

# A Structural Econometric Model of Market Entry Costs, Producer Heterogeneity, and the Evolution of Industry Structure

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## Abstract

I develop and estimate a forward-looking structural model of a firm's entry, exit, and output supply decision. The model is novel because it incorporates estimates of entry costs and scrap values. It is based on the discrete decision of a firm to participate in a market and the continuous decision on the amount of output and is developed for a firm operating in a homogenous-product industry in which output price is determined exogenously, either by government policies or by world's markets, as prices of processed primary commodities sometimes are. In addition to estimating a complete model of firm behavior in a particular market setting, I also quantify the responses, including capital gains and losses and changes in total output and firm turnover, of such industries to changes in industrial policies.

My particular application analyzes the behavior of the Moroccan flour producers from 1984 to 1995. I estimate the output supply function and the discrete market participation rule simultaneously using simulated maximum likelihood. The model incorporates serial correlation in the productivity shocks and allows for persistent unobservable heterogeneity in the profit function with the use of Heckman-Singer mass points. The results demonstrate that firm heterogeneity, age effects and sunk entry costs (amounting to about seven times the industry's average annual profits) are all important determinants of firm behavior.

The policy experiments show that even fairly small changes in the steady state expected value of the price process play a large role in the evolution of the industry in terms of volume adjustments and firm turnover. Furthermore, the effect of such a policy shock depends crucially on its credibility. Stabilizing the price to the steady state expected value has two effects on the industry. It increases the amount of output that the firms produce but, at the same time, decreases the expected future value of the firm. Thus, the credibility of this regime switch determines the resulting effect on firm turnover. Reductions in entry costs increase industry turnover by making it less costly to enter and reducing the option values of remaining in the industry for relatively unproductive firms.

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## Introduction

Even within narrowly defined industries, the population of firms is typically heterogeneous in terms of size and productive efficiency.<sup>1</sup> Furthermore, new firms almost always face significant start-up costs, so exit and entry decisions are forward-looking and heavily dependent upon expectations. These two fundamental features of industries make it very difficult to predict how an industry will respond to exogenous shocks such as market conditions or industrial policy changes. Several theoretical models of industry dynamics have done precisely this by incorporating uncertainty, idiosyncratic productivity shocks, and entry costs and scrap values into their equilibrium analysis of entrepreneurial behavior (Jovanovic, 1982; Hopenhayn, 1992; Ericson and Pakes, 1995). However, it has not been feasible to completely estimate these models since the only decisions that are directly related to the entry costs and scrap values are the entry and exit decisions themselves, and the form of that relationship is typically too complex to be used in an estimation algorithm (Berry and Pakes, 2000).

In this paper, I develop a forward-looking structural model of firm behavior that allows me to estimate the entry costs and scrap values. Additionally, I also estimate the firm's output supply function. This model describes any homogenous-product industry in which the output price is determined exogenously, either by government policies or by world's markets, as prices of processed primary commodities sometimes are. In addition to estimating a complete model of firm behavior in a particular market setting, I am also able to quantify the responses, including capital gains and losses and changes in total output and firm turnover, of such industries to changes in industrial policies.

At the center of my model is a perfectly competitive risk neutral firm that produces a homogenous product. Marginal costs are firm-specific and vary through time with the firm's age

and idiosyncratic productivity shocks. Each period, an active entrepreneur decides, after observing the current market price and its idiosyncratic productivity shock, whether to remain in the market or exit and collect a positive scrap value. If the firm decides to stay, it produces its optimal output and sells it on the spot market. At the same time, heterogeneous potential entrants decide whether to initiate production. Entrants pay a stochastic entry cost that is only partially recoverable upon exit.

I estimate the output supply function and the market participation rule using simulated maximum likelihood. The algorithm I use extends Das, Roberts and Tybout (2000), who develop a firm-level dynamic structural model of export participation of Colombian domestic producers of chemicals. In particular, while Das et al (2000) used a two-step procedure that estimated the supply export supply decision parameters in the first stage and the market participation rule parameters in the second stage, I estimate both of these rules simultaneously. Thus I eliminate the selection bias from my model that Das et al (2000) could only partially correct for with a Mills ratio. Additionally, this permits me to include Heckman-Singer mass points in the profit function and thus capture the firm-specific *invariant* heterogeneity. This is the key to correctly estimating the structural parameters of interest (entry costs and exit values) since both the sunk costs and the firm-specific *invariant* heterogeneity can induce the same persistence in behavior that we observe in the data. Lastly, I include a quadratic function of the firm's age in the firm's profit function to allow for learning by doing and depreciation effects.

My particular application analyzes the behavior of the Moroccan flour producers from 1984 to 1995. The results show that firm heterogeneity, age effects and sunk entry costs are all important determinants of firm behavior. After accounting for both the large amount of firm heterogeneity present in the panel data set as well as important age effects, I recover values of

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<sup>1</sup> See Caves (1998) and Bartelsman and Doms (2000) for reviews and the literature cited there.

the sunk entry costs that amount to about seven times the industry's average annual profits. I also generate reasonable transition dynamics in terms of the entry and exit patterns.

The policy experiments show that even fairly small changes in the steady state expected value of the price process play a large role in the evolution of the industry. For example, with a 10% reduction in mean output price, the industry's total revenue decreases by 69% and the total number of exiting plants increases by 70% over the ten year period. If this price reduction is not deemed credible by the firms, it only has an effect on the volume adjustments since firms' expectations, which determine their participation decisions, remain unchanged. Stabilizing the price to the steady state expected value has two effects on the industry. It increases the amount of output that the firms produce but, at the same time, decreases the future expected firm value. Thus, the credibility of this regime switch determines the resulting effect on firm turnover. Reductions in entry costs increase industry turnover by making it less costly to enter and reducing the option values of remaining in the industry for relatively unproductive firms.

I begin by developing the theoretical model that serves as the basis for the estimation algorithm that I describe in the following section. Then I discuss the estimation results. However, before doing so, I describe the production techniques, the policy environment, and offer some descriptive statistics on the industries. Then I simulate the model back using the resulting parameter estimates and compare the actual industry statistics (total industry output and firm turnover) with the simulated ones to evaluate the performance of my model. Finally, I examine the impact of several policy experiments on the flour industry.

## **A Theoretical Model of Entry and Output Supply**

Like the industrial evolution models referenced above, I focus on the decision of a forward-looking firm to participate in a market. In these models, a firm must pay a stochastic

entry cost that is only partially recoverable upon exit if it wants to participate in the industry. An active firm decides each period whether to produce output or exit the industry after observing its current productivity shock and some market-wide conditions such as the market price. The combination of the uncertain firm-specific productivity shocks and the sunk startup costs allow these models to generate the large amount of heterogeneity found by the empirical studies by deriving the following decision rule. That is, firms with a history of more favorable productivity information grow over time, while the less fortunate firms exit when efficiency falls below some critical threshold value.

I will now explain how I adopt the industrial evolution models to my particular market setting. I will first give a brief overview of my model and then I will set up the firms' decision process formally.

### ***I. Model Overview<sup>2</sup>***

The industry is comprised of perfectly competitive risk neutral firms that produce a homogeneous product using heterogeneous production technologies. The entrepreneurs face two sources of uncertainty. At the market level, the exogenously determined output price  $p_t$  evolves according to a first-order Markov process. Note that the assumption of exogenous price rules out strategic interactions among firms. At the firm level, all the uncertainty arises from firm-specific, serially-correlated cost shocks.

In each period  $t$ , an active entrepreneur  $i$  observes the current market price and his idiosyncratic cost shock and then decides whether to remain in the market or exit. If he exits, he collects positive scrap value  $\Gamma_x + \varepsilon_{2it}$ , where  $\varepsilon_{2it}$  is a stochastic shock to the exit value. The role of the positive scrap value is to provide for an outside opportunity for the firm's resources and

thus to allow for exit to take place. If the firm opts to stay in the market, it earns profits  $\pi_{it}(x_{it}, a_{it}, p_t)$ , where  $x_{it}$  is a cost shock that evolves exogenously each period according to a Markov transition probability function and  $a_{it}$  is the firm's age.

Each period, there are also  $M_t$  entrepreneurs outside of the industry that may enter after paying the entry cost of  $\Gamma_E + \varepsilon_{1it}$ , where  $\varepsilon_{1it}$  is the stochastic shock to entry cost. Note that so long as  $\Gamma_E > \Gamma_X$ , firms expect that they will not fully recover their initial investment. If the firm decides to enter, it takes a full period to set up the plant. However, at the time of entry, the firm does know its cost shock  $x_{it}$  and thus enters knowing only its distribution. This assumption is the key behind generating the “failed entry” phenomenon observed in the data. That is, since the potential entrants do not know their actual productivity level until they enter, it might happen that the draw they receive results in a firm value that is less than the exit value. Additionally, since the distribution of costs is the same for all the potential entrants, they all have the same firm value before they enter and it is the private firm-specific entry costs that determine which of the potential entrants do enter and which do not.

Summarizing, the firm in this model has two decisions to make each period: whether to be active in the market and if so, how much output to supply. I will next describe each decision in greater detail.

## ***II. The Supply Decision for Firms in Production***

Once in the market, the  $i^{\text{th}}$  entrepreneur incurs cost  $c_{it}$  to produce output  $q_{it}$ , where:

$$\ln c_{it} = -\sum_{j=1}^J \omega_{0j} d_{ij} - \omega_1 t - \omega_2 \ln a_{it} - \omega_3 (\ln a_{it})^2 + \alpha \ln q_{it} - x_{it} \quad (1.1)$$

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<sup>2</sup> The timing of the firms' decision process is illustrated in Figure 1.

Here  $d_{ij}$  is an unobserved dummy variable that takes a value of one if plant  $i$  is of type  $j \in \{1, \dots, J\}$ . Entrepreneurs are assumed to know which type their plant is, but from the perspective of the econometrician, the types are unknown and their probabilities,  $\text{Prob}(d_{ij} = 1) = \gamma_{0j}$ , are parameters to be estimated. This random intercept specification accounts for time-invariant unobservable heterogeneity among firms' cost functions.<sup>3</sup> In particular, one can think of the values of the random intercept as crudely correcting for differences in capital endowments among firms.<sup>4</sup> The time trend  $t$  corrects for growth that is common to all the firms such as technical efficiency gains. However, in addition to this industry-wide effect, I also include a quadratic function of the log of the firm's age  $a_{it}$  in the cost function to capture firm-specific learning by doing and capital depreciation effects. The scale parameter  $\alpha$  is common across all the plants and greater than one implying an increasing marginal cost function.<sup>5</sup>

The key to generating the evolution patterns observed in the data is the disturbance term  $x_{it}$  that I model as an AR(1) process (subject to testing):

$$x_{it} = \lambda x_{it-1} + \xi_{it}, \text{ where } \xi_{it} \sim N(0, \sigma_\xi^2) \quad (1.2)$$

To see  $x_{it}$ 's effect on firm's fortunes over time, assume  $\lambda > 0$ . Then an increase in  $x_{it}$  decreases the firm's costs and thus increases profits not only in the current period  $t$  but also in the future periods. Thus, firms with favorable shocks grow over time, while the ones with negative shocks contract.

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<sup>3</sup> Ideally, one would like the intercepts to be firm-specific. However, estimation of such a model would not be feasible given the inherent dynamic nature of my model. See the next section.

<sup>4</sup> For simplicity, I assume that each entrepreneur is born with an exogenously determined level of capital. This could reflect wealth endowments and collateral-based borrowing constraints.

<sup>5</sup> The assumption of increasing costs is needed for the existence of the firm's static equilibrium. As will be seen later, I can infer  $\alpha$  directly from data on firms' revenues and costs, and it is indeed greater than one. Furthermore, since the firm-specific values of  $\alpha$  are fairly homogeneous across the firms, I restrict  $\alpha$  to be the mean value of the firm-specific values.

