Quality, Productivity, and Trade: Evidence from U.S. Microdata*

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Abstract

This paper develops an instrumental variable approach to study the role of product quality in explaining cost, price, export and exit patterns across manufacturing plants. It starts by reviewing an open economy model in which heterogeneous firms can endogenously choose the quality of their products. The model assumes that production costs are increasing in quality but decreasing in productivity. U.S. Census microdata on bread manufacturing plants is shown to be consistent with these assumptions. Further, confirming the model's prediction, the data shows that plants producing high quality goods are larger, more likely to be exporters, and less likely to exit the industry. Overall, the analysis suggests that quality, in addition to productivity, is an important dimension of market competition.

Keywords: Quality, productivity, trade, firm heterogeneity, microdata.

JEL Classification Codes: F12, L11, D2

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1. INTRODUCTION

The growing firm heterogeneity literature revolves around the assumption that an increase in productivity will reduce the unit cost of production but have no effect on the product mix or the characteristics of the firm's output.[1] However, despite being generally ignored in this literature, in differentiated industries the ability to produce goods of high quality confers an important competitive advantage to the firm. Therefore dispersion in product quality across firms, in addition to productivity differences, is likely to be an important determinant of within industry cost and price patterns, and could explain the well documented variation in firm size, export status, and probability of survival.[2] The main objective of the current analysis is precisely to explore the empirical importance of allowing firms to simultaneously compete along two dimensions: price and quality.[3]

In essence the theoretical framework which lies beneath the empirical analysis assumes that firms can decide on the position of their demand curve in the quantity-price space. Basically, by choosing to invest in an expensive technology and face higher unit cost, firms can produce higher quality goods and, as a result, obtain a positive demand shock. The framework leads to a rich set of firm behavior and generates new testable predictions relating product quality, unit cost, output price, and firm productivity. In particular the model predicts that, in equilibrium, relatively productive firms will produce high quality goods that they sell at relatively high prices.

Strong empirical support for the model is obtained using detailed US Census microdata on bread manufacturing plants for the period 1972 to 1997. The analysis yields four main results: (i) All else equal, increasing product quality is costly and higher quality goods sell at higher prices; (ii) Once quality is taken into account, an increase in productivity decreases the unit cost of production and leads to lower prices; (iii) In addition to being larger and more productive, exporting firms produce higher quality goods on average; (iv) Finally, an increase in product quality, controlling for productivity, reduces the probability of exit. Overall these results imply that quality has significant explanatory power, in addition to productivity, in explaining many aspects of the firm's behavior such as production, pricing, export, and exit decisions.

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[1] The leading theoretical models are Melitz (2003) and Bernard, Eaton, Jensen and Kortum (2003). Note that Melitz is careful to point out that the productivity parameter in his model can be interpreted has the ability to produce higher quality products at a given price. Nonetheless the crucial point remains: firms compete on a single dimension: quality or price. The current analysis treats both aspects simultaneously.

[2] In the current context, quality is interpreted as a composite of variables, other than price, that are controlled by the firm and that have a direct influence on consumers' demand for the product. These variables could be intangible product characteristics such as the consumer's perception of the good (e.g. brand recognition), better after sale service, warranties, reliability, or availability, or tangible attributes such as better design or materials which augment the actual performance and durability of the product thereby increasing the service flow obtained from the product.

[3] For a theoretical analysis of the importance of quality see Gervais (2008).

These results also bring to the fore an important weakness of widely used productivity estimation procedure. Typically, in the absence of price information, firm level output revenues and input expenditures are deflated by sector-level price indices, and productivity estimates are defined as the residual in a regression of log deflated output revenues on log deflated input expenditures. If, as shown by the current analysis, product quality varies across firms such a procedure will lead to systematic biases in the productivity estimates. While it does not offer a general solution to that important problem, the current paper nevertheless provides further evidence that ignoring vertical differentiation is likely to lead to misleading inferences.[4]

This is not the only paper that looks at the role of quality in a heterogeneous firm context. Recently, a number of rigorous empirical investigations have sought to understand the role of product quality in shaping export behavior. For instance, using data on shipments by 126 exporting countries to 59 importing countries in 5,000 product categories, Hummels and Klenow (2005) decompose export values in an intensive (larger quantities of each good), extensive (a wider set of goods), and quality (unit value) margin. They find that the extensive margin accounts for around 60 percent of the greater exports of larger economies and that, within categories, richer countries export higher quantities at modestly higher prices. Further, using industry level trade data compiled by Robert Feenstra and Robert Lipsey, Johnson (2008) studies the quantitative importance of cross-country productivity threshold variation in explaining both prices and trade patterns. He shows that, in practice, productivity thresholds play a relatively small quantitative role in understanding price variation, both within and across exporters. Rather, it is the variation in exporter-specific factors (captured by fixed effects) that explains most of the overall variation in prices.

