data. This data also supports the notion that export entry is a discrete decision; the employment growth rates preceding entry are less than or equal to 0, but increase to 1.5 percent in the first year a plant exports. Employment growth rates remain positive after entering, above the average employment growth rate of 0 percent for the entire sample, shown by the dashed line. In addition to the marked change in hiring upon exporting, we are also interested in the magnitudes of the growth rates. A plant entering the export market is increasing its employment by approximately 1-2 percent for the few years following entry, with an exception of the jump to 4.5 percent in period 3. This pattern of small, repeated adjustment is not consistent with the discrete choice made in the standard models, but is consistent with a model in which there are convex costs of adjusting the number of workers employed.

The growth of real sales for new exporters is shown in Figure 3. Real sales data include both domestic sales and exports. The average real sales growth across all plants in the sample is 3.6 percent (dashed line). The pattern here is similar to the employment growth pattern. Real sales growth is below average for the periods leading up to export entry. Upon

entry, there is an increase of about 3 percentage points in real sales growth, and this higher growth rate is maintained for several years. Once again, note that there is no large initial surge during the first year of exporting.

In the preceding figures, calculations for exporters of a given export age were based only on those plants that remained in the export market for the specified duration. Figure 4 shows the survivor rates for exporters – the percentage of plants of a given age that continue to be exporters in the following period. For new exporters, the probability of remaining in the export market for an additional period is 62 percent. This survivor probability increases to 90 percent for plants that have been exporting for 3 periods, and remains at or above that level for subsequent periods. This pattern indicates that there is a higher level of uncertainty for new exporters regarding future participation in the export market than for more established exporters.

3 Model

In this section we describe a model that incorporates costs of labor adjustment into an otherwise standard heterogeneous agent framework. Our focus is on the decisions made by plants in response to changes in relative prices and productivity, and thus we abstract from general equilibrium effects by assuming a constant wage and domestic price level. We model Colombia as a small open economy that takes the real exchange as exogenous. In what follows, we suppress the time subscript on variables unless needed for clarity.

3.1 Demand

A representative agent in the domestic economy supplies labor inelastically and has preferences over the set of differentiated goods of the constant elasticity of substitution form,

$$U(c_1, ..., c_J) = \left(\sum_{j=1}^{J} c_j^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}. \tag{1}$$

The consumer chooses consumption of each variety to maximize utility subject to the budget constraint

$$\sum_{j=1}^{J} c_j p_j = I. \tag{2}$$

Taking prices as given, the representative agent has the following demand for variety j.

$$c_j = \left(\frac{p_j}{P} \right)^{-\theta} C, \tag{3}$$

where C is defined as a unit of the aggregated consumption,

$$C = \left(\sum_{j=1}^{J} c_j^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}, \tag{4}$$

and P is the price of a unit of the aggregated consumption as defined in the usual way,

$$P = \left(\sum_{j=1}^{J} p_j^{1-\theta} \right)^{\frac{1}{1-\theta}}. \tag{5}$$

The rest of the world is populated by a representative consumer with an analogous utility function and budget constraint. Foreign demand for variety j is

$$c_i^* = \left(\frac{p_i^*}{P^*} \right)^{-\theta} C^*. \tag{6}$$

Note that we have assumed that the representative agents in the domestic country and the rest of the world have the same elasticity of substitution, θ.

3.2 Plant's Static Problem

There are n monopolistically competitive plants, each producing a differentiated good. A plant chooses how much to produce for the domestic market, y_i, $i = \{1, ..., n\}$, and how much to produce and export to the rest of the world, y_i^*, $i = \{1, ..., n\}$. Plants produce output using labor as the only input. The production function is of the form

$$f(n) = A\tilde{\epsilon}_i n_i^{\alpha}, \tag{7}$$

where $\tilde{\epsilon}_i$ is an idiosyncratic productivity shock, A is a productivity shock that is common to all plants, and n_i is the amount of labor employed by plant i.

In each period the plant choose prices, production, labor demand, and export status ($X_i = 0$ if not exporting and $X_i = 1$ if exporting) to maximize the value of the plant. The plant's problem can be divided into two subproblems: a static problem in which the plant chooses prices and quantities given its export status and employment level, and a dynamic problem in which the plant chooses its export status and employment. We layout the static problem in this section and the dynamic problem in the next.

A plant's profits are measured relative to the domestic basket of goods. Contemporaneous profits gross of adjustment costs are based on revenue obtained from sales in the domestic market and world market (if exporting) less labor costs

$$\begin{aligned}
\Pi_i &= \frac{p_i}{P} y_i + I\left(X_i = 1\right) \frac{e p_i^*}{P} y_i^* - \frac{W}{P} n_i && (8)\\
&= \frac{p_i}{P} y_i + I\left(X_i = 1\right) \frac{e P^*}{P} \frac{p_i^*}{P^*} y_i^* - w n_i && (9)\\
&= \frac{p_i}{P} y_i + I\left(X_i = 1\right) Q \frac{p_i^*}{P^*} y_i^* - w n_i && (10)
\end{aligned}$$

where e is the nominal exchange rate (domestic currency/foreign currency), $Q = \frac{eP^*}{P}$ is the real exchange rate, and w is the price of labor relative to the price of consumption. The plant is subject to a feasibility constraint,

$$y_i + y_i^* = A\tilde{\epsilon}_i n_i^{\alpha}. \tag{11}$$

We assume that plants satisfy the demand in the markets they choose to enter ($c_i = y_i$ and $c_i^* = y_i^*$ if $X_i = 1$) and substitute the demand functions into the profit function. The plant's static maximization problem is

$$\Pi_i = max_{y_i, y_i^*} Y^{\frac{1}{\theta}} y_i^{\frac{\theta-1}{\theta}} + I\left(X_i = 1\right) Q Y^{*\frac{1}{\theta}} y_i^{*\frac{\theta-1}{\theta}} - w n_i \tag{12}$$

subject to

$$y_i + y_i^* = A\tilde{\epsilon}_i n_i^{\alpha} \tag{13}$$

Maximization yields expressions for the quantities shipped domestically and abroad,

$$y_i^* = \frac{1}{1 + Q^{-\theta}\frac{Y}{Y^*}} A\tilde{\epsilon}_i n_i^{\alpha} \tag{14}$$

$$y_i = \frac{Q^{-\theta}\frac{Y}{Y^*}}{1 + Q^{-\theta}\frac{Y}{Y^*}} A\tilde{\epsilon}_i n_i^{\alpha} \tag{15}$$

Substituting these expression into the (12) gives profits as a function of exporting choice and employment level,

$$\Pi_i = \left(1 + I\left(X_i = 1\right) Q^{\theta} \frac{Y^*}{Y}\right)^{\frac{1}{\theta}} A Y^{\frac{1}{\theta}} \tilde{\epsilon}_i^{\frac{\theta-1}{\theta}} n_i^{\frac{\alpha(\theta-1)}{\theta}} - w n_i \tag{16}$$

The term $Y^{\frac{1}{\theta}}$ is a constant that reflects aggregate demand in the domestic country. Since the idiosyncratic shocks, ϵ, will be stationary, we can define $\epsilon_i = Y^{\frac{1}{\theta}} \tilde{\epsilon}_i^{\frac{\theta-1}{\theta}}$, and the mean of

the ϵ process is normalized to one.