Let  $\eta = \frac{1}{\alpha - 1}$ . Since the firm knows both the current price realization and cost shock

when it makes its output decision, it chooses  $q_{it}$  so that  $p_t = mc_{it}$ , which implies that the log of the firm's optimal output choice is:

$$\ln q_{it}(x_{it}, a_{it}, p_t) = \eta \sum_{j=1}^J \omega_{0j} d_{ij} - \eta \ln \alpha + \eta \omega_1 t + \eta \omega_2 \ln a_{it} + \eta \omega_3 (\ln a_{it})^2 + \eta \ln p_t + \eta x_{it} \quad (1.3)$$

Hence the log of the static operating profits is:

$$\ln [\pi(x_{it}, a_{it}, p_t)] = \eta \sum_{j=1}^J \omega_{0j} d_{ij} - [\eta \ln \alpha + \ln \eta] + \eta \omega_1 t + \eta \omega_2 \ln a_{it} + \eta \omega_3 (\ln a_{it})^2 + \alpha \eta \ln p_t + \eta x_{it} \quad (1.4)$$

I will use (1.3) along with plant-specific revenue and age data and sector-wide price data to estimate the parameters of the cost function. Then I will use these in (1.4) to construct the firm's value function and thus determine the firm's participation decision that I describe next.

### ***III. The Participation Decision***

Unlike the supply choice, the entrepreneur's decision whether to be in business or not depends not only on his current circumstances but on his past choices as well. Define  $y_t$  to be the binary participation decision variable that equals one when the firm is in operation in period  $t$  and zero otherwise. The net current profits from producing in year  $t$ ,  $u(\cdot)$ , can then be written as:

$$u(\cdot) = \begin{cases} -(\Gamma_E + \varepsilon_{1it}) & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 1 \\ \pi(x_{it}, a_{it}, p_t) & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 1 \\ \Gamma_X + \varepsilon_{2it} & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 0 \\ 0 & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 0 \end{cases} \quad (1.5)$$

Note specifically that the realized profits in year  $t$  depend on the firm's participation status in both periods  $t-1$  and  $t$ . Entering the industry requires a firm-specific stochastic entry costs of  $\Gamma_E + \varepsilon_{1it}$ , and the firm spends the whole period building the plant and does not produce any output. Continuing firms receive a profit of  $\pi(x_{it}, a_{it}, p_t)$  resulting from producing the optimal

amount of output defined in (1.3), and the firm recovers  $\Gamma_X + \varepsilon_{2it}$  upon exit and no longer supplies output to the industry in the period it exits.

To solve the firm's market participation problem, define firm  $i$ 's stochastic exogenous state space as  $s_{it} = (x_{it}, \varepsilon_{1it}, \varepsilon_{2it}, p_t)$ , the parameters that govern the evolution of the AR(1) price process as  $\Upsilon = (\delta_0, \delta_1, \sigma_p^2)$ , and  $\theta = \left( \left\{ \omega_{0j}, \gamma_{0j} \right\}_{j=1}^J, \omega_1, \lambda, \sigma_\xi^2, \alpha, \Gamma_E, \Gamma_X, \sigma_{\varepsilon_1}, \sigma_{\varepsilon_2}, \{M_t\}_{t=1}^T, \Upsilon \right)$ , where  $\sigma_{\varepsilon_1}^2 = \text{var}(\varepsilon_{1it})$  and  $\sigma_{\varepsilon_2}^2 = \text{var}(\varepsilon_{2it})$ , as the vector of parameters to be estimated. The firm's planning problem is to maximize its total expected profits, i.e. the value of the firm, given the initial state  $(s_{i0}, a_{i0}, y_{i0})$  and discount factor  $0 < \beta < 1$ :

$$\sup E_0 \left\{ \sum_{t=0}^{\infty} \beta^t u(s_{it}, a_{it}, y_{it-1}, y_{it}, \theta) \right\} \quad (1.6)$$

Before specifying the value function corresponding to (1.6), it is convenient to introduce Rust's (1988) "conditional independence" assumption, which I will invoke to simplify computation. Let  $H(\cdot|\cdot)$  stand for the transition function between the states in period  $t$  and  $t+1$ . Conditional assumption amounts to the assumption that  $H(\cdot|\cdot)$  may be written as:

$$H(p_{t+1}, x_{it+1}, \varepsilon_{1it+1}, \varepsilon_{2it+1} | p_t, x_{it}, \varepsilon_{1it}, \varepsilon_{2it}) = Q(p_{t+1}, x_{it+1} | p_t, x_{it}) F(\varepsilon_{1it+1}, \varepsilon_{2it+1}) \quad (1.7)$$

That is, the restriction of conditional independence assumes that  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$  are not correlated over time and that the correlation between  $x_{it}$  and the transitory noise to the entry costs and scrap value,  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$ , is restricted to be zero. As I will argue later,  $p_t$  is independent  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$  as well. Thus, I can write  $H(\cdot|\cdot)$  as the product of the transition function for the serially correlated first-order processes  $x_{it}$  and  $p_t$ ,  $Q(\cdot|\cdot)$ , and the transition function for the serially uncorrelated shocks  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$ ,  $F(\cdot)$ . This simplifies the solution algorithm for the Bellman

operator significantly since, as Rust (1988) shows, it allows me to calculate the fixed point of the value function using a considerably smaller state space than would be possible otherwise. However, at the same time, this assumption has the unattractive feature of ruling out entry cost and exit value adjustments as the firm revenues grow or decline over time.

The value function corresponding to (1.6) can then be written as:

$$V_t(s_{it}, a_{it}, y_{it-1}, \theta) = \max_{y_{it} \in \{0,1\}} \left[ u(s_{it}, a_{it}, y_{it-1}, y_{it}, \theta) + \beta E_t V_{t+1}(s_{it+1}, a_{it+1}, y_{it}, \theta) \right] \quad (1.8)$$

Letting  $\varepsilon_{it+1} = (\varepsilon_{1it+1}, \varepsilon_{2it+1})$ , the expected value function  $E_t V_{t+1}(\cdot)$  has the following form:

$$E_t V_{t+1}(s_{it+1}, a_{it+1}, y_{it}, \theta) = \int_{\varepsilon_{it+1}} \int_{x_{it+1}} \int_{p_{t+1}} V_{t+1}(s_{it+1}, a_{it+1}, y_{it}, \theta) dQ(x_{it+1}, p_{t+1} | x_{it}, p_t) dF(\varepsilon_{it+1}) \quad (1.9)$$

It is easy to show that there exists a unique solution to the value function  $V^*$  because the value function is bounded, continuous, and monotonic, the property of discounting holds, and the transition function has the Feller property.<sup>6</sup>

The values of the Bellman equation, exclusive of  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$ , corresponding to the current operating profits in (1.5) are defined as:

$$\begin{aligned} V_{11it} &= \pi(x_{it}, a_{it}, p_t) + \beta E_t V_{it+1}(\cdot, 1) & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 1 \\ V_{10it} &= \Gamma_X + \beta E_t V_{it+1}(\cdot, 0) & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 0 \\ V_{01it} &= -\Gamma_E + \beta E_t V_{it+1}(\cdot, 1) & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 1 \\ V_{00it} &= \beta E_t V_{it+1}(\cdot, 0) & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 0 \end{aligned} \quad (1.10)$$

The key equations in this section are (1.10) that essentially determines the firm's participation decision and (1.9) that allows me to calculate the firm's future expected value in (1.10). I will now move to the estimation algorithm to explain how I use these along with (1.3) and (1.4) to obtain the parameters estimates.

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<sup>6</sup> See Ch. 9 of Stokey and Lucas (1989) for more details.

## Econometric Framework

The model I have developed in the previous section can be applied to any homogenous product industry, where the industry price is determined exogenously, either by government policies or by world's markets, as prices of processed primary commodities sometimes are. I will apply the model to an annual panel data set describing Moroccan flour producers from 1984 to 1995.<sup>7</sup> For each year a particular producer is present in the data set, I observe total sales revenues  $r_{it}$ , and thus the participation decision  $y_{it}$ , total variable costs  $c_{it}$ , firm's age  $a_{it}$  (the data set contains the year the firm was born), and invariant firm characteristics  $z_i$  such as geographical location and business type. I use a wholesale price index specific to the food industry and the economy-wide factor price index to obtain the real counterparts of  $r_{it}$  and  $c_{it}$ . Finally, I deflate the time series on Moroccan wholesale flour prices from 1970 to 1995 by the Moroccan national manufacturer's wholesale price index to obtain the real flour price.

I will now explain how I utilize the firm-specific and market level data to uncover the parameter vector of interest  $\theta$ .

### *I. Estimation Algorithm*

The parameter vector  $\theta$  can be estimated by maximizing the following sample log-likelihood function:

$$L = \sum_{i=1}^N \sum_{j=1}^J \ln G(r_{iT}, \dots, r_{i1} | (s_{iT}, a_{iT}, \dots, s_{i1}, a_{i1}), y_{i0}(\omega_{0j}, z_i), \theta) \phi(y_{i0} | \omega_{0j}, z_i) \gamma_{0j} \quad (2.1)$$

The function  $G$  is the probability of observing an entire trajectory of firm revenues over the sample period conditional on the state vector and the initial participation decision  $y_{i0}$ . Since  $y_{i0}$  is itself endogenously determined by  $\omega_{0j}$  and other firm characteristics, I correct for this fact by

including the probability function  $\phi$  in the likelihood as I explain below. Additionally, since the real output price is dictated to the industry, it is reasonable to assume that it is independent of the cost shock  $x_{it}$  as well as the transitory noise to the entry costs  $\varepsilon_{1it}$  and exit value  $\varepsilon_{2it}$ . Thus I estimate it separately as a simple AR(1) process (subject to testing). Thus, while the firms' decisions are based on  $\Upsilon$ , its parameters are not estimated by maximizing (2.1).

Given that a firm's payoff in a given period is not only determined by its current participation status but by its previous participation choices as well, G takes the following form:

$$G(\cdot | \cdot) = \prod_{t=1}^T \left[ \Omega_{11it}(\cdot)^{y_{it}y_{it-1}} \Omega_{10it}(\cdot)^{y_{it}(1-y_{it-1})} \Omega_{01it}(\cdot)^{(1-y_{it})y_{it-1}} \Omega_{00it}(\cdot)^{(1-y_{it})(1-y_{it-1})} \right] \quad (2.2)$$

Essentially, G is a Type 2 Tobit.<sup>8</sup> The probability of observing a particular level of revenues in a given year,  $\Omega$ , is determined by the product of the density of output *conditional* on the firm's participation decision and the probability of being active/inactive in the market. Defining the former as  $\Psi$  and the latter as  $\Phi$  and using the conditional independence assumption implies the following form for  $\Omega$ :<sup>9</sup>

$$\begin{aligned} \Omega_{11it} &= \Psi(r_{it} | p_t, r_{it-1}, a_{it}, \theta) \Phi(V_{11it} > V_{10it} + \varepsilon_{2it}) & \text{if } & y_{it-1} = 1 \text{ and } y_{it} = 1 \\ \Omega_{10it} &= \Phi(V_{10it} + \varepsilon_{2it} > V_{11it}) & \text{if } & y_{it-1} = 1 \text{ and } y_{it} = 0 \\ \Omega_{01it} &= \Phi(V_{01it} - \varepsilon_{1it} > V_{00it}) & \text{if } & y_{it-1} = 0 \text{ and } y_{it} = 1 \\ \Omega_{00it} &= \Phi(V_{00it} > V_{01it} - \varepsilon_{1it}) & \text{if } & y_{it-1} = 0 \text{ and } y_{it} = 0 \end{aligned} \quad (2.3)$$

In the periods that the firm produces,  $\Omega$  is determined by the probability of observing the firm's revenues conditional on its likelihood of being in the market. Note that while the entrant draws an unconditional shock  $x_{it}$  from the cost distribution in the first period that it produces, the incumbent that has been in the operation for more than two periods uses his prior information on

<sup>7</sup> See the next section for the description of the policy environment and the industry.