These studies reveal important insights into the overall importance of product quality. However, because they use aggregate industry level information, they do not shed much light on the impact of vertical product differentiation (quality) on firm behavior. Conversely, two contemporaneous empirical studies using microdata provides such insights. First, Hallak and Sividassan (2008) incorporate endogenous quality choices with minimum quality requirements for exporting into a Melitz style model of trade. Using four different firm-level data sets (Chile, Colombia, India, and United States) the authors find that exporters in these countries sell at a higher unit price than non-exporting firms. They interpret this result as evidence that exporters produce relatively higher quality goods. Second, Kugler and Verhoogen (2008) use data on the

[4] A number of techniques have recently been developed. Melitz (2000), and Bernard, Eaton, Jensen, and Kortum (2003) separate technical efficiency and mark-ups. De Loecker (2007), and Katayama, Lu, and Tybout (2006) estimate demand systems to help distinguish the contributions of mark-ups, demand shocks (i.e. output quality) and productive efficiency.

average unit values of outputs and inputs of Colombian manufacturing plants to draw inferences about the extent of quality differentiation at the plant level. They extend the Melitz (2003) framework to include heterogeneity of inputs and a complementarity between plant productivity and input quality in producing output quality. They report that on average input and output prices are positively correlated with plant size within industries and that both correlations are more positive in industries with more scope for quality differentiation.

Obviously, the main difficulty in this line of research is that product quality is generally unobservable. The four papers just mentioned use unit value (revenue over quantity), an estimate of price, to make inferences about quality. However, according to Gervais (2008), the pricing decision of the plant is influenced by two unobservable factors: productivity, which tends to decrease price and product quality, which tends to increase it. Since in equilibrium relatively productive plants produce higher quality goods, using the observed average unit value as a proxy for the quality of the output is likely to lead to misclassification of plants across quality segments.[5] These considerations point to the importance of moving away from unit values and taking plant productivity into account when studying the role of product quality in explaining firm behavior. In that spirit, I build on the work of Foster, Haltiwanger, and Syverson (2008) and use plant-level price and quantity information to obtain productivity and demand shocks estimates. The procedure uses the portion of homogenous input prices orthogonal to the plant's market power in the input market as instruments for output price in a two stage least square estimation of a demand equation. The resulting price elasticity of demand is then used to construct plant-level demand shocks from which product quality estimates are inferred. After providing some evidence that they do in fact capture voluntary actions by the plant aimed at increasing the quality of its output, these estimates are used to empirically test the validity of the model's main assumptions and predictions.

The rest of the paper is structured as follow. Section 2 reviews the theory underlying the empirical analysis. The data sets are described in section 3. Section 4 presents the basic characteristics of the manufactured bread industry (SIC2051). Section 5 develops the econometric methodology required to obtain the quality estimates and explores their basic properties. Section 6 presents the results of different tests of the model's assumptions and predictions, and provides an overview of robustness checks. Conclusions are presented in section 7. Theoretical proofs and details on the construction of variables can be found in appendix at the end of the paper.

[5] Consider two plants that charge the same price, if the econometrician does not look at any other indicator he will attribute the same quality to both output. However, this is not necessarily the case. If plant A is more productive than plant B and the price is the same, the theory says that the output of plant A is of higher quality.

2. THEORY

This section presents a brief review of the underlying theory; the reader is referred to Gervais (2008) for a detailed exposition. Consider an economy composed of a measure L of infinitely lived consumers each endowed with one unit of labor per period. Consumers have no taste for leisure and inelastically supply their labor to the market at the prevailing wage rate. Therefore, in each period, the labor supply is equal to L.

2.1 Preferences

The economy is composed of two sectors: a homogeneous perfectly competitive industry and a differentiated monopolistically competitive industry. The upper-tier preference of the consumer takes the following Cobb-Douglas form:

$$U = Y^{\alpha} Q^{1-\alpha} \qquad \text{with} \quad \alpha \in (0,1), \tag{1}$$

where Y represents the consumption of homogeneous goods and Q is an index related to the consumption of varieties of the differentiated product. Since all consumers are identical and there is no asset accumulation, there is no borrowing and lending. Therefore, at each point in time, the representative consumer will maximize its utility, defined in (1), subject to the following period budget constraint: $P_Y Y + PQ \leq E$, where P_Y is the price of a unit of homogenous good, P is the price of the aggregate Q, and E is the aggregate income per period. The consumer's maximization problem implies that a constant fraction of aggregate income will be spent on each sector. Precisely, the two optimality conditions are given by:

$$P_Y Y = \alpha E, \quad \text{and} \quad R \equiv PQ = (1-\alpha)E,$$

where R denotes the total expenditure in the differentiated industry.