3.3 Dynamic Programming Problem

The presence of costs to adjusting employment and sunk export entry costs makes the plant's decision regarding labor and export status a dynamic one. If the plant decides to adjust the amount of labor it employs, it must pay adjustment costs, which include convex and nonconvex costs,

$$C_n\left(n_i, n_i'\right) = \left(F_n + \nu\left(\frac{n_i' - n_i}{n_i}\right)^2 n_i\right) I\left(\Delta n_i \neq 0\right), \tag{17}$$

where n_i is the beginning of period stock of labor and n_i' is the end of period stock of labor.

The plant faces costs of entering and maintaining an export operation. When a plant enters the export market having not exported in the previous period—export entry—a sunk cost, f_{X_1}, is paid. This sunk cost represents the initial outlays required to set up exporting operations discussed in section 1. If the plant has exported in the previous period and wishes to continue to export it must pay f_{X_2}. The cost of maintaining exporting operations will induce some plants to exit the export market when the discounted expected value from exporting becomes low enough. The exporting cost function is given by

$$C_X\left(X_i, X_i'\right) = f_{X_1} I\left(X_i' = 1 | X_i = 0\right) + f_{X_2} I\left(X_i' = 1 | X_i = 1\right). \tag{18}$$

The state variables are the individual state variables (ϵ_i, n_i, X_i) and the aggregate state variables (Q, A). The random variables A, Q, and ϵ_i are modeled as time invariant AR(1) processes,

$$\ln \epsilon_t = \rho_\epsilon \ln \epsilon_{t-1} + \omega_{\epsilon,t},\ \omega_\epsilon \sim N\left(0, \sigma_\epsilon^2\right) \tag{19}$$

$$\ln A_t = \rho_A \ln A_{t-1} + \omega_{A,t},\ \omega_A \sim N\left(0, \sigma_A^2\right) \tag{20}$$

$$\ln Q_t = \rho_Q \ln Q_{t-1} + \omega_{Q,t},\ \omega_Q \sim N\left(0, \sigma_Q^2\right). \tag{21}$$

Given the presence of nonconvex costs of labor adjustment and export status, a plant will make two discrete choices each period. One choice determines whether the plant participates in the export market. The second choice determines whether the plant adjusts its workforce. A plant's dynamic decision problem is given by the Bellman equation,

$$\begin{aligned} V(\epsilon_i, n_i, X_i, A, Q) &= \max_{n_i', X_i'} \Pi(n_i', X_i'; \epsilon_i, A, Q) - C_n\left(n_i, n_i'\right) - C_X\left(X_i, X_i'\right) \\ &\quad + \beta E_{\epsilon_i', Q', A' | \epsilon_i, Q, A} V(\epsilon_i', n_i', X_i', A', Q'). \end{aligned} \tag{22}$$

4 Estimation

We seek to jointly estimate the costs associated with exporting and the costs associated with factor adjustment. Let ϕ be the vector of parameters we wish to estimate. To do so, we employ an indirect inference method which chooses the model parameters so that key moments generated by the model match those in the Colombian data. For a given vector of parameters we solve the Bellman equation in (22) and find the policy functions of the plant. Starting from an initial distribution of 2177 plants we draw realizations of Q, A, and ϵ_i and simulate the model for a minimum of 200 periods. After the minimum number of periods we continue to simulate the model until we come to a state in which Q and A have the same values as they do in the data in 1975. We then compute the last 13 years of the simulation using the values of Q and A that correspond to those observed in the data. In this way, we are replicating in the model the aggregate observable conditions in the data.

We construct the vector of moments from the simulation, $m_s(\phi)$ using the last 11 years of the simulation, which corresponds to the years 1981-1991. These moments are computed in

the exact same way that they were computed in the data. The estimation procedure solves

$$L(\phi) = \min_{\phi}(m_s(\phi) - m_d)'W(m_s(\phi) - m_d). \tag{23}$$

The weighting matrix, W, is the identity matrix. The function $L(\phi)$ is neither analytically tractable nor well behaved, so we use a simulated annealing algorithm to solve (23).

The minimization algorithm requires solving the Bellman equation, simulating a panel of data, and computing the moment vector a very large number of times. As is often the case, solving the Bellman equation is time consuming so we remove some parameters from the vector ϕ. The parameters that describe the exogenous shock processes, $(\rho_A, \sigma_A, \rho_Q, \sigma_Q)$ are estimated from observed data, which is discussed below. Additionally, we take the discount factor, β to be 0.96. Lastly, we use data on the mean and the standard deviation of the export to total sales ratio to choose the elasticity of substitution between goods, θ and the demand scale parameter, $\frac{Y}{Y^*}$. From (16) we derive the export to sales ratio,

$$\frac{\text{exports}}{\text{total sales}} = 1 - \left(1 + Q^{\theta}\frac{Y}{Y^*}\right)^{-\frac{1}{\theta}}. \tag{24}$$

As all varieties in the model have the same elasticity, the export-sales ratio in the model is constant. Using data on Q and values for $\frac{Y}{Y^*}$ and θ we can compute the mean and standard deviation of the export-sales ratio. From the data we calculate mean export sales ratio to be 0.17 and the standard deviation to be 0.03 over the period 1981-1991. The values $\theta = 2.3$ and $\frac{Y}{Y^*} = 0.49$ make the export to sales ratio in the model correspond with that in the data.

4.1 Exogenous Processes

We take the processes for the real exchange rate and aggregate productivity from the data. We estimate the AR(1) process for Q using data on the real effective exchange rate for Colombia from 1975-2005. We remove a Hoddrick-Prescott trend from the logged data and

find $\rho_Q = 0.75$ with a standard error of 0.11 and $\sigma_Q = 0.06$.

We use data on aggregate total factor productivity in Colombia to estimate the process for the common productivity shock, A. Total factor productivity is constructed using data on real gross domestic product, aggregate capital stocks (constructed from aggregate investment data), and aggregate employment. Using aggregate data allows us to capture changes in the domestic economy that we are not modeling. As the idiosyncratic shocks have mean zero and the number of plants in our model is large, measured aggregate productivity in the model will recover the common productivity shock. Using data from Hoddrick-Prescott filtered logged data from 1975-2000, we find $\rho_A = 0.41$ with a standard error of 0.18 and $\sigma_A = 0.017$. The shocks to productivity are less persistent than those found in other countries at this frequency. An alternative estimation using aggregate labor productivity (real GDP divided by aggregate employment) produces similar values, $\rho_A = 0.53$ with a standard error of 0.17 and $\sigma_A = 0.027$.

4.2 Estimated Parameters and Moments

Using the moment matching methodology described above, we estimate the parameter vector $\phi = (\alpha, \rho_\epsilon, \sigma_\epsilon, f_{x_1}, f_{x_2}, \nu, f)$. To identify these 7 parameters, we choose 7 moments that are informative about the parameters. Based on the analysis in section 2 we choose the fraction of plants that are exporters, the fraction of plants that begin exporting (the starter rate), the fraction of plants that stop exporting (the stopper rate), the fraction of plants that continue to export from one year to the next (the 1 year survival rate), the employment growth rate for new exporters in the first year of exporting, the average growth rate of real sales, and the fraction of plants who do not adjust their labor force in a period. We average these statistics across the sample, 1981-1991, though not all statistics are defined for each year.

The model does not admit a clear mapping of each parameter to each particular moment; the parameters jointly determine the moments. The cost of entering the export market, f_{x_1},

Table 2: Data moments.