<sup>8</sup> See Ch. 10 of Amemiya (1985) for the overview of the five different types of Tobit models.

<sup>9</sup> If  $\text{cov}(x_{it}, \varepsilon_{1it}) \neq 0$  and  $\text{cov}(x_{it}, \varepsilon_{2it}) \neq 0$ , then  $\Psi$  would be weighted by an additional term that would depend on the variances and covariances of the three shocks.

revenues in  $t-1$  to infer his cost shock in  $t$  up to the noise  $\xi_{it}$ . For the rest of the cases in (2.3),  $\Omega$  collapses to  $\Phi$ . That is, when the firm goes out of business or is in the process of entry, it does not produce and thus  $\Omega$  is determined only by the probability of observing the firm out of business conditional on its last year's participation choice. Note that once the firm goes out of business, it cannot re-enter in the future.

I will now discuss in greater detail how to estimate  $\Psi$ ,  $\Phi$  and correct for the initial condition problem using  $\phi$ .

#### A. The Probability Function $\Psi$

Using (1.3), the log of the firm's revenues can be written as:

$$\ln r_{it}(x_{it}, a_{it}, p_t) = \eta \sum_{j=1}^J \omega_{0j} d_{ij} - \eta \ln \alpha + \eta \omega_1 t + \eta \omega_2 \ln a_{it} + \eta \omega_3 (\ln a_{it})^2 + \alpha \eta \ln p_t + \eta x_{it} \quad (2.4)$$

Then using standard maximum likelihood techniques that allow for first-order serial correlation in the error term, I construct  $\Psi$  based on (2.4).<sup>10</sup> However, four issues deserve further discussion. First, since I estimate the supply decision simultaneously with the participation decision, the estimates of (2.4) are not subject to selection bias. Second, I can infer the scale parameter  $\alpha$  and thus  $\eta$  directly from the data since the firm's first-order condition implies that it is the ratio of revenues to costs for each firm:

$$\alpha_i = \frac{p_t}{q_{it}^{\alpha_i-1} e^{x_{it}}} = \frac{p_t}{q_{it}^{\alpha_i-1} e^{x_{it}}} \times \frac{q_{it}}{q_{it}} = \frac{r_{it}}{c_{it}}, \text{ where } \alpha_i \text{ is the firm-specific scale} \quad (2.5)$$

Thus, letting  $T_i$  be the number of years firm  $i$  is present in the data,  $\alpha$  can be calculated as follows:<sup>11</sup>

<sup>10</sup> See, for example, Ch. 8 of Judge et al (1985).

<sup>11</sup> Note that I assume that while I observe a noisy measure of  $\alpha$ , the firms know its true value and thus this measurement error does not affect their optimal output and market participation choices. In other words,  $\alpha$  is

$$\alpha = \frac{1}{N} \sum_{i=1}^N \left( \frac{1}{T_i} \sum_{t=1}^{T_i} \frac{r_{it}}{c_{it}} \right) \quad (2.6)$$

Third, as mentioned in the introduction, correctly modeling the persistence in the participation status requires careful accounting for firm heterogeneity since both heterogeneity and sunk costs imply persistence. While the serially correlated cost process does precisely that, it might not be enough, because it implies all firms share the same steady state profit distribution. In particular, one of the common findings of empirical studies is that cohorts of firms of different sizes coexist at the same time in an industry. This is certainly the case in my model since the firms are assumed to be born with an exogenous level of capital that does not change through time. To account for this fact, I let the intercepts of the revenue function vary among  $J$  groups. Using the Heckman-Singer procedure, I then estimate the number of groups  $J$ , the values of the intercepts  $\omega_{0j}$  as well as their associated probabilities  $\gamma_{0j}$ .<sup>12</sup>

Lastly, given the dynamics of the problem, I need to correct for the initial conditions problem that arises because the firm's initial participation decision  $y_{i0}$  is not exogenous. In particular, it depends on  $\omega_{0j}$ . Thus, ignoring the endogeneity of  $y_{i0}$  would result in biased estimates. I use the method proposed by Heckman (1981) that essentially approximates the distribution of the initial condition. In my case, since  $y_{i0}$  is a dichotomous variable, I model  $\phi$  as a reduced-form probit, where  $y_{i0}$  is modeled as a function of unobservable intercepts  $\omega_{0j}$  and some *invariant* exogenous characteristics of the firms  $z_i$  such as the geographical location and business type. It seems reasonable to assume that these characteristics are pre-determined given the stringent governmental regulations and very limited mobility in the developing countries.

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independent of  $x_{it}$ ,  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$  and thus estimating it separately is equivalent to including it in the likelihood function.

### B. The Probability Function $\Phi$

Since the participation decision is discrete, I cannot use first-order conditions to characterize the firm's decision to be in or out of business. However, the firm's decision in period  $t$  can be determined by comparing its value of being versus not being in the market conditional on its last period's activity status as defined in (1.10). Thus, the parameters underlying the discrete choice can be estimated by maximizing the probability of observing the firm's participation trajectory found in the data. Assuming that the shocks to the entry costs and scrap values are normally distributed and serially uncorrelated, this probability,  $\Phi$ , is estimated as a dynamic probit:

$$\begin{aligned}
 \Phi(V_{11it} > V_{10it} + \varepsilon_{2it}) &= \Phi\left(\frac{V_{11it} - V_{10it}}{\sigma_{\varepsilon_2}}\right) & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 1 \\
 \Phi(V_{10it} + \varepsilon_{2it} > V_{11it}) &= 1 - \Phi\left(\frac{V_{11it} - V_{10it}}{\sigma_{\varepsilon_2}}\right) & \text{if } y_{it-1} = 1 \text{ and } y_{it} = 0 \\
 \Phi(V_{01it} - \varepsilon_{1it} > V_{00it}) &= \Phi\left(\frac{V_{01it} - V_{00it}}{\sigma_{\varepsilon_1}}\right) & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 1 \\
 \Phi(V_{00it} > V_{01it} - \varepsilon_{1it}) &= 1 - \Phi\left(\frac{V_{01it} - V_{00it}}{\sigma_{\varepsilon_1}}\right) & \text{if } y_{it-1} = 0 \text{ and } y_{it} = 0
 \end{aligned} \tag{2.7}$$

Evaluating the probabilities in (2.7) requires calculation of the firm's value function that consists of two parts. That is, the current profits and the future expected value of the firm conditional on the firm's participation decisions in the past and the present period as specified in (1.10). Starting with the static operating profits  $\pi_{it}$ , if a firm is an entrant or has never been active in the market, it receives profits of zero in the current period. If a firm is an incumbent, its profits can be calculated according to (1.4) since for a given  $\theta$ , the firm's revenues  $r_{it}$  imply the

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<sup>12</sup> See Heckman and Singer (1984).

unobservable cost shock  $x_{it}$ . Calculating profits for quitters is a little bit more complicated because the revenues are unobserved when  $y_{it} = 0$ . However, given that the productivity shock follows an AR(1) process, this unobservable shock is easily integrated out.

To evaluate the firm's expected value in (1.9), I use the method of successive approximations, which entails approximating the firm's infinite dynamic problem by a finite planning horizon of sufficient length  $T$  given that (1.8) is uniformly bounded and  $\beta \in (0,1)$ . This allows me to use backward induction to calculate the expected value function in the initial period,  $E_0 V_1(\cdot)$ , that is the maximized present value of utility in all the future periods  $T$ . The basic idea behind backward induction is that the firm only solves a static optimization problem in the terminal period  $T$  since there are no future periods. Therefore, in period  $T-1$ , the firm's expected value is the utility it obtains in period  $T-1$  plus the discounted utility in the terminal period  $T$ . Applying the same logic to all the other periods yields the firm's expected value in the initial period,  $E_0 V_1(\cdot)$ .

Unfortunately, this straightforward algorithm requires that, at each step of the process, I evaluate a multivariate integral of continuous state variables as seen in (1.9). That is, calculate the firm's utility in each possible state in the current period weighted by the probability of reaching this state given every possible state in the last period. This is trivial for the serially uncorrelated shocks  $\varepsilon_{1it}$  and  $\varepsilon_{2it}$  that are assumed to be drawn from a standard normal distribution. However, evaluating the integral over the serially correlated shocks is rather demanding. The most common method is to discretize the state space and thus replace the integral by a summation:

$$E_t V_{t+1}(s_{it+1}, a_{it+1}, y_{it}, \theta) = \frac{1}{K} \sum_{k=1}^K V_{t+1}(s_{it+1}^k, a_{it+1}, y_{it}, \theta) dQ(x_{it+1}^k, p_{t+1}^k | x_{it}, p_t) \quad (2.8)$$

That is, the value function in  $t+1$  is evaluated at  $K$  states and then the expected value function is calculated as the average over the  $K$  states.

Until recent work by Rust (1995, 1997), the state space was usually discretized deterministically. As he shows, doing so quickly results into an intractable problem as the dimension of the state space increases since the number of grid points necessary for the Bellman operator to converge, i.e. be within a certain distance of the true value function with probability one, is very large, and the time required to solve such problems grows exponentially in the dimensions of the state space. Rust (1997) develops a new algorithm that does not have such strict requirements on convergence. In particular, his algorithm only requires the approximate solution to be close to the true value function with probability arbitrarily close to one (Rust 1995). As he shows, he can accomplish that with a randomly drawn grid of a “reasonable size.” As a result, the time required for convergence grows only linearly in the dimension of the state space.

As in Das et al (2000), I use Rust’s random algorithm. Since both shocks to  $p_t$  and  $x_{it}$  are serially correlated and normally distributed, it is relatively straightforward to construct the grid points and their associated transition probabilities. To do so, I draw an IID random sample of points from a standard normal distribution that stays fixed for all the iterations. Then, using the parameters of the two AR(1) processes, I construct the grid points and their associated probabilities for each iteration. Note that as the parameters of the cost process are updated each iteration, the grid points as well as the probabilities change as well. Since the random operator does not necessarily retain the property of a contraction mapping of (1.8), I normalize the sum of the probabilities of each of the grid points in the sample to unity.

Lastly, I have to calculate the pool of potential entrants  $M_t$  to make sure that the vector of parameter estimates that maximize the sample likelihood defined in (2.1), say  $\theta^*$ , supports bounded entry. First, note that given  $\theta^*$ , there is a different probability of entry  $P_{01t}^j$  associated with each mass point  $j$ . Thus, I calculate the unconditional probability of entry  $P_{01t}$  as follows:

$$P_{01t} = \sum_{j=1}^3 \gamma_{0j} P_{01t}^j \quad (2.9)$$

Second, I observe the actual number of entrants  $A_t$  in the data. Thus I can use this information along with  $P_{01t}$  to determine  $M_t$  as:

$$M_t = \frac{A_t}{P_{01t}} \quad (2.10)$$

I will now turn to fitting the model to the Moroccan flour producers. Before presenting the results, I will briefly describe the milling process and relate its features to my model. Furthermore, I will discuss the policy environment and provide some summary statistics for the data.

## **Overview of the Milling Techniques, Policy Environment and Data**

### ***I. The Milling Process***

In the simplest terms, the wheat grain consists of three parts. The endosperm and germ form the kernel that is enclosed by a protective layer called the bran or hull. The germ grows into a new plant if a seed is planted, while the endosperm that contains all the starch and protein serves as its food source when it germinates. Given the endosperm's nutritional value, the objective of milling is to isolate the endosperm. However, while the germ can be easily detached,

no layer separates the bran and the endosperm. Thus the successful partition of the two is one of the most important tasks of the milling process.