The differentiated industry is interpreted as consisting of a *narrowly* defined product class that address specific needs and admits a fair amount of differentiation. It is composed of multiple *vertically differentiated market segments* within which producers can develop *horizontally differentiated varieties*. In equilibrium, a measure $X \equiv \{X(p, \omega_i)\}_{i \in N}$ of commodities, defined on the set of market segments (N) and prices (p) is available for consumption. For simplicity, I assume that the number of market segments and the segment-specific quality levels are constant over time and exogenously determined. In particular, I consider the case where only two levels of quality (or market segments) are available; call them high (H) and low (o), so that $N = \{o, H\}$.

Preferences over the differentiated commodities are additively separable with weights defined by the quality of the commodity. This implies that all commodities of the same quality and trading at the same price are consumed at the same rate. Let $q_i(x)$ represent the consumption level of a variety of quality i selling at price $p_i(x)$.[6] The composite good Q is a version of the Dixit and Stiglitz (1977) aggregator extended to allow for substitution between quantity and quality:

$$Q = \left[\sum_{i \in \{o,H\}} \int_{x \in X_i} \omega_i^{1-\rho} q_i(x)^{\rho} dx \right]^{1/\rho} . \quad (2)$$

This formulation includes a type specific weight (ω_i) which is interpreted as a measure of a commodity's quality and acts as a demand shifter. By assumption the taste shifter is increasing in quality such that: $\omega_o < \omega_H$. The parameter $\rho \in (0, 1)$ governs the elasticity of substitution: $\varepsilon = 1/(1-\rho) > 1$. The optimal level of consumption of each commodity $q_i(x)$ is chosen to minimize the cost of acquiring the aggregate Q. This implies that:

$$q_i(x) = \omega_i Q \left[\frac{P}{p_i(x)} \right]^{\varepsilon} \quad \text{where} \quad P = \left[\sum_{i \in \{o,H\}} \omega_i \int_{X_i} p_i(x)^{1-\varepsilon} dx \right]^{\frac{1}{1-\varepsilon}} \quad (3)$$

is the ideal *quality-adjusted* aggregate price index.

2.2 Production

The homogenous good is produced under constant returns to scale at unit labor cost and is taken to be the numeraire of the economy. Profit maximization in this perfectly competitive sector therefore implies that the labor wage rate will be equal to one, $w = P_Y = 1$. Hence, the total cost function for the homogenous good sector will be given by:

$$\Gamma_Y = Y .$$

Since consumers spend a constant fraction α of their income (L) on homogenous goods and the latter is produced at unit labor cost, αL workers will be employed by firms in the homogenous industry.

The quality of the differentiated good depends on the technology used in its production. For convenience, I assume that each technology produces goods of a unique quality. Production entails both a fixed and a marginal cost. I assume that it is costly to produce quality such that the fixed acquisition/maintenance cost and, conditional on the plant's productivity, the constant marginal cost are increasing in quality. Finally, the general form of the total cost function is assumed to be the same for all technologies and is given by:

[6] Note that there may be more than one variety of quality ω selling at price p. Thus X is not defined over the set of prices but over the set of varieties.

$$\Gamma_i(\varphi) = f_i + \frac{c_i}{\varphi} q, \qquad i \in \{o, H\} \text{ with } c_o < c_H \text{ and } f_o < f_H, \tag{4}$$

where the subscript i indexes the technology, or equivalently the quality of the production, and φ is a measure of firm-level productivity.[7]

Firms are assumed to be single-plant, single-product profit maximizer. As a result, they will set marginal cost equal to marginal revenue. This leads to the following segment specific pricing rule:

$$p_i(\varphi) = \frac{c_i}{\rho\varphi}, \qquad i \in \{o, H\}. \tag{5}$$

This equation highlights the importance of the interaction between quality and productivity in determining the output price. While the output price is increasing in the product's quality it is also decreasing in the plant's productivity. Hence, it could be the case that a relatively productive plant sells a relatively high quality good at a price lower than a low quality good produced by an unproductive plant. Therefore, *only after controlling for productivity, is the correlation between price and quality always positive.*

Using the pricing rule (5) and the optimal demand schedule defined in (3), the plant's segment specific revenue can be expressed as:

$$r_i(\varphi) = R(\rho\varphi P)^{\varepsilon-1}\Omega_i, \quad \text{where } \Omega_i \equiv \omega_i c_i^{1-\varepsilon},\ i \in \{o, H\}. \tag{6}$$

Hence, for any given productivity (φ), revenue is increasing in the differentiated segment's aggregate expenditure (R) and the aggregate price index (P). By definition, the plant's segment specific profit is the difference between its revenue and production costs, and can be expressed as:

$$\pi_i(\varphi) = r_i(\varphi) - \Gamma_i(\varphi) = \frac{r_i(\varphi)}{\varepsilon} - f_i \quad \text{for } i \in \{o, H\} \tag{7}$$

where the last equality uses equations (4)-(6). It will also be useful to define the segment specific zero-profit productivity cutoff, φ_i, as the minimum productivity level needed to profitably produce a variety of quality i. Specifically, let φ_i satisfy $\pi_i(\varphi_i) = 0$, so that from (6) and (7):

$$\varphi_i = \frac{1}{\rho P}\left(\frac{\varepsilon}{R} \cdot \frac{f_i}{\Omega_i}\right)^{\frac{1}{\varepsilon-1}}, \quad \text{for } i \in \{o, H\}. \tag{8}$$

[7] Note that the costs are implicitly functions of quality and could have been written $f(\omega_i)$, $c(\omega_i)$. Since quality is not continuous, I opted for a more compact notation.