Moment	Data
Fraction of Plants that Export	0.2420
Starter Rate	0.0364
Stopper Rate	0.0257
1 Year Exporter Survival Rate	0.8900
Growth of n for Export Entrants	0.0359
Growth Rate of Real Sales	0.0666
Fraction of Non-adjusting Plants	0.0940

Note: Values are averages from 1981-1991.

affects the fraction of exporters and the starter rate but also influences the stopper rate, as the higher barrier to entry implies that, on average, more productive plants will choose to be exporters. The serial correlation of the idiosyncratic shocks has a clear effect on the survival rate of exporters, but it also influences the starter and stopper rates, as plants have stronger reactions to more persistent shocks. The standard deviation of the idiosyncratic shocks, along with the curvature of the production function determines, among other things, the growth rate of sales in the model and the growth in employment when a plant becomes an exporter.

The key parameters in this model are those associated with adjusting employment, ν and f. Strong convex adjustment costs will dampen the response of employment to the decision to export and will also increase the costs associated with exporting; the increase in employment that is needed to serve the foreign market will require payment of adjustment costs. Similarly, the fixed cost of adjusting employment imposes additional costs to exporting. The fixed cost of adjusting employment creates a tension in the decision to adjust employment. Large fixed costs make the plant more likely to adjust less frequently but in larger increments while large convex costs make the plant desire smaller (and more frequent) adjustments.

Table 3: Moments from the data and the simulated model.

Moment	**Data**	**Model**
Fraction of Plants that Export	0.2420	0.2210
Starter Rate	0.0364	0.0413
Stopper Rate	0.0257	0.0202
1 Year Exporter Survival Rate	0.8900	0.9130
Growth of n in For Export Entrants	0.0359	0.0321
Growth Rate of Real Sales	0.0666	0.0506
Fraction of Non-adjusting Plants	0.0940	0.1100
$L(\phi)$		0.00156

Note: Values are averages from 1981-1991.

Table 4: Parameter values for the baseline model.

	α	ρ_ϵ	σ_ϵ	f_{x_1}	f_{x_2}	ν	f
Model	0.558	0.863	0.255	0.565	0.301	1.90	0.00

5 Results

The moments from the simulated model are reported in Table 3. The model fits the data quite well, although plants are less likely to leave the export market in the model than they are in the data. This manifests itself as a stopper rate that is too low and a survival rate and entry rate that are too high.

The estimated parameter values are shown in Table 4. The persistence in export status that we observe in the data is commonly attributed to two causes: sunk investments made in entering the export market, and persistent unobservable productivity. The estimation places weight on both of these factors. The idiosyncratic shock is strongly serially correlated, though the standard deviation of the innovations to the shocks is large as well. There is also a significant sunk aspect of the exporting cost structure. The entry cost is almost twice as large as the continuation cost of exporting.

The values of the parameters that govern the adjustment cost function are striking. The

estimation needs a substantial convex cost and no fixed cost to fit the model to the data. The convex cost of adjustment is needed in to keep plants that begin exporting from growing too fast. The convex costs are large enough, though, that they keep plants from desiring to adjust, so the fixed cost of adjustment has little effect.

5.1 How Large are Export Entry Costs?

A benefit of the structural approach that we have pursued in this paper is the recovery of the size of the costs associated with exporting. In Table 4 we have reported the fixed cost parameters, (f_{x_1}, f_{x_2}) as a fraction of the median plant's revenues. In the data, a median plant has 50 employees. The average value of sales for plants with 50 employees in 1986, is 52,463 thousand Pesos. The value of the entry cost is 57 percent of this, or 29,903 thousand Pesos, which at the exchange rate of 1986 (194.26 Peso per Dollar) is $153,937. Expressed this way, the cost of continuing to export, f_{x_2} is 15,738 thousand Pesos, or $81,862. To better place these values in the context of the model, Table 5 shows how the export entry cost compares to the profits of the plants at different points in the distribution. When compared to the 20th percentile plant, entry costs seem large, requiring more than one year's revenues, and 1.5 times one year's profits. When comparing the entry costs to the 20th percentile of exporters, entry costs look much smaller, only 35 percent of annual profits. These results reflect the fact that in the model (as in the data) most plants are small, while exporting plants are larger and more productive.

Are these results reasonable? Since we are using data that cover the same episode as Das et al. (2007), (henceforth DRT) it is natural to compare our results to theirs as a check. Before we do so, we should point out some fundamental differences between our approach

Table 5: Profits and sales from the model simulations in 1986 (thousands of Pesos).

	All Plants			Exporting Plants		
Percentile	**Profits**	**Sales**	$\frac{f_{x_1}}{profit}$	**Profits**	**Sales**	$\frac{f_{x_1}}{profit}$
20	20,007	38,072	1.49	85,494	107,152	0.35
40	31,369	51,132	0.95	100,809	119,835	0.30
60	44,204	67,712	0.68	106,718	130,143	0.28
80	85,875	108,305	0.35	146,868	169,537	0.20

and theirs. DRT allow for idiosyncratic shocks to the fixed costs parameters,

$$f_{x_2} = \gamma_F - \epsilon_{it}^2 \tag{25}$$

$$f_{x_1} = \gamma_S z_i + \epsilon_{it}^2 - \epsilon_{it}^1, \tag{26}$$

and so the values they report are the average costs that plants face, but the the costs actually paid by plants are likely to be lower. DRT also allow for more heterogeneity among plants than we do in this paper; the cost of entry for a plant can vary according to whether the plant is "large" or "small." With this in mind, the estimates of average entry costs in DRT are 61,000-64,000 thousand Pesos for small producers and 51,000-59,000 thousand Pesos for large producers. Our estimates of 29,903 thousand Pesos, are about half as large, but in the same ballpark. For the continuation costs, DRT find the average to be approximately 0, but the distribution of the shocks to the costs are bounded above 0, so continuation costs are important for plants sometimes. This is a bigger departure from our findings, which estimate the continuation costs to be almost half as large as the entry costs. This implies a second difference between our findings and those in DRT: only $f_{x_1} - f_{x_2} = 14,165,000$ Pesos of our entry costs are actually "sunk" while the entire entry cost in DRT are, on average, sunk.

The export specific costs that must be paid are not the only barrier to entry that plants face in our framework. If a plant is to export it will need to hire more labor, and adjustment costs must be incurred. In Figure 5 the solid line shows the average value of the adjustment

Table 6: Moments from the data and the simulated model.

Moment	**Data**	**Model**	**Model** $\boldsymbol{\nu = 0}$	**Model No Cost**
Fraction of Plants that Export	0.2420	0.2210	0.2670	0.2490
Starter Rate	0.0364	0.0413	0.0506	0.0424
Stopper Rate	0.0257	0.0202	0.0308	0.0221
1 Year Exporter Survival Rate	0.8900	0.9130	0.8920	0.9170
Growth of n in For Export Entrants	0.0359	0.0321	0.7370	0.6810
Growth Rate of Real Sales	0.0666	0.0506	0.0954	0.0771
Fraction of Non-adjusting Plants	0.0940	0.1100	0.1120	0.1060
$L(\phi)$		0.00156	0.4940	0.4240

Note: Values are averages from 1981-1991. The third column reports the results from the baseline model, the fourth column the results from the model in which all parameter values are the same except $\nu = 0$, and the fifth reports the model reestimated without any labor adjustment costs.

costs (as a fraction of median plant sales) that new exporters are paying, while the dashed line is the average value of adjustment costs being paid by all plants. Before a plant begins exporting it is adjusting little, though the costs of adjustment are slightly increasing. Upon entering the export market plants pay, on average, 2.3 percent of median plant sales in adjustment costs and continue to adjust their employment level, in smaller increments over the following years. The discounted sum of the costs of adjustment being paid by the average new exporter

$$f_{adj} = \sum_{t=0}^{5} \beta^t \nu \left(\frac{n_t - n_{t-1}}{n_{t-1}} \right)^2 n_{t-1}, \tag{27}$$

is 0.078, as a fraction of median plant sales. These costs represent a significant barrier to exporting: 13.8 percent of the export entry cost.