While many different technologies exist for wheat milling, the three basic parts of the process are cleaning, grinding and sieving. First, foreign material such as dirt and weeds and damaged wheat is separated from the wheat. This usually involves running the wheat through sieves of different sizes. The second step of grinding is the most important since it determines the amount of flour than can be extracted from the kernel. It basically reduces to breaking off the bran. Therefore, if a part of the endosperm is detached along with the bran, the flour yield is lower. The most common grinding machines are stone and roller mills. In the stone mill, the grinding takes place between stones. While the top stone does not move, its bottom counterpart rotates and grinds the wheat. The roller mill, on the other hand, feeds the wheat between two rotating horizontally positioned rollers that grind the wheat by pressing against each other. The last step involves sieving, whereby the flour is separated from the crushed bran particles and other impurities. Many sieves of different size can be used separately or simultaneously depending on how clean and purified the flour should be.

Overall, the technology used in the milling process appears to be fairly uniform. Thus, it seems reasonable to restrict the scale parameter  $\alpha$  to be the same across all the firms. However, the costs of recovering a given amount of flour are still very heterogeneous among the mills since that depends on factors such as the quality (cleanliness) of the wheat that enters the mill, the efficiency of the grinding process, and the logistics behind the operation of the mill that is determined in large part by the experience of the head miller. To account for that, I allow the cost shock to be correlated over time and also include age effects in the cost function that proxy for the head miller's experience and depreciation of capital. Given the huge volume of wheat that

goes through the sieves and grinding machines, the whole milling process is usually fully automated with hot air used as the “vehicle” for the transport of wheat and later flour. As such, there are huge capital investments associated with building an industrial mill that depend on the volume of wheat/flour that the mill can handle. I capture that by including the Heckman-Singer mass points in the cost function. Furthermore, since mills use very industry-specific equipment, it suggests that the initial investment might be very hard to recover. Thus, there seem to be large sunk entry costs associated with flour milling.

## ***II. Policy Environment***

Wheat and flour are the most important staples of Morocco’s diet. Two kinds of wheat are consumed in Morocco. Hard wheat has been traditionally grown in Morocco, while the French colonists introduced soft wheat to Moroccan agriculture in the first half of the 20th century. However, by 1985, 75% of consumed wheat was soft (Kydd and Thoyer, 1992). Given that the majority of the output of the flour industry is soft flour and that soft and hard flour are very close substitutes, I will assume that there is enough arbitrage between the two markets so that the price of soft wheat flour also determines the price in the hard wheat flour market.<sup>13</sup> Thus, I will further discuss only the policies regarding the soft wheat and soft wheat flour markets.

Since the late sixties, the objectives of the overall wheat/flour policy were to: insulate the economy from wheat price fluctuations in international markets, make it financially attractive to expand production of wheat, and maintain low flour and bread prices (Kydd and Thoyer, 1992). To accomplish the first two objectives, the government created the Office Nationale Interprofessionnel des Cereales et des Legumineuses (ONICL) that managed all the wheat imports (around 30-40% of overall production depending on the weather conditions in any given

year during the sample period) as well as bought all the wheat produced by the farmers through a network of licensed traders.<sup>14</sup> At the same time, the Office Nationale de Transport was charged (and funded) by the government with delivery of wheat to flourmills. Thus, ONICL was able to fix a guaranteed pan-territorial price (in nominal terms) of both hard and soft wheat well above the world price at which wheat entered the flourmills. To accomplish the third objective, the ONICL had the mills sell the flour at uniform pan-territorial subsidized prices to the end users and reimbursed the mills for the difference between the subsidized price and the cost of producing the flour. This single pan-territorial price at which ONICL reimbursed the mills was set at the official wheat price plus a fixed milling margin that was calculated based on the *average* milling costs (Kydd and Thoyer, 1992).

By 1985 this regime was imposing an unacceptable burden on the public sector budget. Thus, the government set out to completely liberalize the cereal market (domestic and imports) by the end of 1992 (Kydd and Thoyer, 1992). However, these changes were adopted very slowly. For example, in 1995, about half of the soft wheat flour output was still regulated using the old pricing scheme, while ONICL oversaw the price of the rest of the soft flour output through price controls. At the same time, ONICL still kept tight control over the imports in the wheat/flour markets. Thus, given the slow full adoption of the reforms, I will assume that the relevant price that all the mills use for their marginal cost pricing of their *total* output is the single pan-territorial price that the mills were reimbursed with for all their output before the reforms and for only a large portion of their output by the end of the sample period.

### ***III. Data Overview***

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<sup>13</sup> The policies for both soft and hard wheat flour as well as their products were almost identical until 1987. However, beginning in 1987, the market for hard wheat and flour was largely liberalized.

The firm-level data were collected in an annual survey of all Moroccan manufacturers.<sup>15</sup> In principle, they include all firms that have more than 10 employees or output of more than 100,000 dirham for the period from 1984 to 1995. Table 1 summarizes the evolution of the real flour price, total industry output (both in 1990 prices) and the transition patterns in the industry over the sample period. The real flour price has fluctuated from the low of 308 DH/q to the high of 343 DH/q with values mostly in the 320 range. However, while the price was steady throughout the period, there was a considerable amount of entry and exit throughout the sample period. Over the 11 years, 31 firms entered while 15 exited, increasing the number of active firms from 123 in 1985 to 136 in 1995. The net positive entry along with an increase of the incumbents' outputs resulted in a rise of the industry's output from 5,093 million dirham (506.5 million dollars) in 1986 to 7,627 million in 1995 (861.31 million dollars). The flour producers' share of total manufacturing output ranges from the low of 4.95% in 1990 to the high of 6.70% in 1993. This translates to about 3% of Morocco's GDP.

Table 2 summarizes the micro features of the data. Even though I am looking at an industry at the 5-digit SIC level, there is a considerable amount of heterogeneity among the firms. Starting with the revenue statistics, the median revenue (in 1990 prices) is 50.828 million DH (6.855 million \$). However, the revenue mix of the firms in the industry is quite staggering; while the first quartile firm has a revenue of 12.535 million DH, its third quartile counterpart produces flour worth 77.397 million DH. Similarly, the employment quartiles are 21, 46 and 67 employees, respectively. These summary statistics suggest that it will be crucial to correctly account for the heterogeneity among the firms. At the same time, the firm-specific scale parameter is fairly homogeneous across the firms. Its median value is 1.16, while the lower and

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<sup>14</sup> It buys around 40% of overall production, while 50% is consumed on the farm and 10% is sold at the village level.

upper quartiles are 1.13 and 1.19. Thus, it seems reasonable to set  $\alpha$  to the industry's mean value of 1.182.

## Results

Before estimating the model, I fit an AR(1) process to the flour price data. The regression results are (standard errors in parentheses):

$$p_t = 0.437(0.317) + 0.926(0.058)p_{t-1} \text{ and } \sigma_p = 0.103 \quad (3.1)$$

The Dickey-Fuller statistic of -1.27 implies that the null of a unit root cannot be rejected (the critical value at 10% is -2.63). However, this can be simply a result of the short time series that is available to me. Additionally, the Durbin-Watson statistics is 2.51 and thus the null of no positive autocorrelation cannot be rejected since the critical value at 1% using the Savin-White bounds is 1.211. Adding a trend or a second-order price lag into the regression does not produce a better fit and  $R^2 = 0.91$ . This suggests that the first-order lag does a good job in predicting the price series' evolution.

Table 4 summarizes the parameters estimates of the three models that I estimate. The first two models rule out the age effects. In addition to that, I set  $\omega_{oj} = \omega_0 \forall j$  in the first model. The second one allows the intercepts in the profit function to differ among groups of firms using the Heckman-Singer mass points. The last model includes the age effects in addition to the heterogeneous intercepts. I will now describe the results for each of the three models.

### *I. Single Intercept Model*

Starting with the parameters of the revenue function, they are all estimated with a high degree of precision. This is consistent with the Monte-Carlo results. Specifically, the intercept of

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<sup>15</sup> See Haddad et al (1996) for overview of the data set and data preparation.

the cost function  $\omega_0$  has a value of  $-4.93$ . The trend term  $\omega_1$  has a value of  $0.0079$  that implies (after adjusting for  $\eta = 5.49$ ) annual growth rate of revenues of  $4.34\%$ . This is consistent with the findings in the previous section that suggests that the industry output in DH terms increased by  $53\%$  over the 11-year period. The AR parameter  $\lambda$  of the cost function disturbance is estimated at  $0.9502$ . This clearly shows that there is a large amount of persistence in the data. Lastly, the variance of the cost process  $\sigma_\xi^2$  has a value of  $0.0131$ .

Turning to the “dynamic” parameters, while the entry costs  $\Gamma_E$  and variance of the exit value  $\sigma_{\varepsilon_2}^2$  are significant, the exit value  $\Gamma_X$  and the variance of the entry cost  $\sigma_{\varepsilon_1}^2$  are not. All the parameters are in 1990 prices. The entry costs are estimated to be  $216.35$  million DH ( $29.21$  million \$), while the estimate of the exit values is  $38.14$  million DH ( $5.15$  million \$). Thus, the model implies that the sunk entry costs are  $178.21$  million DH ( $24.06$  million \$). This amounts to about 21 times the average annual firm profits. Lastly, the variances on entry and exit shocks are estimated at  $14.3$  and  $63.58$ , respectively.

Clearly, the band between the entry costs and scrap values as well as the actual investment costs needed to break into the industry seem unreasonably large. One of the reasons for this result might be that I am not correctly accounting for all the heterogeneity that is present in the data. Thus, the estimator explains the persistence by increasing the value of the non-recoverable costs, and thus increasing the option value of staying in the industry. To explore this possibility, I have allowed the intercepts to differ among firms using the Heckman-Singer mass points. I will now discuss the results.

## ***II. Heckman-Singer Mass Points***

Table 3 that shows that there are still considerable size differences among the firms even after taking the log of the revenue. The distribution ranges from 4.06 (1% percentile) to 12.13 (99% percentile) with a median value of 10.84. Therefore, while the upper two quartiles of the distribution are relatively homogeneous, there is substantial heterogeneity in the lower half of the distribution. This suggests that while one mass point might be enough for the firms in the upper half of the distribution, capturing the size heterogeneity in the lower half might require more than one mass point.

This is indeed confirmed by the results of the Heckman-Singer procedure that estimates that there are three types present in the data. All three of the intercepts  $\omega_{0j}$  are significant and their respective values are  $-5.7183$ ,  $-5.0916$  and  $-4.7175$ . In addition to the mass points, Heckman-Singer also estimates their associated distribution. The probabilities of the three types  $\gamma_{0j}$  are also significant and estimated to be 0.1182, 0.3128 and 0.569. Thus, as suggested, the largest mass point captures the upper half of the distribution while the other two capture the second half. Not surprisingly, allowing this correction for heterogeneity results in a decrease in  $\lambda$  from 0.9502 to 0.7308. In other words, by allowing for another source of persistence in profits, I have reduced the role attributed to serial correlation in cost shocks. Similarly, the variance of the cost shock  $\sigma_{\xi}^2$  slightly decreases to 0.0118. Lastly, the trend term parameter  $\omega_1$  increases to 0.011, which suggests an annual growth rate of 6.04%.

Turning to the “dynamic” parameters, one can immediately notice the huge drop in the band between the entry costs and exit value. The significantly estimated entry cost  $\Gamma_E$  decreases to 58.79 million DH (7.93 million \$), while the exit values are again not estimated significantly and are almost zero. This should not be surprising, however, since the flour milling equipment is very industry-specific and thus probably has almost no resale value. However, the band between

the entry costs and exit value implies more reasonable sunk entry costs, now equaling seven times the annual average profits. The variances of entry costs and exit values are both estimated as significant and their respective values are 24.41 and 21.01. Thus this clearly shows how important it is to account for the invariant heterogeneity among the firms in order to be able to model the firm's dynamic participation decision correctly.