This equation indicates, in particular, that the technology specific profitability cutoffs φ_i are increasing in fixed costs and decreasing in the segment specific component of revenue Ω_i. Next, I define the transition productivity cutoff, $\varphi_{o,H}$, as the productivity level at which a plant is indifferent between producing a low or a high quality good. Formally, let $\varphi_{o,H}$ satisfy $\pi_o(\varphi_{o,H}) = \pi_H(\varphi_{o,H})$. Then, using (7) and (8), the following expression holds:

$$\varphi_{oH} = \Delta \cdot \varphi_o, \quad \text{with } \Delta \equiv \left(\frac{f_H - f_o}{f_o} \cdot \frac{\Omega_o}{\Omega_H - \Omega_o} \right)^{\frac{1}{\varepsilon - 1}}.$$

This equation clearly shows that the ratio of the productivity of the marginal plant in the high segment to the productivity of the marginal plant in the low segment (Δ) is exogenously fixed by the model's parameter.

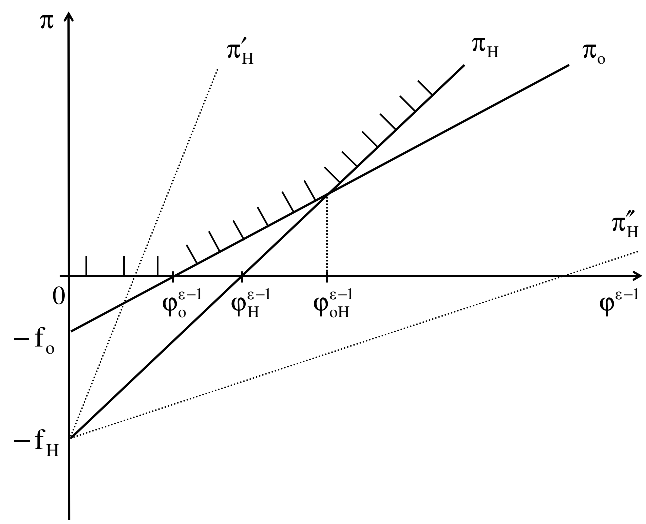

Figure 1. Profit Functions and Productivity Cutoffs

The profit functions for the two segments defined in (7), are depicted in Figure 1 in $(\varphi^{\varepsilon-1}, \pi)$ space. To make the model interesting I want to ensure that both technologies are relevant in the sense that some plants choose to use it in equilibrium. I will refer to the case in which both qualities are produced as an "equilibrium with sorting". It can be shown that sorting will occur if and only if:

Assumption 1. $1 < \Omega_H / \Omega_o < f_H/f_o$.

The first inequality ensures that the slope of the high quality profit function is steeper than in the low segment. Therefore, given the assumption on fixed cost, the two profit functions will intersect – ruling out cases such as (π_o, π''_H). The second inequality implies that the intersection occurs at a point where profit is positive – ruling out cases such as (π_o, π'_H). Together these inequality implies that there will be sorting of plants across product quality.

The presence of fixed costs implies that plants will choose to produce a unique variety, different from the varieties produced by all other plants in the same segment. Moreover, since plants are profit maximizer, they will produce in segment j only if: (i) segment j provides them with the highest conditional profit, i.e. $\{j : \pi_j(\varphi) \geq \pi_i(\varphi), \text{for } i, j \in \{o, H\}\}$; and (ii) their revenue at least covers the cost associated with production in that segment, i.e. $\pi_j(\varphi) \geq 0$. Hence, in the equilibrium with sorting, plant behavior can be described as follows: exit if $\varphi < \varphi_o$; produce a low quality variety if $\varphi \in [\varphi_o, \varphi_{oH})$; and produce a high quality variety if $\varphi \geq \varphi_{oH}$.