5.2 Eliminating Adjustment Costs

The cost of adjusting labor inputs constrains the plants significantly. To see how constrained these plants are, we keep all of the other parameters fixed at their estimated values and set the convex adjustment cost parameter to zero. (The fixed adjustment cost parameter is already estimated to be zero.) The moments from this specification are shown in Table 6.

The fraction of plants that exports increases by 4.6 percentage points, as the barriers to entry imposed by the adjustment costs are removed. The plants in the unconstrained model are more likely to exit the export market as well and this is reflected in the exporter survival rate which has fallen by 2 percentage points. The most dramatic difference is in the size of employment growth for new exporters; plants adjust completely, growing, on average, by 74 percent. Figure 6 shows the average employment growth rates for new exporters (the solid line) and the average growth rate of employment for all plants. When a plant decides to export, it completely adjusts its labor force to the desired level. A second difference in Figure 6 is that the growth rates that follow entry into the foreign market are negative. This result follows from the selection of the sample, as new exporters will tend to be the plants that have received the best shocks: on average, there is no where else to go but down, and with no costs of adjustment, plants will decrease their labor inputs.

By comparing Figure 6, which is the model with no adjustment costs, to Figure 7, which is the baseline estimation with adjustment costs, we can see how the employment dynamics differ. In the model with adjustment costs there are dramatically smaller adjustments made upon entering the export market, and these adjustments continue to be made after the plant has entered. This is in sharp contrast to the model with no adjustment costs. Compared to the data in Figure 1, the model with adjustment costs does a better job of capturing the dynamics of plant level employment. An aspect of the data that the adjustment cost model does not capture is the high levels of continued adjustment that take place after export entry. Despite the costs of adjustment, plants would like to adjust quickly, in order to capture as many export sales as possible. This is due to the discrete nature of the export revenue process. If we were to allow export sales to gradually increase after entry, we would likely need smaller adjustment costs and be able to replicate better the employment dynamics. The point of this study, however, is to keep to the standard model as closely as possible, so we do not pursue this further.

5.3 Estimation without Adjustment Costs

To further asses the importance of the barriers to entry in these models, we reestimate the model without the labor adjustment frictions. It is clear from the above discussion that the model will never be able to match the employment growth rates of new exporters, so we drop the employment growth rate and the fraction of non-adjusting plants from the moment vector, so we estimate a 5 parameter system with 5 moment restrictions. The results of this estimation are presented in Table 6 in the column labeled Model No Cost. When compared against only the moments that do not involve labor adjustment, the model fits well, with a sum of squared error of 0.00093. In the table, we report the fit of the model on all the moments, which does poorly: the sum of squared errors is 0.424. The poor fit is driven by the very high employment growth rates for new exporting plants. The biggest difference between the estimates is the entry cost, f_{x_1} which is now 68.5 percent of the median plant's sales, which is 21 percent larger than the estimate when there are adjustment costs. Clearly, the foreseen adjustment costs that would be paid by an export entrant are influencing the estimate of export entry costs. Notice that the reestimated entry costs are larger by 21 percent when our earlier calculation of the discounted average adjustment costs paid by new exporters are in the neighborhood of 14 percent. What the new estimation is taking into account—which our measure of adjustment costs paid does not—are the foregone sales that the plant could have made if it been able to completely adjust its employment immediately. These lost sales make entry even less profitable in the model with adjustment costs resulting in lower estimated barriers to entry.

5.4 Additional Moments

The preceding analysis shows that the baseline model cannot match the average dynamics of new exporters. To help further understand the export-entry decision problem, it may be useful to explore the underlying heterogeneity of export entrants. The type and amount of

heterogeneity observed could help determine the appropriate source of friction to be added to the baseline model.

Given our focus on the export entry decision, a natural starting point for examining heterogeneity is the intensive margin decision for exports at the time of entry. The first row of Table 7 shows the distribution of new export entrants (age = 1) based on their export-to-sales ratio. For 60 percent of new export entrants, exports represent less than 1 percent of total sales. About 26 percent of entrants have exports between 1 and 5 percent of total sales, while 14 percent have exports in excess of 5 percent of total sales. For plants that remain in the export market in subsequent years after entry, the distribution gradually shifts to the right. Five years after entering the export market, 32 percent of plants still have exports less than 1 percent of total sales. This table contrasts sharply with the baseline model, in which all firms have identical export-to-sales ratios for every period in the export market.

Table 7: Distribution of plants by exports-total sales ratio, conditional on years in export market

	exports as a percentage of total sales							
age of exporter	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 10$	$10 \leq x < 15$	$15 \leq x$
1	60.6	10.9	5.3	5.2	3.9	7.1	2.8	4.2
2	43.5	18.9	8.2	2.6	2.3	12.2	4.5	7.9
3	37.2	15.8	6.4	9.9	3.9	10.7	4.4	11.6
4	32.6	13.7	10.4	4.0	4.2	9.1	10.4	15.6
5	32.4	7.8	7.3	9.3	5.7	10.0	6.5	21.0

To further explore this heterogeneity, it is useful to examine whether a firm that has a larger share of exports to total sales is more likely to remain in the export market in subse-

quent periods. This could provide information on the degree of heterogeneity in idiosyncratic shocks. Potentially, plants that receive larger productivity or demand shocks may enter the export market with a larger share of exports because they expect the large shocks to persist into future periods. Table 8 shows the probabilities of remaining in the export market for each bin in the distribution. For example, for new export entrants with exports less than 1 percent of total sales, 56 percent of these plants continue exporting in the subsequent period. Interestingly, the survival probabilities for new exporters (age = 1) are pretty flat across the export-to-sales distribution. This suggests that the relative size of exports for a plant is not a significant factor in determining whether the plant continues exporting in the future. With each subsequent age vintage of exporters, the survival probabilities increase, but there is not clear pattern with respect to the cross-sectional distribution.

Table 8: Survival probabilities for each bin in distribution of plants by exports-total sales ratio, conditional on years in export market

	exports as a percentage of total sales							
age of exporter	$0 \leq x < 1$	$1 \leq x < 2$	$2 \leq x < 3$	$3 \leq x < 4$	$4 \leq x < 5$	$5 \leq x < 10$	$10 \leq x < 15$	$15 \leq x$
1	56.3	51.0	56.4	60.9	44.7	63.4	46.4	61.5
2	63.1	71.4	70.6	48.2	46.7	69.1	71.4	71.4
3	68.8	79.5	62.5	86.4	78.6	54.9	53.8	74.5
4	85.1	82.8	90.9	77.8	85.7	76.2	73.7	69.0
5	83.9	66.7	71.4	81.8	75.0	85.7	66.7	74.3

The distribution of employment growth for new export entrants can be used to provide information on the nature of labor market frictions and idiosyncratic shocks. Table 9 shows

this distribution for new export entrants during their first five years of exporting. It is important to recall that the employment measure represents labor for total production, regardless of the final destination market for the good. For new export entrants, there is a very wide range of employment growth. 12 percent of plants are contracting employment by more than 15 percent, while 18 percent are increasing employment by more than 15 percent. The overall distribution is skewed to the right, which matches evidence from Figure 2 showing that employment growth is positive on average for new entrants. For exporters in subsequent years, the left-hand tail of the distribution gets smaller while the right-hand tail remains fairly constant. Across all export ages, more than 35 percent of firms experience employment growth rates less than 5 percent in absolute terms. Combining the evidence from Tables 7 and 9, a significant number of new exporters experience small relative growth of export sales along with a small change in total employment. This could be a results of labor adjustment frictions, export market penetration costs, or a stochastic export entry cost.