Adding the Heckman-Singer mass points into the estimation routine also involves an initial conditions correction. As discussed earlier, this amounts to estimating the initial participation decision as a function of the firm's invariant characteristics. The entrepreneur's characteristics I choose are the geographical location and his business type. As the results in Table 4 show, this correction proves to be very important. In particular, the three geographical dummies (Northern, Central and Southern regions) and the two business types are all estimated with a high degree of precision.

### ***III. Heckman-Singer Mass Points/Age Effects***

Both of the previous models rule out learning and depreciation effects. As can be seen in Table 5, which contains the resulting probabilities of entry in each year, the transition dynamics for these two models are not very realistic. The increase in the probability of entry in the first model from 0.12 in 1985 to 0.67 in 1995 is driven purely by the time trend in the profit function. In the model with heterogeneous intercepts, each type has its own value function and thus its own probability of entry. The probabilities of entry for the two types in the lower half of the size distribution range from 0.065 to 0.07 and 0.26 to 0.41, respectively. However, the probability of entry for the firms with the largest mass point is essentially one. Thus the unconditional probability of entry defined in (2.9) ranges from 0.64 to 0.71. Clearly, having 70% of all the potential entrants entering on average each period is not very reasonable. Thus I add the age

effects, which essentially recognize that firms get bigger and more profitable as they get older (up to a certain point) as is found in many empirical studies. The lower profits in the initial periods imply lower value of the firm and thus lower probability of entry.

The coefficient on the log of age,  $\omega_2$ , that captures the growth over time due to learning effects is significant and has a value of 0.188. The parameter estimate of  $\omega_3$  that recognizes that the learning effects die out at some point and are outweighed by depreciation is significant as well with a value of -0.023. Comparing the rest of the parameters to the Heckman-Singer model without the age effects, the coefficient on trend decreased by 50% but is still positive, significant, and implies growth of 3.02%. Thus, there are still some technical advances at the industry level. Not surprisingly, the mass points have all decreased to -5.8792, -5.3528 and -5.0384 with the biggest decrease for the largest mass point. They are all significant. Their associated probabilities (0.1465, 0.2187 and 0.6347) are significant as well. Both the (significant) slope and the variance of the cost process have decreased to 0.7036 and 0.0114. Interestingly, the entry costs and scrap values as well as their variances are very close to the results of the previous model. The entry costs are 64.83 million DH, while the scrap value is zero again. Their respective variances are 27.43 and 23.71. As before, they are all significant with the exception of the mean scrap value.

Thus, while adding the age effects has a significant impact on the profit function parameters, it does not change the “dynamic” parameters significantly. As mentioned above, including the age effects lowers the firm’s profits in the initial periods. Since the entry costs and scrap values and their variances do not change by very much, the entrants’ value function decreases, resulting in more sensible entry probabilities. The probability of entry for the smallest type remains at almost the same level as in the previous model. However, the range of the medium type’s entry probability decreases to 0.13 to 0.16, while the range of the largest type’s

probability decreases to 0.36 to 0.43. This implies an unconditional probability that varies from the low of 0.27 to the high of 0.36. In other words, one firm out three potential entrants enters on average each period, which seems very reasonable.

## **Model Validation**

The structural framework of my model allows me to evaluate its performance by simulating observations on the firms' output and market participation choices. To do that, I base the firm's states on the actual data in 1985 and simulate the values for  $x_{it}$  and  $p_t$  from 1986 to 1995 over 200 trajectories to predict the firms' optimal output and market participation choices in those years. To compare the actual industry statistics with the simulated ones, Figure 2 presents the 25%, 50% and 75% of the distribution of total industry output across all 200 simulations. Additionally, Table 6 presents simulated firm turnover (number of entrants and exiting plants).

As can be seen in Figure 2, the median total industry output is fairly close to the actual industry output. While the median industry output is higher than its actual counterparts in some years, the first quartile of total output always encloses the actual industry output. There are two reasons for this. First, since firm profits are unobservable to me and I use firm revenue to infer profits, this suggests that I overestimate firm profits and output. Second, looking at the relationship between the distribution of the simulated real output price and the actual values in Figure 2, the median real output price process is slightly higher than its real counterpart. Since the firms are very price-responsive (as will be seen from the policy experiments), they tend to produce more in the simulations than actually observed because the simulated prices are somewhat higher than in reality. However, given that I have only 25 years of annual data, my approximation of the evolution of the price process seems pretty reasonable. Thus, overall, it

appears that my model does an acceptable job of modeling the firms' static output supply decision.

Turning to the participation decision patterns summarized in Table 6, the median simulated number of entrants corresponds to the actual number in all the years. With the exception of the first three years, the model also predicts the number of exiting plants very accurately. While only one firm exited in the data in the first three years, my model predicts the 25% and 50% number of exiting plants at 6.5 and 10 plants, respectively. Nonetheless, on the whole, the model also seems to capture firm turnover fairly well.

I will now use the results of this simulated model, which I refer to as the "base case scenario," to address the impact of several policy experiments on the flour industry.

## **Policy Experiments**

There are two key channels through which industrial policies can affect the industry: the stochastic price process and the magnitude of the non-recoverable initial investment. Note that this sunk initial investment depends on both entry costs and scrap values. I will examine three different scenarios. First, I will simulate a 10% decrease in the steady state expected value of the price process. Second, I will look at the effects of stabilizing the price at the steady state expected value for all the years. Since expectations play a key role in the firms' participation decision, I will examine what role the credibility of the regime switch has on the firm behavior. That is, if the firms deem the policy change to be credible, they will use the new price process to calculate their expected future payoff. However, if the regime switch is not viewed as credible by the firms, as is often the case in developing countries, the firms will still continue to use the original process for the expected future value calculations even though the price follows the new price process in reality. Third, I will study the implications of a 30% and 60% reduction in the

entry costs as a means of encouraging the industry's growth over time. Such entry cost reductions correspond to lowering the sunk entry costs from seven times the average annual firm profit to about five and three times the average annual firm profit.

To quantify the effects of each scenario, I assume that the policy shift occurs in the second period. Thus, as in the previous section, while the firms' states are based on the actual data in the first period, I simulate the values for  $x_{it}$  and  $p_t$  for the rest of the periods until 1995. I then compare the results with the "base case." For the price shifts, I report a figure with the *median* percentage change in the total industry output and total industry capital (approximated by the sum of the value function over all firms). Note that since the entering firms internalize the shock after the second period, I only look at the firms that were in operation in the first period to model capital gains and losses. Thus, for my experiments that alter entry costs, I do not present capital gains and losses since the entry costs are sunk for the firms that are already in business in 1985, and I do not allow re-entry. Additionally, I describe the changes in firm turnover in a table that contains the *median* number of entrants and exiting plants. For the price process changes, I present results for both credible and non-credible regime switches. For the entry cost subsidies, I compare the effects of 30% reduction with a 60% reduction.

The first scenario examines a permanent reduction in the steady state expected value of the price process by 10% while keeping the variance unchanged. This is very relevant for developing countries that are slowly moving from heavily regulated and protected economies to free market environment. For example, in Indonesia, the sugar industry suffered huge losses after the Indonesian government dramatically decreased its protection within a matter of few years. Thus, one can loosely think of the reduction in the steady state expected value of the price process as a price drop caused by the opening of the industry to foreign competition. Figure 3

and Table 7 report the results for both credible and non-credible shifts. When this shift is credible, the total industry revenue decreases by 23% in the first year, while by the tenth year it is reduced by 69%. While a large portion of this reduction comes from the volume adjustments of the incumbents, there is also net exit in the industry. The total number of exiting plants over the ten year period increases by 70% since future expected payoffs in the industry no longer look as favorable. Thus, the industry experiences large capital losses that amount to 80% of firm's values per period. Additionally, the reduction in future expected profits also decreases the total number of entrants by 69%.

The picture is very different under the non-credible shift since the firms still use the original price process parameters to evaluate their expected future payoffs. Thus only the total industry revenue drops significantly by the end of the sample period. Notice that the per-year reduction in revenues is very similar to the credible scenario. However, the total revenues under the non-credible regime shift are marginally higher because the firms' expectations that determine their market participation choices are not greatly affected. To see this, note that the number of entrants under the non-credible scenario does not change since the expected future opportunities do not change. Additionally, the number of exiting plants is lower by 25% compared to the credible scenario because the decrease in the incumbents' total firm values is mostly due to the decrease in *current* profits and thus the firm's are less likely to exit. Notice, however, that since both entrants and exiting plants are smaller than the incumbents, it only has a small effect on total industry revenue. Furthermore, this also shows the important role that expected future value plays in determining the current value of the firm. In particular, while under the credible shift the per-period capital losses amount to about 80%, it is only 10% under

the non-credible scenario. This occurs because, while current firm profits decrease, the expected future firm value that makes up majority of the firm value is unchanged.

The second experiment stabilizes the price to the steady state expected value of 367.02 DH/q. This has two effects on the industry. First, as can be seen in Figure 2, the simulated median price process for the base case scenario starts out at around 320 DH/q and converges towards the steady state value throughout the sample period. Thus, the total industry output that the firms produce is higher than in the base case scenario but this difference slowly falls over time as the prices under the base case scenario rise, whether the regime switch is credible or not since credibility affects only the firm's expectations.

While stabilizing the output price has a positive effect on the total industry output, its effect on the firms' value is no longer favorable, when this shift is credible. To understand this, note that stabilizing of the output price decreases the firms' expected future value of producing in the industry. This can clearly be seen in Table 8, where the amount of entry decreases by 26% over ten years, when the regime shift is credible. Therefore, even though the current profits increase, the firms actually experience capital losses of around 28% per period under the credible scenario since the expected future value determines the majority of the firm's total value.

It is interesting to note that, under the non-credible regime, firm turnover actually decreases. To see this, recall that the unchanged firm expectations imply that the expected future value is unchanged and thus there is the same amount of entry. However, at the same time, the current profits for active firms increase and thus the total firm value is actually higher than under the base case scenario. This can also be seen by the 13.5% average increase in capital gains each period. Thus, the firms are less likely to exit.

The third experiment alters the sunk entry costs. The reduction in entry costs has two effects on the firms. First, it increases the probability of entry and thus the expected amount of entry into the industry. However, at the same time, it increases the likelihood of exit because a reduction in entry cost decreases the option value of remaining in operation in order to produce in the next period. Thus, the firm is more likely to collect the scrap value and exit. I simulate the evolution of the industry under 30% and 60% decrease in the entry costs. This decreases the sunk entry costs from seven times the annual average firm profit to five and three times, respectively, and the results are presented in Figure 5 and Table 9. Since the entry costs directly affect only the entrants' participation choice and the entrants tend to be smaller than the incumbents due to age effects, the median increase in total industry revenue over the ten year period is only 1.63% and 1.41% for the 30% and 60% reduction, respectively. That is, heterogeneity implies that subsidies to production have a larger effect on revenue than subsidies to entry.

Interestingly, in both cases, the total number of firms decreases slightly indicating that there is net exit. This is a result of the increased firm turnover that, on one hand, increases the number of new plants that set up their production facilities, but, on the other hand, increases the number of failed entrants since the option value of staying in the industry is reduced for these firms. The decline in option value becomes larger as the reduction in the entry costs increases. This is seen by the fact that the total number of exiting plants increases by 22% when the entry costs are reduced from 30% to 60%.

## **Conclusions and Caveats**

Using the theoretical models of industrial evolution literature as a guide, I have developed and estimated a structural model of entry, exit, and output supply for firms in a homogeneous goods industry, where the output price evolves exogenously. As in the industrial

evolution literature, my model relies on two key assumptions. First, while the active firms know the current market price and their idiosyncratic productivity shock, they do not know their future values with certainty. Additionally, entering the industry requires an entry cost that is only partially recoverable upon exit.