2.3 International Trade

I assume that the world is composed of $n+1$ identical countries.[8] In order to sell their products in foreign markets, plants must build and maintain relations with foreign distributors (see Roberts and Tybout (1997)). Further, plants generally face tariffs and pay freight costs to send their products to foreign markets. Following the literature, I assume that trade impediments take the form of a fixed export cost (f_x) that must be paid every period by exporting plants, and a constant melting-iceberg cost per-unit shipped to foreign countries. Precisely, if $\tau > 1$ units are shipped to the foreign country, only one unit arrives. Since I do not want arbitrary differences in trade costs to drive the results, these will be assumed common to both market segments. The increase in marginal cost will be reflected by a proportional increase in price such that the pricing rule for exported goods is:

$$p_i^x(\varphi) = \tau\, p_i(\varphi),$$

where $p_i^x(\varphi)$ and $p_i(\varphi)$, defined in (6), respectively denote the foreign and domestic price of a domestically produced variety. Therefore, using the optimal demand defined in (3), the *additional* revenue from export to any foreign market will take the following form:

$$r_i^x(\varphi) = \tau^{1-\varepsilon} r_i(\varphi), \tag{9}$$

[8] When all countries are identical, they all share the same aggregate variables which greatly simplifies the analysis. It is important to note however that, since the number of countries is variable, the size of the domestic country relative to the rest of the world is left unrestricted.

where the domestic revenue $r_i(\varphi)$ is defined in (7), while the *additional* profit from exports is given by:

$$\pi_i^x(\varphi) = \frac{\tau^{1-\varepsilon} r_i(\varphi)}{\varepsilon} - f_x . \tag{10}$$

Consumers' love for variety and the presence of fixed export costs ensure that no plant will export without also producing for its domestic market. Also since trade barriers are symmetric across countries, if a plant finds exporting to one of the foreign markets profitable, it will export to all countries. Thus, each plant now faces four different options: (i) produce low quality goods and sell exclusively in the domestic market; (ii) produce low quality goods and export; (iii) produce high quality goods and sell exclusively in the domestic market; (iv) produce high quality goods and export.

Next, I define the export productivity threshold, φ_i^x, as the minimum level of productivity required to enter the export market, conditional on producing in segment i. That is, φ_i^x satisfies $\pi_i^x(\varphi_i^x) = 0$. Equations (6) and (10) can be used to obtain expressions for these cutoffs:

$$\varphi_i^x = \frac{\tau}{\rho P}\left(\frac{\varepsilon}{R}\right)^{\frac{1}{\varepsilon-1}}\left(\frac{f_x}{\Omega_i}\right)^{\frac{1}{\varepsilon-1}}.$$

Hence, these thresholds are decreasing in the foreign country's market size (equal to R since all countries are identical), aggregate price index and quality but increasing in fixed and variable trade cost. However, the number of trading partner (n) has no impact on the export productivity threshold. Further, by definition, $\varphi_o^x / \varphi_H^x = (\Omega_H / \Omega_o)^{1/(\varepsilon-1)} > 1$ such that, in equilibrium with sorting, if a low quality plant finds it profitable to export, *every* high quality plant will find it profitable to export. Finally, since the ratio of the export to the domestic cutoff is given by $\varphi_i^x / \varphi_i = \tau(f_x/f_i)^{1/(\varepsilon-1)}$, partitioning of plants by export status within a segment occurs if and only if $\tau^{\varepsilon-1} f_x > f_i$.[9] These results imply that there can be selection of plants along exporting status in at most one market segment. I will focus on the partitioned equilibrium where both high and low quality goods are exported. Hence, I assume that:

Assumption 2. $1 < \Delta_x < \Delta$, where $\Delta_x \equiv \tau\left(\frac{f_x}{f_o}\right)^{\frac{1}{\varepsilon-1}}$.

This assumption implies that the relevant productivity cutoffs are ordered as follow: $\varphi_o < \varphi_o^x < \varphi_{oH}$. Together, assumptions 1 and 2 ensure that there is plant sorting across market

[9] Note that by assumption on fixed costs, the condition is more likely to hold in the low segment.

segment and selection along exporting status in the low segment. In this type of equilibrium, as productivity increases, plants expand their potential consumer base by exporting their production to foreign markets before investing in a more expensive technology that enables them to produce higher quality output.

2.4 Equilibrium

The definition of the unique equilibrium is very similar to that of other models in the literature and is given in the appendix. It can be shown that:

Proposition. *There exists a unique costly trade open economy equilibrium.*

Proof: See appendix. □

This completes the characterization of the unique costly trade open economy equilibrium. The next subsection explores a number of important testable properties of the equilibrium.

2.5 The impact of Quality

This section presents a subset of the model's predictions that can be tested using the data set available.[10] At the heart of the model lies the assumption that the production costs are increasing in quality but decreasing in productivity. Hence, in order to evaluate the impact of quality on unit production costs, it is important to control for the effect of productivity. Further, as can be seen from the pricing rule defined in equation (5), in equilibrium the variation in cost will result in proportional price dispersion. Finally, as depicted in figure 1, in an equilibrium with sorting lower productivity plants choose to produce low quality goods while higher productivity plants produce high quality goods. Intuitively, higher productivity plants have lower marginal costs, as a result they can charge lower price and sell a larger number of units in equilibrium. Higher productivity therefore allows a plant to overcome both "barriers" to quality: the increase in marginal production cost (c) and the increase in the fixed cost of technology (f). These testable predictions are summarized in the following:

Prediction 1: Cost, Price, Productivity and Quality

(i) After controlling for productivity (φ), there is a positive association between quality (ω) and production costs (c);

[10] The model also generates important prediction regarding the impact of trade liberalization on the distribution of quality. For a complete description of the model and a comprehensive analysis of the prediction see Gervais (2008).