Table 9: Distribution of plants by employment growth rate, conditional on years in export market

	percentage growth in employment						
age of exporter	$\Delta e < -25$	$-25 \leq \Delta e < -15$	$-15 \leq \Delta e < -5$	$-5 \leq \Delta e < 5$	$5 \leq \Delta e < 15$	$15 \leq \Delta e < 25$	$25 \leq \Delta e$
1	6.2	6.0	15.8	36.2	20.0	10.2	5.6
2	5.4	3.4	20.2	40.5	17.1	5.1	8.3
3	5.4	2.6	17.9	44.8	14.8	8.9	5.5
4	2.7	3.1	15.2	40.1	18.5	10.1	10.2
5	6.7	3.3	14.6	42.7	19.0	8.9	4.8

6 Conclusion

In this paper we have assessed the standard heterogeneous plant model of trade's ability to account for plant level dynamics. We document the experience of new exporters in a data set on Colombian manufacturing plants and find, most notably, that the response of employment to the decision to export does have a discrete nature, in that growth rates increase markedly following export entry, but they tend to grow smoothly, rather adjust completely on entry. This finding adds to the growing body of empirical knowledge on plant level behavior.

To account for the slow adjustment we see in the data, we adopt the adjustment cost approach that has been successful in the closed economy literature regarding plant level employment dynamics. Our estimates find that convex costs of adjustment are important for replicating the employment dynamics of new export entrants, but fixed costs of adjustment are not.

Our results suggest that a country's domestic policies, to the extent that they influence adjustment costs, can have important implications for the export decisions of firms. This idea has recently been explored, in a different context, in Kambourov (2006).

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Figure 1: Average export-sales ratio for new exporters, Colombia 1981-1991.

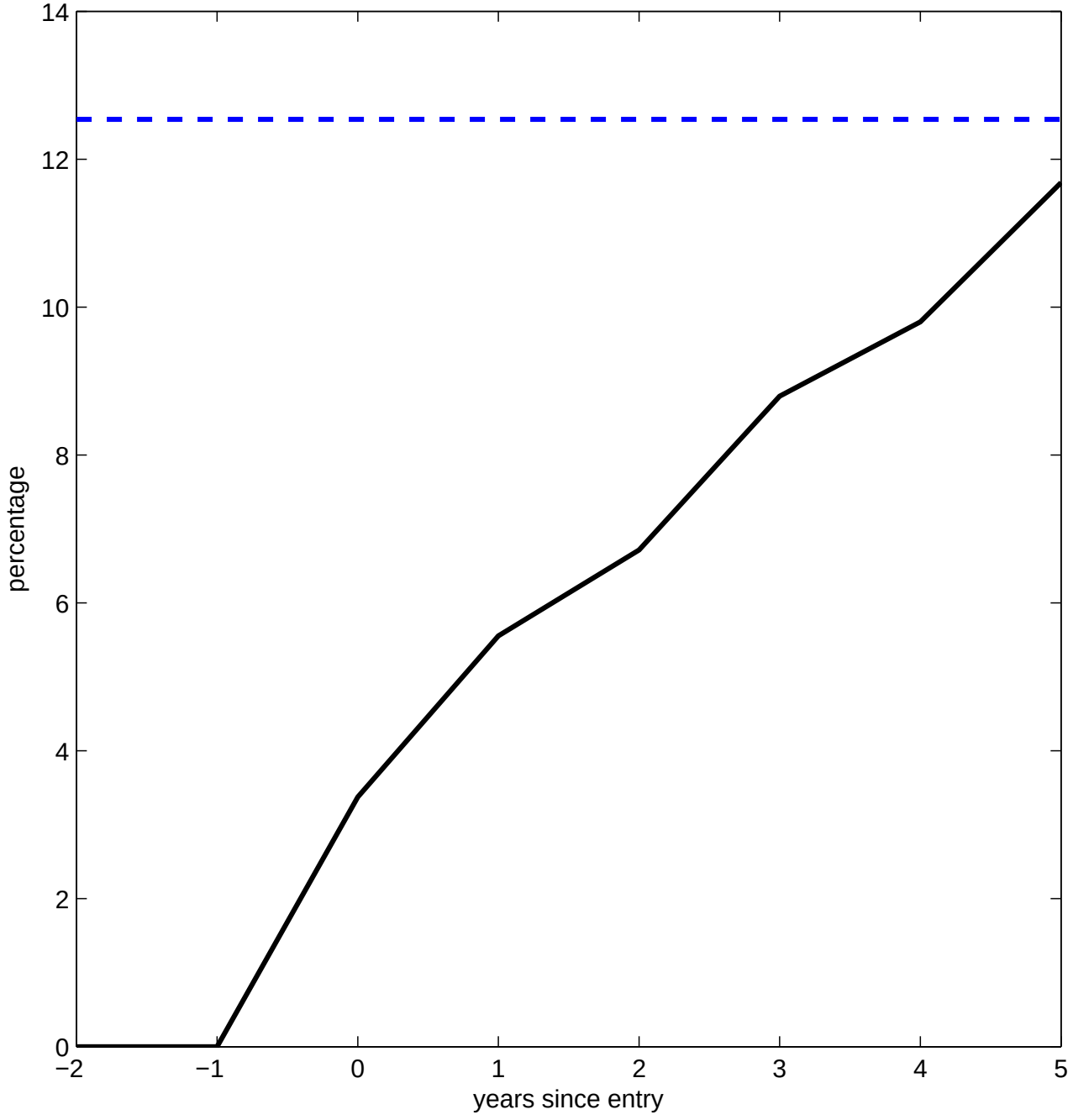

Figure 2: Average employment growth for new exporters, Colombia 1981-1991.