Using simulated maximum likelihood, I fit the model to firm-level panel data for the Moroccan flour industry from 1984 to 1995. The results show that firm heterogeneity, age effects and sunk entry costs are all important determinants of firm behavior. After correctly accounting for the large amount of firm heterogeneity present in the panel data set as well as age effects, I estimate sunk entry costs that amount to approximately seven times the industry's average annual profits. The model also produces reasonable transition dynamics in terms of the entry and exit patterns.

The policy experiments show that even fairly small changes in the steady state expected value of the price process play a large role in the evolution of the industry, both in terms of volume adjustments and firm turnover. Furthermore, the effect of this type of policy shock depends crucially on its credibility. Stabilizing the price to the steady state expected value has two effects on the industry. It increases the amount of output that the firms produce but, at the same time, decreases the expected future value of the firm. Thus, the credibility of this regime switch determines the resulting effect on firm turnover. Reductions in entry costs increase industry turnover by making it less costly to enter and reducing the option values of remaining in the industry for relatively unproductive firms.

The model I have developed can be used to analyze any homogeneous good industry with an exogenously determined price. Clearly, such a model can be applied to only a special class of industries. Nonetheless, its insights can be used for future work aimed at uncovering the entry

costs and exit values that are much needed for analyzing firm supply behavior. In particular, many governments use price floor/ceiling mechanisms to regulate their agricultural markets. Example of such an industry are the rice mills in Indonesia. If the band between the price floor and ceiling is very tight, it can be argued that this does not change the validity of the model developed in this paper. On the other hand, a wide band implies that, even in a competitive setting, the uncertain aggregate output price depends on the total amount of output produced that, in turn, depends on productivity levels of all the firms in the industry including potential entrants. However, solving such problems requires a multi-agent framework much like in the Hopenhayn (1992) model. Therefore, my next step is to develop an estimation algorithm that would allow for the calculation of the firm's entry costs and scrap values in this more complicated setting.

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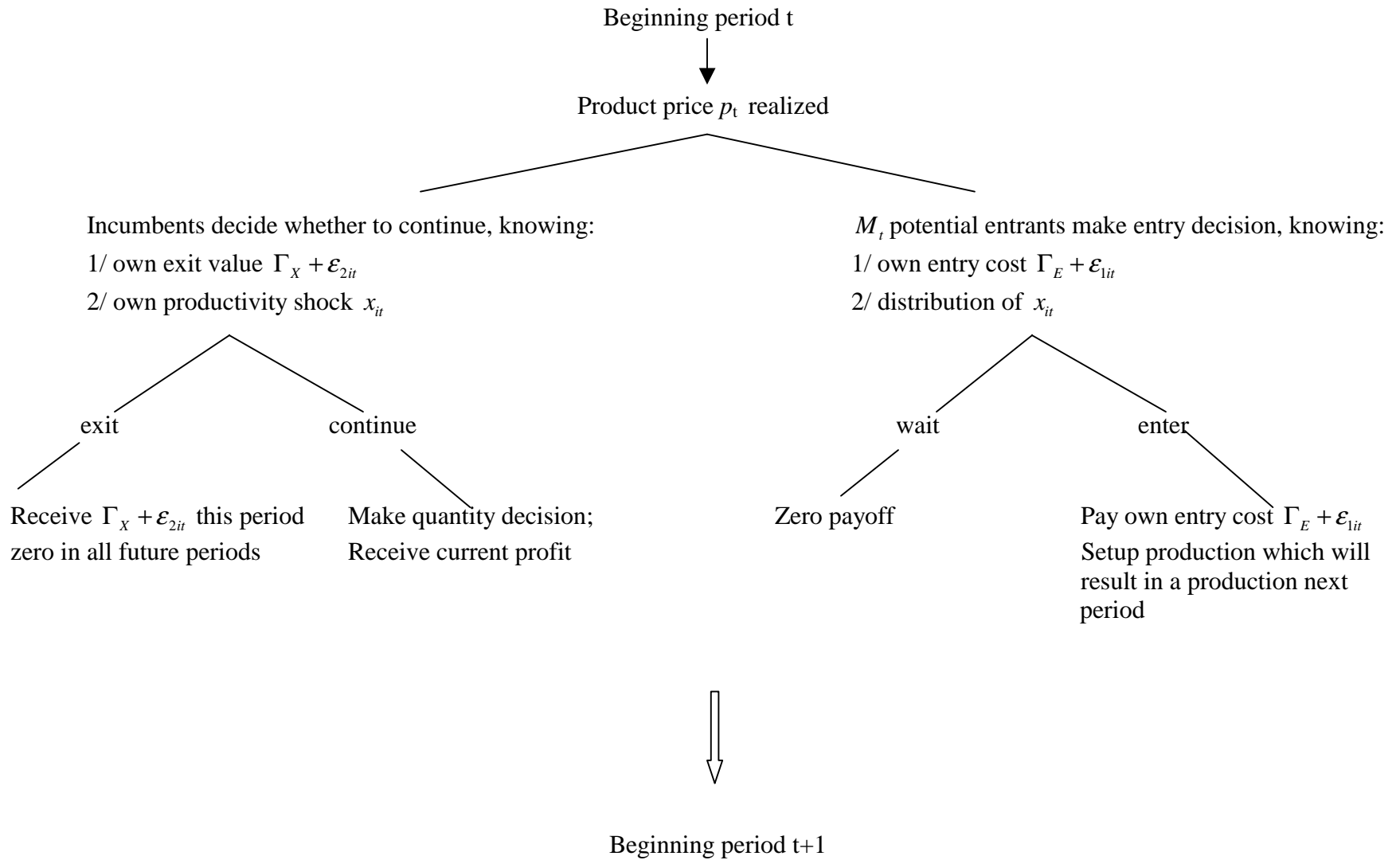
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**Figure 1: Timing of the Firms' Decision Process**



**Table 1: Real Flour Price\* (1990 DH/Q), Transition Patterns, Industry Output (1990 prices) and Flour Producers' Share of Total Manufacturing Output**

	Real Flour Price (1990 DH/Q)	Transition Patterns			Industry Output (1990 prices)		% of Total Manufacturing Output
		Stayers	Entrants	Quitters	Million DH	Million \$	
1985	320.86	121	2	0	4,975	405,13	5.59
1986	342.86	123	5	0	5,093	506.50	5.57
1987	334.32	128	3	0	5,892	694.52	6.42
1988	308.13	130	2	1	5,487	670.65	5.45
1989	332.21	130	5	2	4,977	568.80	5.29
1990	313.43	133	4	2	5,125	621.97	4.95
1991	326.43	135	3	2	5,743	624.96	5.37
1992	320.95	135	4	3	6,387	722.07	5.73
1993	326.17	137	1	2	7,889	751.34	6.70
1994	320.91	135	1	3	7,563	736.28	6.11
1995	322.70	135	1	1	7,627	861.31	6.08

\* Kydd and Thoyer (1992) and Najib Akesbi's lecture contain official nominal wheat prices from 1970 to 1995. Tyner and Channing (1996) provide the official flour price in 1995. Dividing the 1995 flour price by the wheat price yields a ratio of 1.39 that is very close to the official rate of 1.38 used by the European Union to determine flour prices from wheat prices (FAO/EBRD Agribusiness Handbooks, 1999). Thus, I use the multiple of 1.39 to construct the nominal flour prices for 1970-1994 since the data on the flour prices for these years is currently not available to me. The nominal prices are then deflated by the Morocco's manufacturer's wholesale price index obtained from the International Financial Statistics Database.

<b>Table 2: Summary Statistics (Quartiles)</b>			
	25%	50%	75%
Revenue (1990 1,000 DH)	12,535	50,828	77,397
Employment	21	46	67
Scale Parameter	1.13	1.16	1.19

<b>Table 3: Distribution of <math>\ln r_{it}</math> (in Percentiles)</b>	
1%	4.06
5%	6.08
10%	7.48
25%	9.44
50%	10.84
75%	11.26
90%	11.60
95%	11.86
99%	12.23

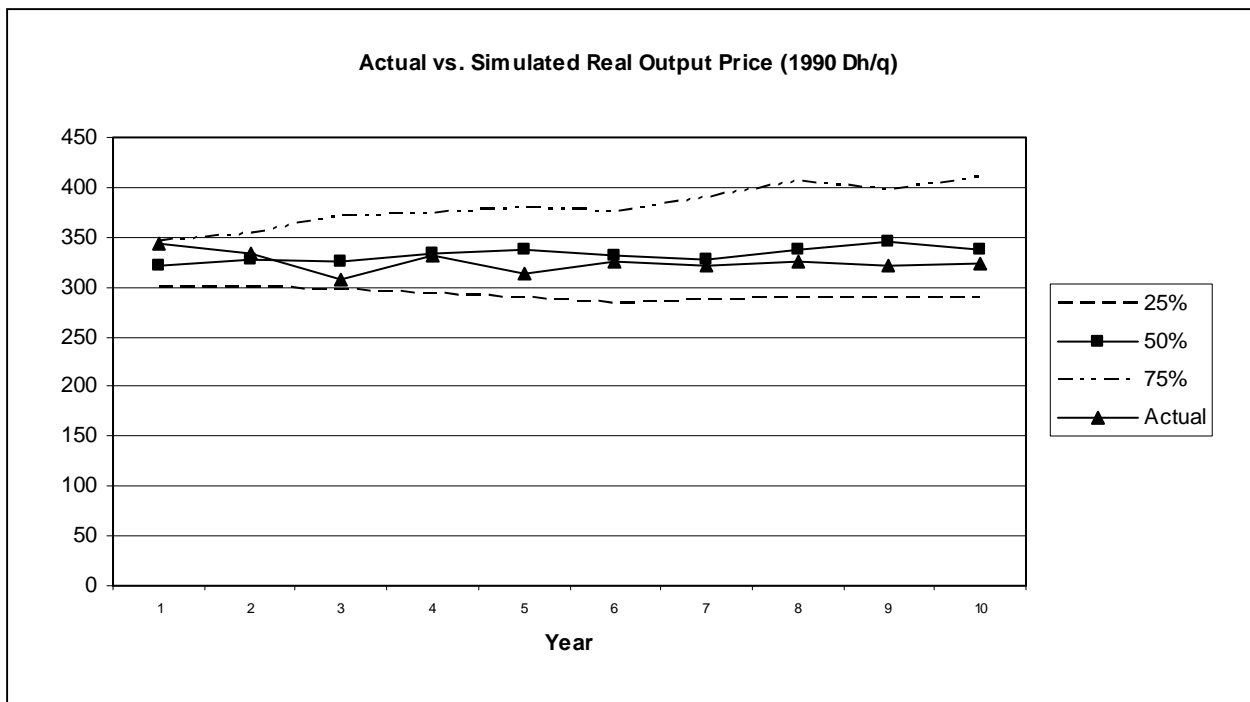
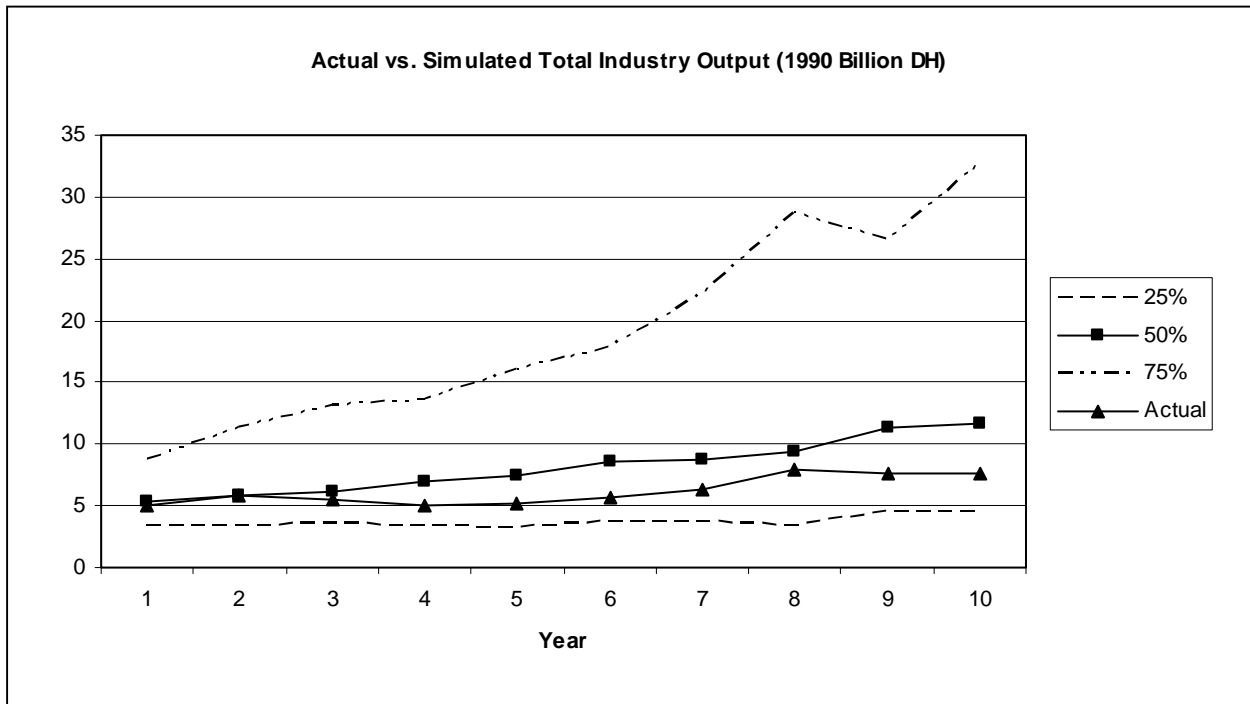
**Table 4: Parameter Results (standard errors in parentheses)**