(ii) After controlling for productivity (φ), there is a positive association between quality (ω) and price (p);

(iii) There is endogenous sorting of plants across quality such that higher productivity plants choose the high quality product.

From (6) and (9), total plant revenue can be expressed as:

$$r_o(\varphi) = R(\rho\varphi P)^{\varepsilon-1}\Omega_o \tag{11a}$$

if the plant is a domestic producer, and by

$$(1+n\tau^{-\varepsilon})r_i(\varphi) = (1+n\tau^{-\varepsilon})R(\rho\varphi P)^{\varepsilon-1}\Omega_i\,,\ i\in\{o,H\} \tag{11b}$$

if the plant is an exporter. Further, from the optimal demand (3), the pricing rule (5), and the equilibrium condition that the marginal entrant makes zero profit, $\pi_o(\varphi_o)=0$, it can be shown that the equilibrium firm level output is given by:

$$q_o(\varphi) = \frac{\rho\varepsilon f_o}{c_o\varphi_o^{\varepsilon-1}}\varphi^{\varepsilon} \tag{12a}$$

if the plant is a non-exporter and by:

$$q_o(\varphi) = (1+n\tau^{1-\varepsilon})\frac{\rho\varepsilon f_o}{c_o\varphi_o^{\varepsilon-1}}\varphi^{\varepsilon}\,,\ \text{and}\ q_H(\varphi) = (1+n\tau^{1-\varepsilon})\frac{\rho\varepsilon f_o}{c_o\varphi_o^{\varepsilon-1}}\left(\frac{\Omega_H}{\Omega_o}\right)\varphi^{\varepsilon}\,, \tag{12b}$$

if the firm is an exporter producing a low or a high quality variety respectively. From (11), (12), and the result that quality is increasing in the firm's productivity, it follows that:

Prediction 2: Quality and Plant Size

Plant size, as measured by units of output (q) or revenue (r), is unambiguously increasing in quality (ω) and plant productivity (φ);

From (11), since productivity is increasing across segments and $n\tau^{-\varepsilon}>0$, it follows that revenue is higher for exporters than non-exporters. Further, from (12), since productivity is increasing across segments, $n\tau^{-\varepsilon}>0$, and $(\Omega_H/\Omega_o)>1$, it follows that quantity produced is higher for exporters than non-exporters. As a result:

Prediction 3: Quality and Export Status

Quality (ω), productivity (φ), and plant size – measured by output (q) or revenue (r) – are greater for exporting plants.

Finally, high quality high productivity firms are further away from the threshold they are therefore less likely to exit following an aggregate shock that decreases the industry's profitability. The model therefore predicts that:

Prediction 4: Quality and Exit Probability

On average, the probability of exit is decreasing in quality (ω) and productivity (φ).

This section reviewed the basic theory and put forth a number of important predictions. Before moving on to the empirical investigation, the next two sections describe the data set that will be and provide an overview of the bread manufacturing industry.

3. DATA

The bulk of the information comes from the Census of Manufacture (CM) – a component of the US Census Bureau's Economic Census. The CM is conducted quinquenially and covers all manufacturing establishments (plants) with one or more paid employees. A firm operating at more than one location is required to file a separate report for each plant. Importantly, each establishment is assigned a separate industry classification based on its primary activity and not that of its parent company. The CM contains plant level data on payroll, production and nonproduction worker employment, production worker hours, book values of equipment and structures, cost of materials, cost of energy, energy consumed, value of shipments, and export value. For a subset of the 11,000 goods for which it records data, the CM also collects information on plants' annual value of shipments by product category and, when feasible and for some selected years, shipments in physical units.[11] Finally, the CM contains price and quantity information for a subset of 4 digit SIC material input purchased by plants.

Certain characteristics of the CM require that some observations be removed from the samples. First, administrative records, balancing codes as well as receipt for contract work, resale, and miscellaneous receipts are excluded since the information is either imputed or unrelated to actual production.[12] Second, in order to remove gross reporting error, observations with price outliers for output and/or inputs are dropped.[13] Third, for material inputs, I removed a few

[11] The US Census Bureau adds two digits to the 5 digits SIC product class to form 7 digits product codes. The specific products for which quantity produce are recorded varies from year to year. For instance, much of the apparel SIC 23 were dropped in 1982.

[12] Administrative Records (AR) are exempt from filling census forms. In that case, there is no product level information and the establishment level information is imputed.