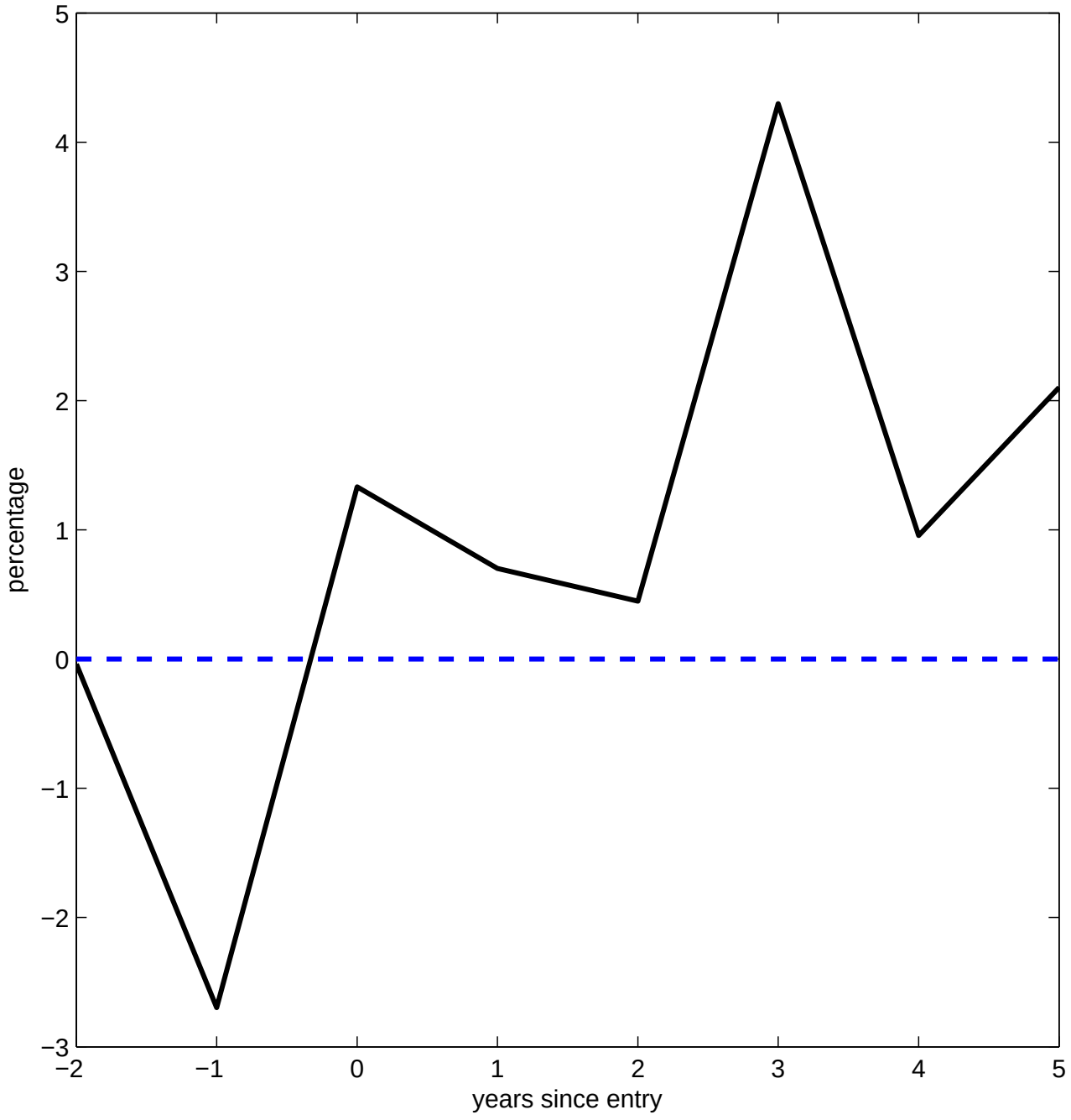

Figure 3: Average real sales growth for new exporters, Colombia 1981-1991.

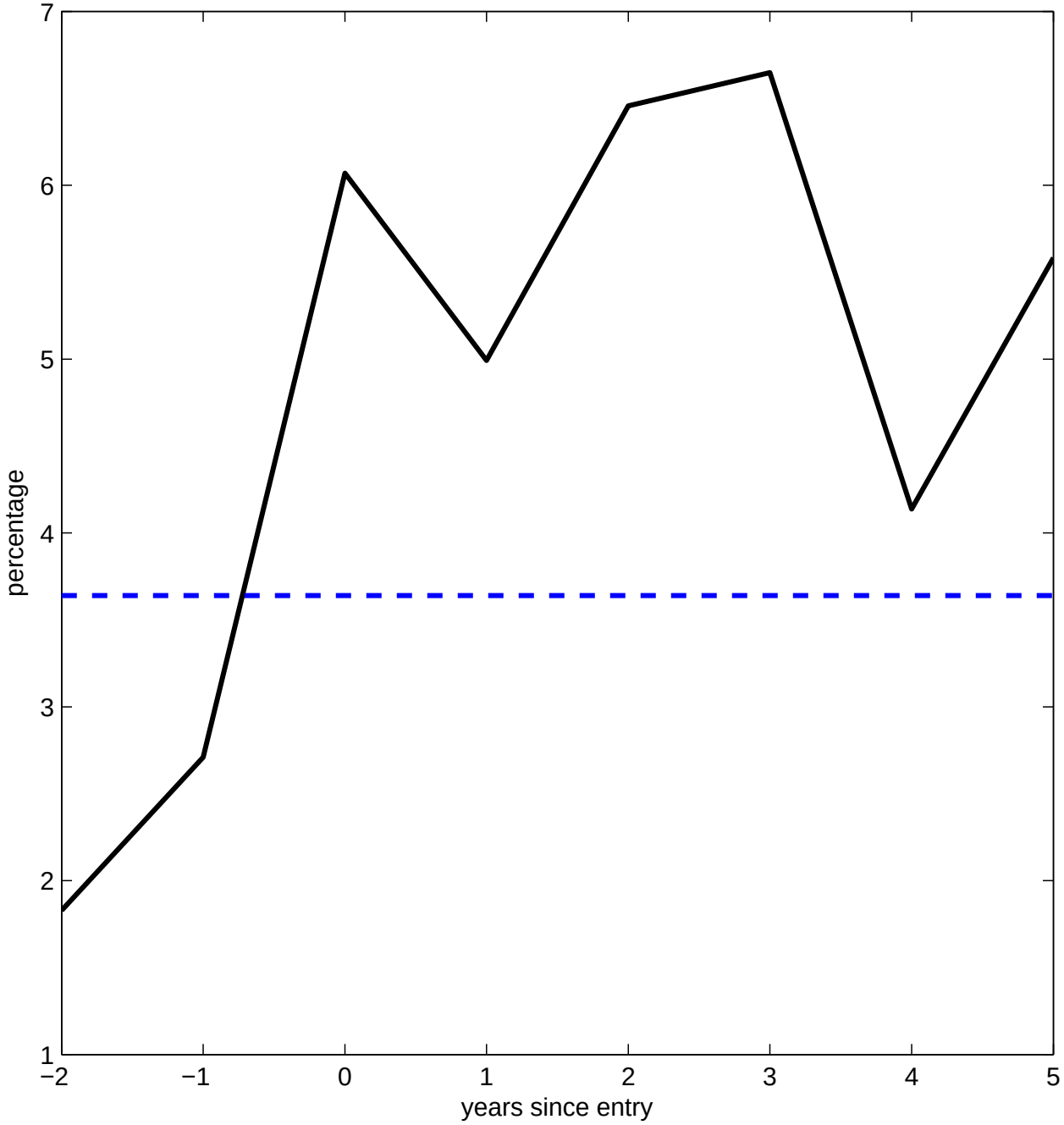

Figure 4: Survivor rates for exporters conditional on years in export market, Colombia 1981-1991.