Parameters	Single Intercept	Heckman-Singer	Heckman-Singer/Age
$\omega_{01}$	-4.9386* (0.0358)	-5.7183* (0.0384)	-5.8792* (0.0444)
$\omega_{02}$		-5.0916* (0.0266)	-5.3528* (0.0514)
$\omega_{03}$		-4.7175* (0.0182)	-5.0384* (0.0468)
$\gamma_{01}$		0.1182* (0.0272)	0.1465* (0.0305)
$\gamma_{02}$		0.3128	0.2187
$\gamma_{03}$		0.5690* (0.0431)	0.6347* (0.0483)
$\omega_1$	0.0079* (0.0035)	0.0110* (0.0021)	0.0055* (0.0021)
$\omega_2$			0.1880* (0.0346)
$\omega_3$			-0.0230* (0.0071)
$\lambda$	0.9502* (0.0198)	0.7308* (0.0406)	0.7036* (0.0415)
$\sigma_{\xi}^2$	0.0131* (0.0024)	0.0118* (0.0022)	0.0114* (0.0021)
$\Gamma_E$	216.3541* (32.4755)	58.7921* (13.9039)	64.8291* (19.4437)
$\Gamma_X$	38.1427 (34.4520)	0.000057 (0.0278)	0.000002 (0.0018)
$\sigma_{\varepsilon_1}^2$	14.3004 (8.1509)	24.4115* (6.4924)	27.4297* (9.2116)
$\sigma_{\varepsilon_2}^2$	63.5844* (18.4044)	21.0126* (4.6186)	23.7115* (5.5590)
Northern Region		4.3846* (0.2254)	4.4867* (0.2282)
Central Region		3.1923* (0.3490)	2.9528* (0.3637)
Southern Region		2.6270* (0.5405)	2.8830* (0.5382)
Legal Form 1		2.4092* (0.3135)	2.6047* (0.3123)
Legal Form 2		3.7759* (0.3013)	4.0871* (0.3028)

**Table 5: Probability of Entry**

	Single Int.	Heckman-Singer				Heckman-Singer/Age			
	Unconditional	Type1	Type2	Type 3	Uncond.	Type 1	Type 2	Type 3	Uncond.
1985	0.12	0.065	0.26	0.97	0.64	0.068	0.13	0.36	0.27
1986	0.15	0.066	0.27	0.98	0.65	0.068	0.14	0.36	0.27
1987	0.19	0.066	0.28	0.99	0.66	0.069	0.14	0.37	0.28
1988	0.24	0.066	0.29	0.99	0.66	0.069	0.14	0.38	0.28
1989	0.29	0.067	0.31	1.00	0.67	0.069	0.14	0.38	0.29
1990	0.35	0.067	0.32	1.00	0.68	0.069	0.14	0.39	0.29
1991	0.41	0.068	0.34	1.00	0.68	0.069	0.15	0.40	0.29
1992	0.47	0.068	0.36	1.00	0.69	0.069	0.15	0.41	0.30
1993	0.54	0.069	0.37	1.00	0.69	0.069	0.15	0.41	0.31
1994	0.60	0.069	0.39	1.00	0.70	0.069	0.15	0.42	0.31
1995	0.67	0.070	0.41	1.00	0.71	0.069	0.16	0.43	0.32

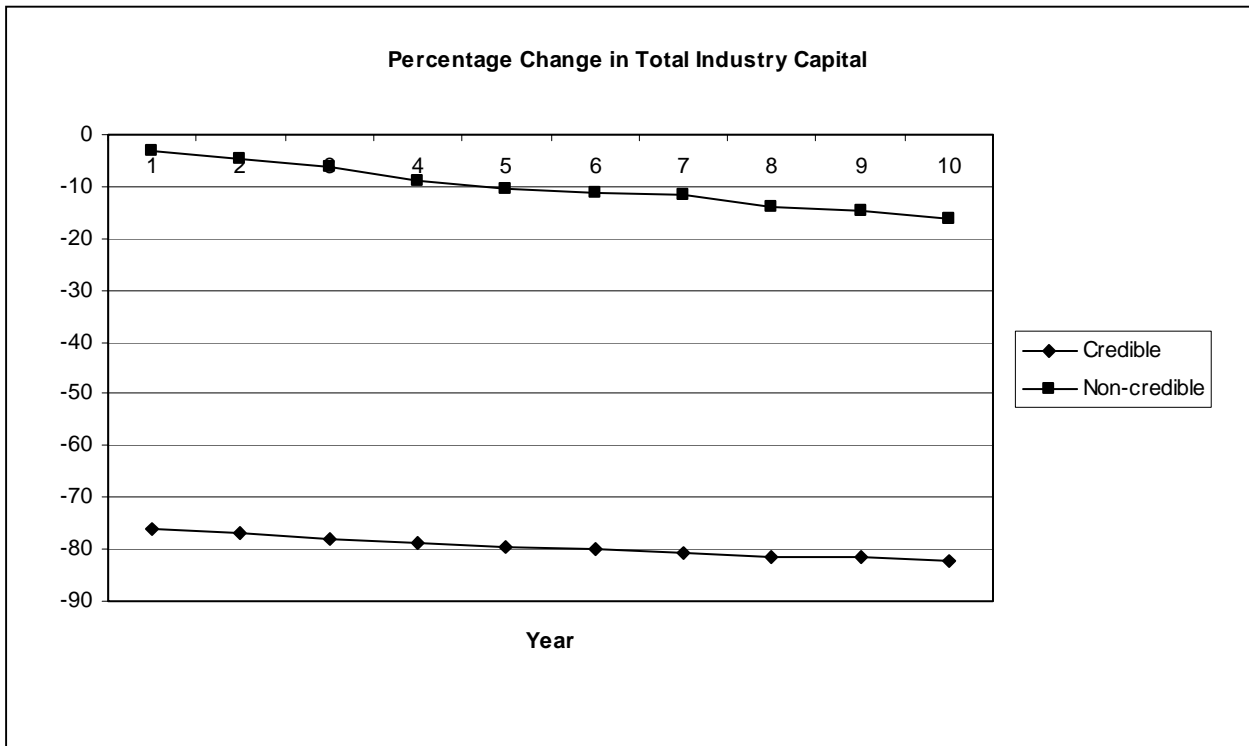
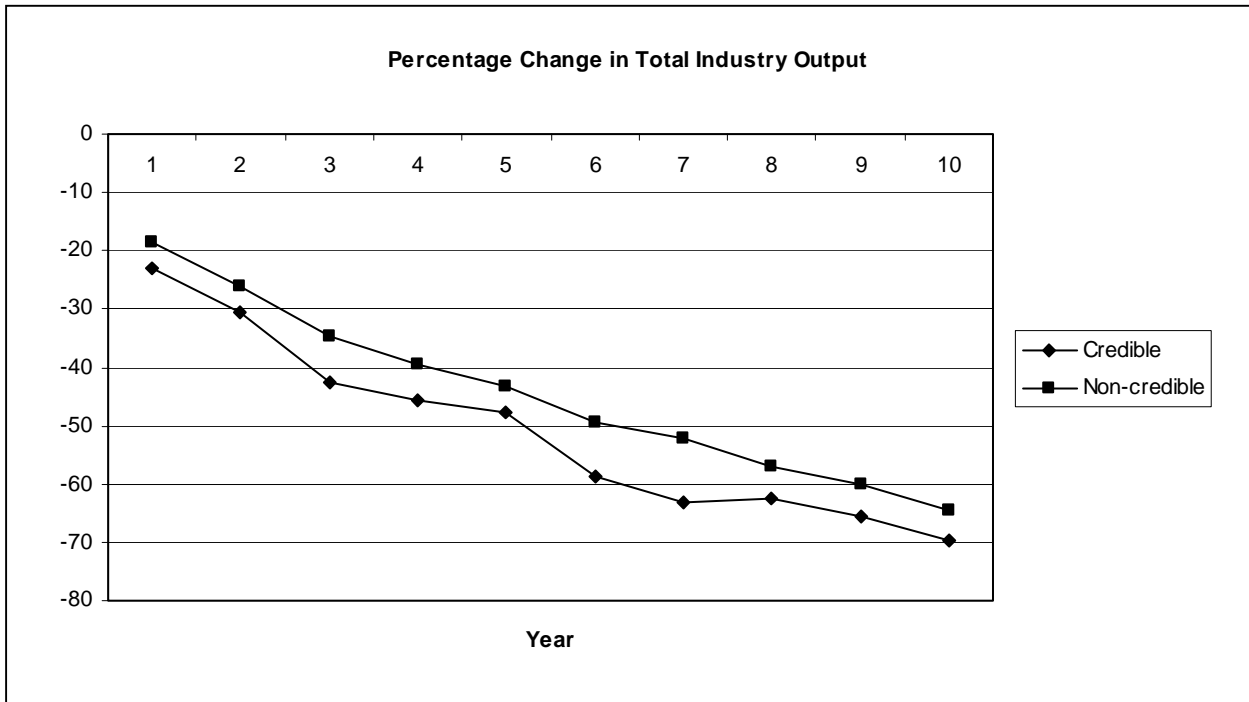
**Figure 2: Model Validation (Actual vs. Simulated Aggregate Industry Statistics)**



**Table 6: Actual vs. Simulated Entry and Exit Patterns**

	Number of Entrants				Number of Exiting Plants			
	Actual	Simulated			Actual	Simulated		
		25%	50%	75%		25%	50%	75%
1986	5	3	5	6	0	2.5	4	5
1987	3	2	3	4	0	2	3	5
1988	2	1	2	3	1	2	3	5
1989	5	3	5	6	2	2	3	4
1990	4	3	4	5	2	1	2	3
1991	3	2	3	4	2	1	2	3
1992	4	3	4	5	3	1	2	3
1993	1	0	1	1	2	1	2	3
1994	1	0	1	1	3	1	2	3
1995	1	0	1	1	1	0	1	3