[13] Observations with an input or output price above 10 times the median or lower than one tenth of the median are dropped.

product classes for which the units of measurement for quantity are not compatible.[14] Finally, because plants' factor inputs are not reported separately by product but rather at the plant level when computing productivity or when productivity is included in a regression only specialized plants are included in the sample. This restriction reduces measurement problems in computing productivity measures. In the basic specification, a plant is considered to be specialized if it obtains at least 50% of its revenue from sales of the product of interest.[15]

For reasons explained in details in the next section, the procedure is very demanding in terms of the data required. First, in terms of theory, the products should exhibit sufficiently rich within-product differentiation and price variation. Precisely, varieties of the product should be direct substitute and consumers should not be indifferent between every unlabeled units of the same product. Second, in terms of empirical implementation, information on product level prices and quantities for output and material inputs should be available. Third, because they will serve as instruments for output price, at least some homogenous inputs must be used to produce the final good. Finally, the sample should be large enough to satisfy the U.S Census Bureau's Disclosure policy. Given these considerations, the analysis concentrates on the bread industry (SIC 2051), the most important of the baked goods sector, for census years 1972 through 1997.[16]

The analysis uses four different subsamples defined on the availability of input price information and the specialization criterion defined above. The numbers of observations by years for each of the samples are reported in Table 1. The relation between these samples and the reason to define them will become clear as the analysis proceed. For now the important points to note are that: (i) The number of observations tends to decrease over time; (ii) The panels are relatively balanced in terms of share of revenue, and share of output. Time series fluctuations in the reported indicators are due to many factors such as technological innovation, consolidation, and changes in consumer behavior. The next section briefly reviews the evolution of the industry.

4. BREAD PRODUCTION INDUSTRY

This section presents an overview of the main characteristics of the manufactured bread industry.

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[14] This does not affect the output which is always measured in baked weight pounds. However in the flour industry some inputs are measure in sacks which cannot be converted to pounds, the measure generally used. Overall very few product classes and observations are dropped because of this.

[15] On average plants obtain 60 percent of their revenue from bread products.

[16] I do not use 1963, 1967, and 2002 for technical reasons. First, the tfp trailer of the CM is unavailable for those years. In addition, for 2002 the classification codes changed from SIC to NAICS making a concordance less than perfect and NBER price deflators are not available.

4.1 Brief Historic

According to some historians, the ancient Egyptians created the world's first leavened breads.[17] During the first Roman Empire, baking progressed to an art form and the first commercial bakeries appeared. However, as the Empire began to crumble, bakeries were taken over by the government and commercial baking became virtually nonexistent. During the Middle Ages, only monasteries and manor houses baked large quantities of leavened products and white flour was a luxury available only to royalty. Commercial baking as a trade began to rise again during the urbanization that accompanied the early Industrial Revolution. Innovations of the late nineteenth and early twentieth century enabled the mass-production of baked goods. As a result, large baking facilities began to supplant small "street corner" establishments. Today, in the typical large-scale bakery, there is little manual labor directly involved in production. After the dough is mixed in large steel vats, it is sheeted and molded by machine, then left to prove in a heated chamber before proceeding on a conveyor belt to the ovens where it is baked. After being taken from the oven, the bread is extracted from the tin by suction and is then sent off by conveyor belt to the cooling cabinets. Machines have been introduced which result in fully mechanized slicing and wrapping. The bread is then dropped into plastic trays ready for delivery.

4.2 US Bread Industry

The US Bread Production industry comprises establishments primarily engaged in manufacturing fresh and frozen bread. These plants acquire raw materials such as flour, dry milk, sugar, preservatives, additives, and vitamins and process them into consumer food products. More than half of the industry's many thousand establishments operate with fewer than twenty employees. However, these small plants capture a very small share (about 2 percent) of the industry's total revenues. The Wheat Flour Institute calculated that during the early 1980s, U.S. bakers produced approximately 250 million pounds of bread every *week*.[18] On average, about 60 percent of the industry's output is sold to supermarkets. Most of the remainder is purchased by convenience stores and foodservice providers (e.g. catering firms, hotels, and restaurants). Retail outlets (e.g. coffee shops) and consumers are only minor sources of sales for this industry as are exports. Sales to customers abroad account for about 2 percent of industry revenues on average. Major sales are

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[17] Leavened bread is made with ingredients possessing the chemical properties necessary to make dough rise. By contrast, unleavened breads were made from doughs that did not rise. Existing written record attest to the existence of such flat bread as early as 2600 B.C.

[18] The most popular kind of bread is white bread made from white flour. According to figures for 1990, the average U.S. citizen consumed 28 pounds of white bread, 23 pounds of variety breads, and 23 pounds of rolls.

to Canada, Mexico, and Japan. Low export shares are due to the fact that fresh breads are perishable and transporting frozen breads long distances is generally not cost effective with respect to the value of the end product. However, although the majority of establishments are locally owned and operated, major industry players do have global interests. For instance, Sara Lee Corporation – the largest bread producer in the US with a 6.5 percent market share – currently has operations in 55 countries and sells its products in approximately 200 nations.