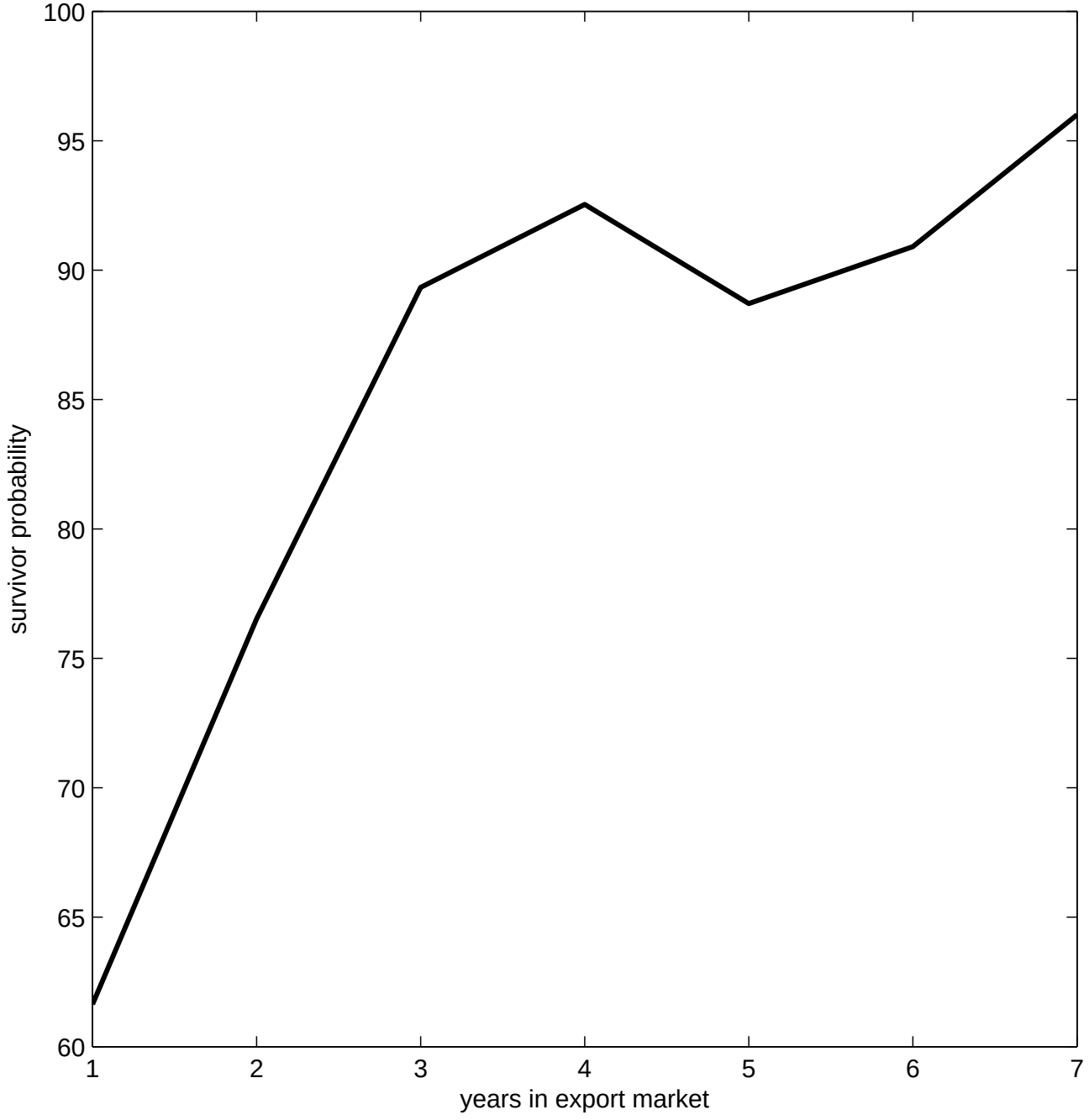

Figure 5: Average costs of adjustment paid by new exporters in model simulation.

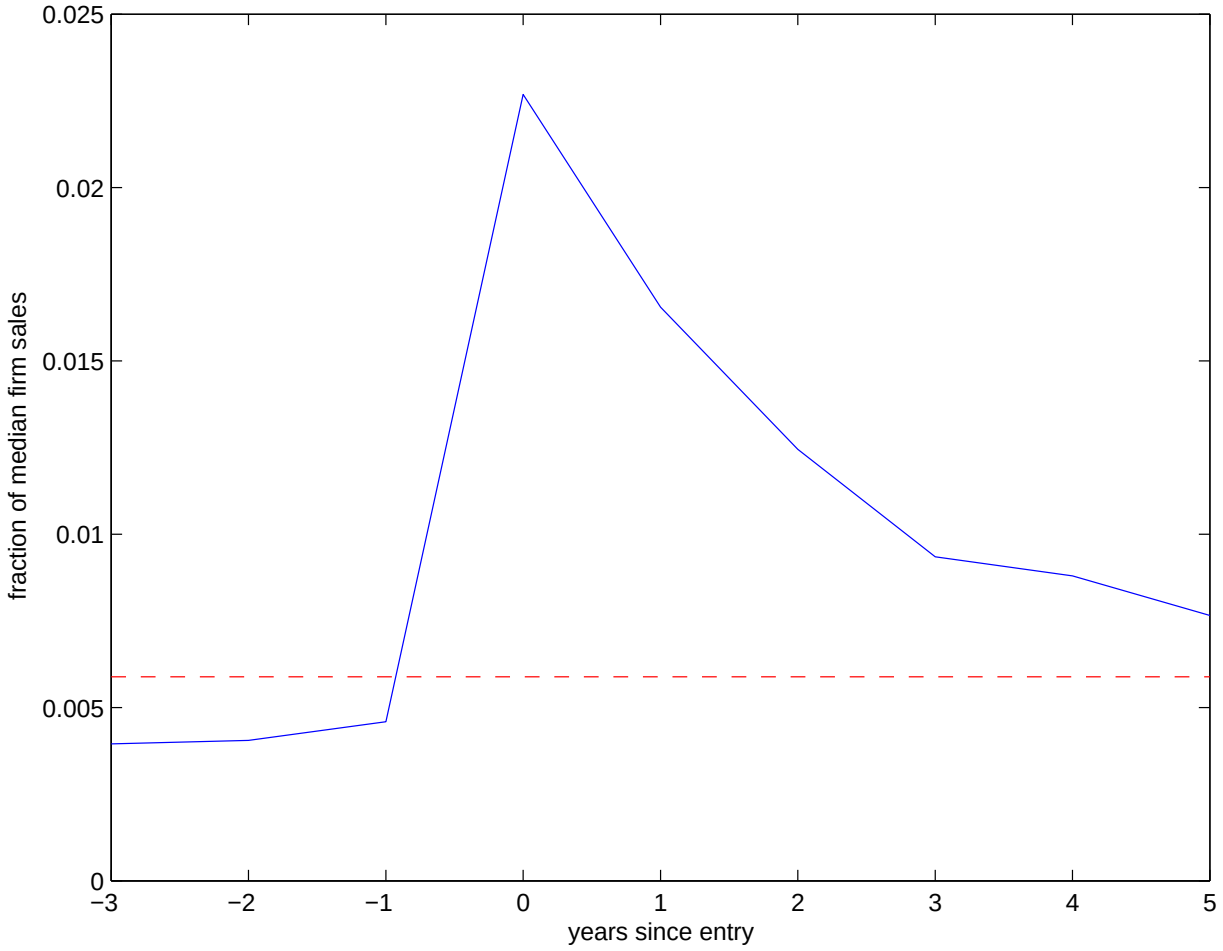

Figure 6: Average employment growth for new exporters, model without adjustment costs.