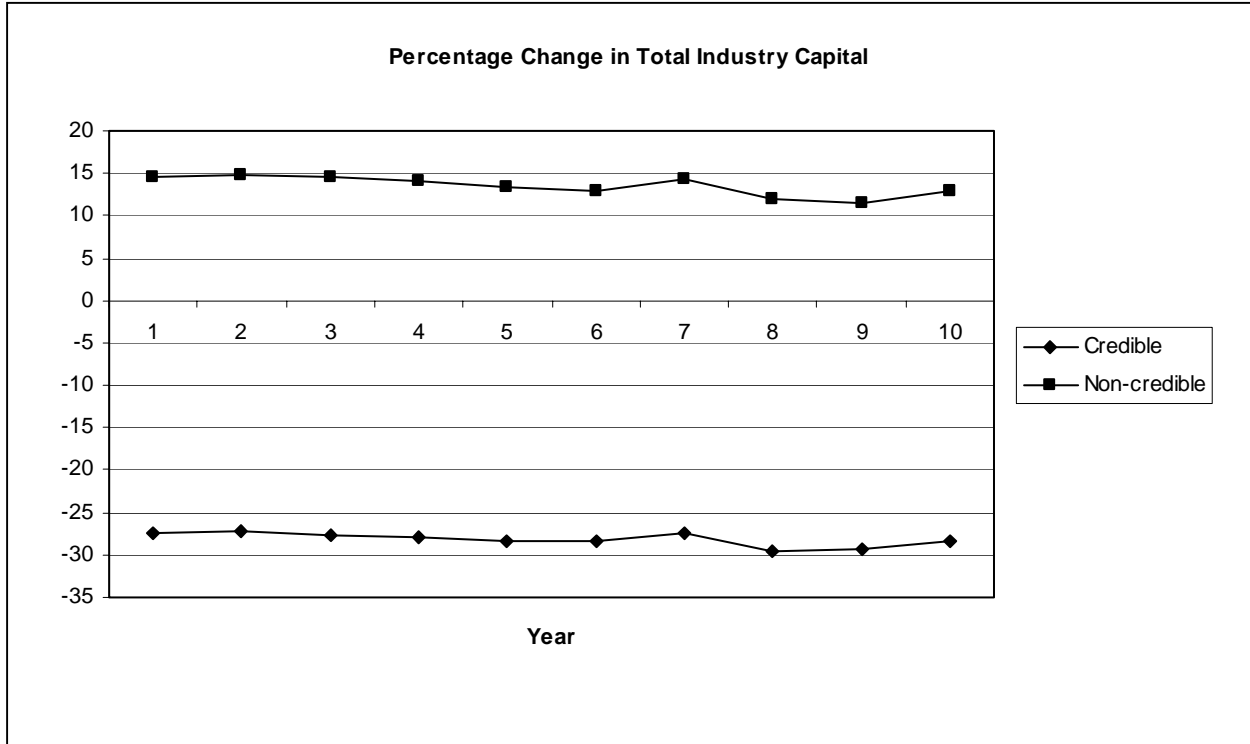
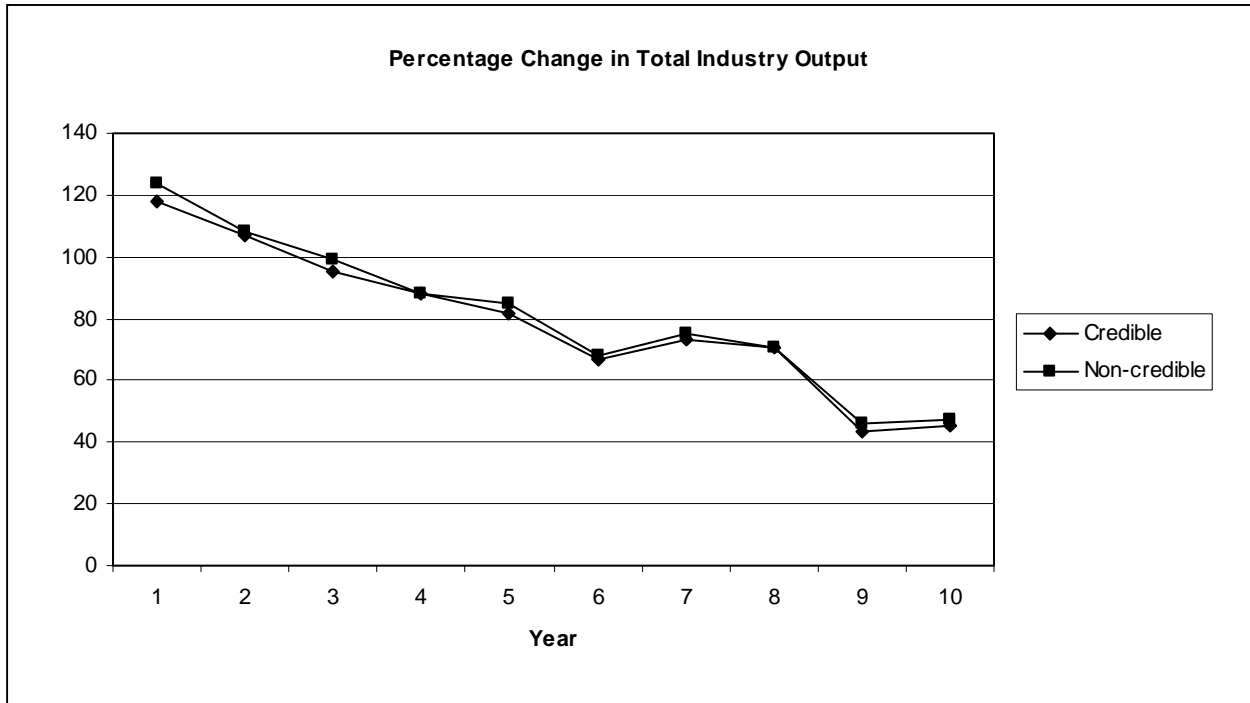
**Figure 3: Industry-level Statistics under a 10% Decrease in the Steady State Expected Value of the Price Process**



**Table 7: Entry and Exit Patterns under a 10% Decrease in the Steady State Expected Value of the Price Process**

	Number of Entrants			Number of Exiting Plants		
	Base Case	Policy Experiment		Base Case	Policy Experiment	
		Credible	Non-Credible		Credible	Non-Credible
1986	5	2	5	4	6	4
1987	3	1	3	3	5	4
1988	2	1	2	3	5	4
1989	5	2	5	3	4	3
1990	4	1	4	2	4	3
1991	3	1	3	2	4	3
1992	4	1	4	2	3	2
1993	1	0	1	2	3	2
1994	1	0	1	1	3	2
1995	1	0	1	1	2	2
<b>Total</b>	<b>29</b>	<b>9</b>	<b>29</b>	<b>23</b>	<b>39</b>	<b>29</b>

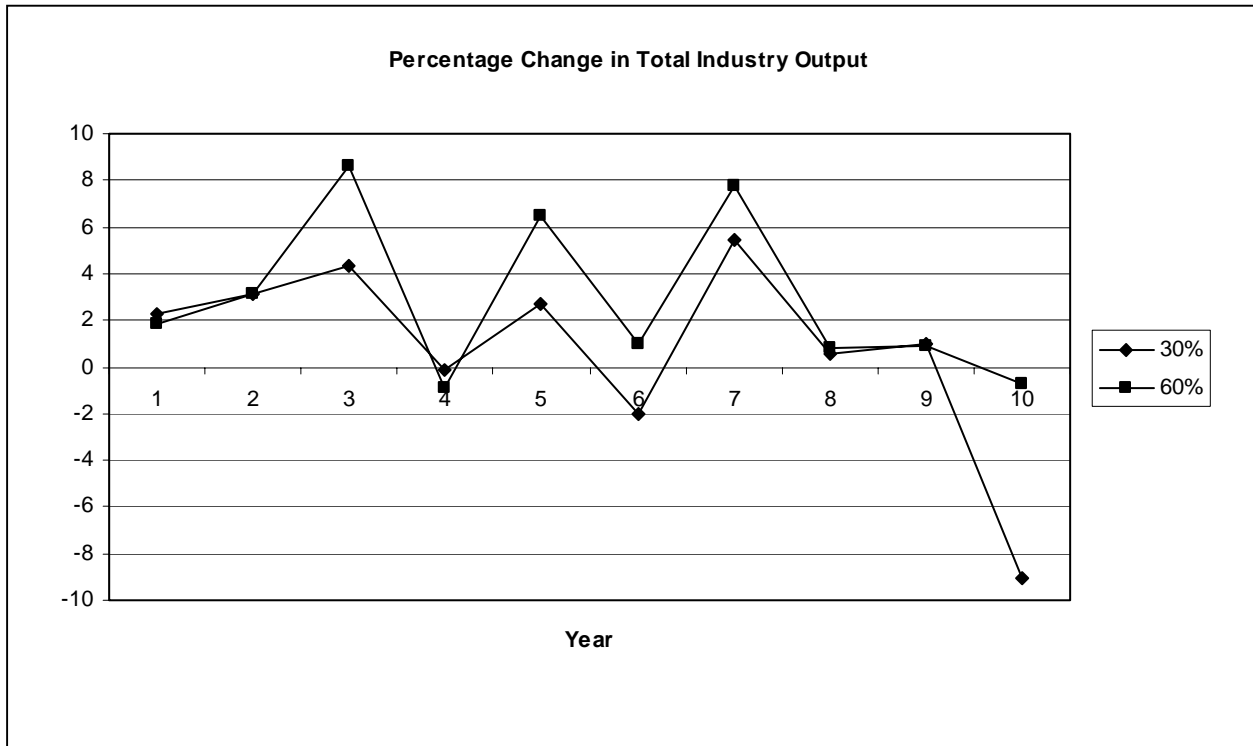
**Figure 4: Industry-level Statistics under Stable (Uncertain) Price**



**Table 8: Entry and Exit Patterns under Stable (Uncertain) Output Price**

	Number of Entrants			Number of Exiting Plants		
	Base Case	Policy Experiment		Base Case	Policy Experiment	
		Credible	Non-Credible		Credible	Non-Credible
1986	5	4	5	4	3	3
1987	3	2	3	3	3	3
1988	2	1	2	3	3	2
1989	5	3.5	5	3	2	2
1990	4	3	4	2	2	2
1991	3	2	3	2	2	2
1992	4	3	4	2	1	1
1993	1	1	1	2	2	1
1994	1	1	1	1	2	1
1995	1	1	1	1	1	1
<b>Total</b>	<b>29</b>	<b>21.5</b>	<b>29</b>	<b>23</b>	<b>21</b>	<b>18</b>

**Figure 5: Industry-level Statistics under 30% and 60% Reduction in the Entry Costs**



**Table 9 : Entry and Exit Patterns under 30% and 60% Reduction in the Entry Costs**

	Number of Entrants			Number of Exiting Plants		
	Base Case	Policy Experiment		Base Case	Policy Experiment	
		30%	60%		30%	60%
1986	5	6	7	4	5	5
1987	3	3.5	4	3	4	5
1988	2	2	3	3	3.5	4
1989	5	5	7	3	3	4
1990	4	4	6	2	3	3
1991	3	4	4	2	3	3
1992	4	5	5.5	2	2	3
1993	1	1	1	2	2	3
1994	1	1	1	1	2	3
1995	1	1	1	1	2	3
<b>Total</b>	<b>29</b>	<b>32.5</b>	<b>39.5</b>	<b>23</b>	<b>29.5</b>	<b>36</b>