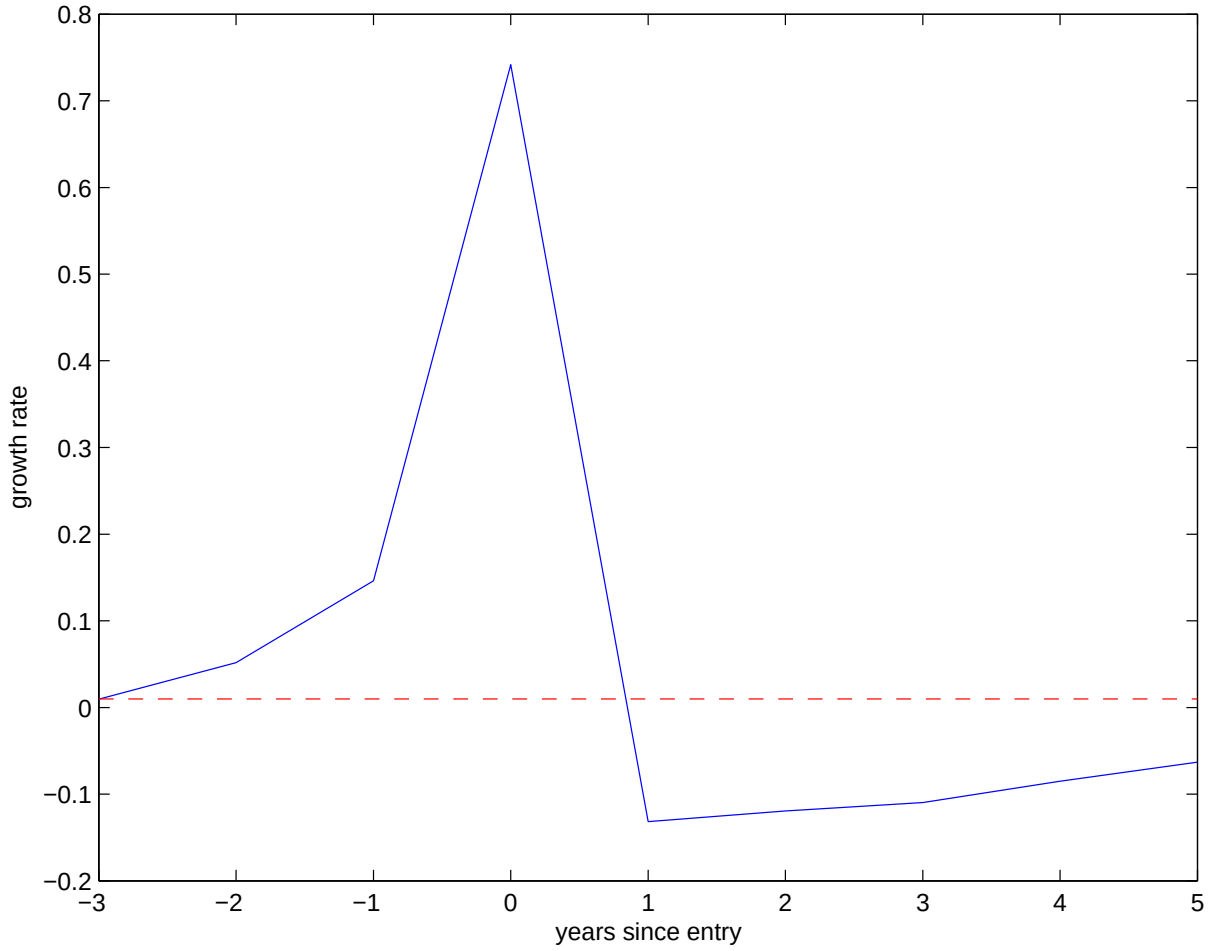
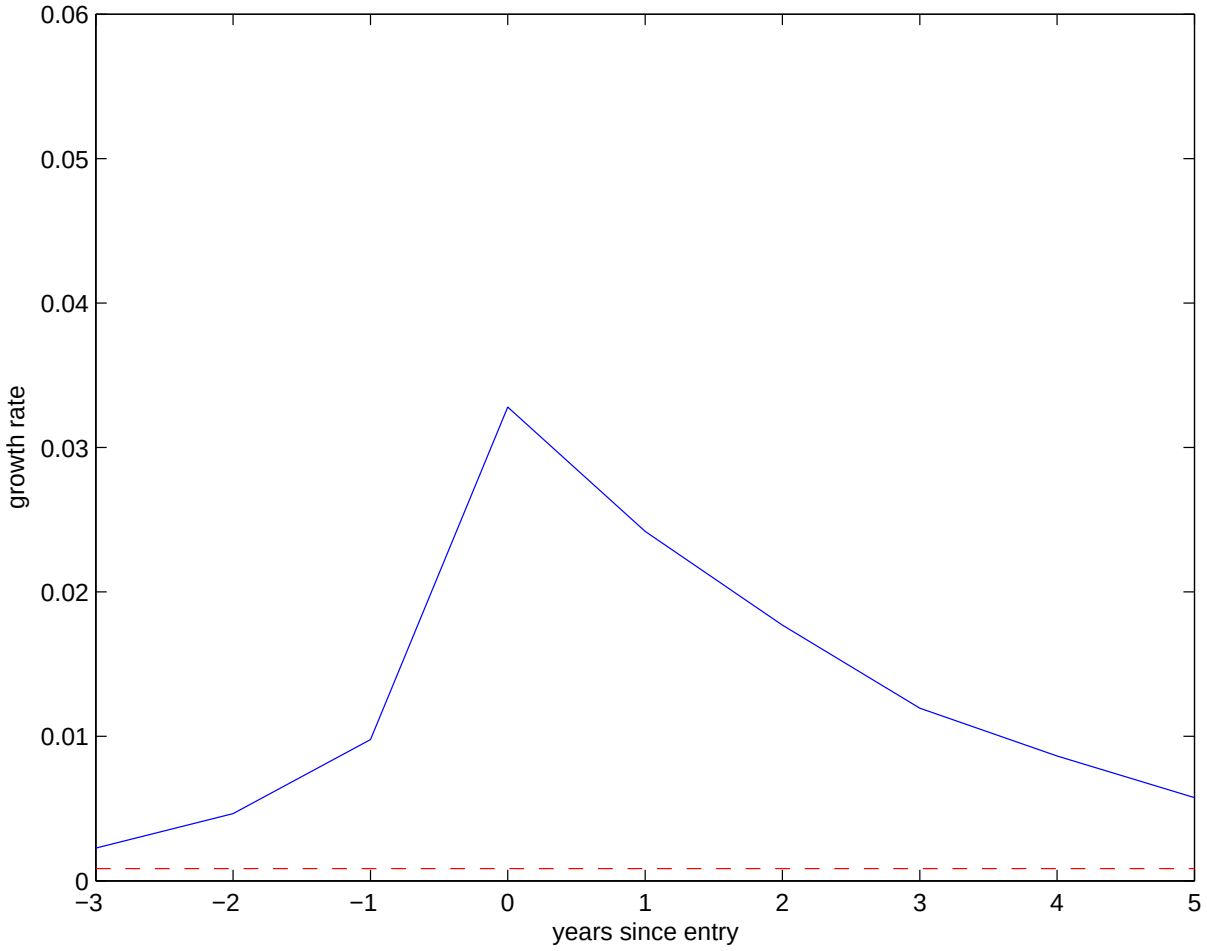
Figure 7: Average employment growth for new exporters, model with adjustment costs.