Because bread is perishable, proximity to a customer base always has been a primary concern and, although some are strategically located close to flour mills and other raw materials, bread production establishments are usually based around major population centers. Bakeries overcome geographic constraint due to product characteristics by purchasing companies in other areas. Many acquisitions and mergers within the industry during the last decades of the twentieth century transformed baking establishments with regional shipping systems into large conglomerates with national distribution networks. However, concentration remains relatively low due to the small barriers to entry in the industry – the largest three players account for about 6 percent of the market each.[19]

4.3 Demand Determinants

While price is important, and must be competitive, there are many other determinants of demand for bread in the United States. First, due to *general lifestyle changes* beginning after World war II and accelerating rapidly beginning in the 1970s, household baking declined considerably as individual consumers increasingly tend to purchase their bread from grocery stores. Second, the emergence of *health, nutritional, and dietary concerns* has stimulated growth in demand for products with a health food image, such as whole wheat products and decreased the demand for products which are perceived to be high in calories. Third, change in the *ethnicity structure of the American population* has greatly influenced the product mix of the industry. These trends have supported the emergence of bread producers specializing in ethnic products. Last but not least, *product quality* is an important source of competition in the industry.

The quality of the bread and, more broadly, the willingness to pay of the consumers is determined by many factors. The most important tangible component of quality is the taste of the bread which depends mainly on the freshness of the ingredients and the bread itself. Firms can

[19] Regulations relating to the manufacture, packaging and labeling of baked foods is something for entrants to consider carefully but are far from insurmountable. Perhaps more important is the fact that established brands can provide barrier to access to supermarket shelf space. In addition, existing operators in this product segment tend to be large and have large budgets to pursue aggressive marketing strategies. However, offsetting these impediments is the fact most raw materials are readily accessible and production technology and know-how are also widely dispersed and therefore easily obtained.

increase the freshness of their product by developing efficient supply chain and distribution networks. Technological development in packaging can also extend shelf life and preserve product freshness.[20] Consumer perception is the crucial intangible component of product quality. Major industry participants recognize it and invest considerable resources in branding their products. Of course, the technological methods used to combine ingredients and the expertise of the workforce will play a role in determining the overall quality of the product. Hence bread manufacturers can influence the quality, perceived or real, by investing in different aspect of the production process: technology, distribution, or advertising.

5. ESTIMATING QUALITY

In this section, I begin the empirical implementation of the model. The main objective is to develop a sensible way to measure the elusive dimension called product quality.

5.1 Econometric Model

From the optimal demand function, defined in (3), it follows that the log quantity demanded of plant j's output at time t can be expressed as:

$$\ln q_{jt} = \lambda_t + \ln R_t - \varepsilon \ln p_{jt} + \nu_{jt}, \quad \text{with} \quad \nu_{jt} \equiv \ln \omega_{jt}. \tag{13}$$

The first term $\lambda_t \equiv (\varepsilon - 1)\ln P_t$, is a time varying effect common to all plants in the market. The second term (R_t) is the log of the total revenue in the market while the last term (ν_{jt}) represents the unobservable product quality and will serve as the error term of the regression.[21] Estimating (13) using ordinary least squares methods (OLS) leads to biased estimates of the price elasticity (ε) and, as a result, of the plant's average output quality ($\omega_{jt} = \exp(\nu_{jt})$). This happens for at least two reasons. First, the theory predicts that, all else equal, plants charge higher prices for high quality varieties thereby creating a positive correlation between p_{jt} and the error v_{jt}. Second, in practice, the error term could also include exogenous demand shocks. If plants respond to positive shocks by raising their prices these will also create a positive correlation between price and the error term.

[20] Extensive ongoing research within the industry lead to the development of innovative packaging processes. Modified atmosphere packaging (MAP) involves introducing a predetermined atmosphere inside special barrier packaging materials at the time products were sealed for shipping and controlled atmosphere packaging (CAP) relies on active means of manipulating the gas in a package's headspace.

[21] It is important to mention that moving from theory to empirics implies a key change in the definition of the variables. Since plants are generally multi-products producers the price and quality variables are in fact averages defined over the different varieties.

To deal with the problem, I suggest using a two stage least square instrumental variable procedure. Proper instrumental variable candidates will have four properties: (i) correlated with output price; (ii) uncorrelated with output quality; (iii) exhibit both cross sectional and time series variation; (iv) available in the data. In general, input prices will be positively related to the output price and satisfy the first condition. However, the increase in input price could be due to an increase in its quality which, in turn, could influence the quality of the final good thereby violating condition (ii). Since input quality is generally unobservable and, as a result, cannot be controlled for, only homogenous inputs will be considered. However, even in that case, input and output prices might still be correlated. For instance, as explained in details in Davis et. al. (2007) and Haltiwanger et. al. (2008), bulk pricing is a ubiquitous characteristic of electricity, a canonical homogenous input: large purchasers pay systematically less for a Kw/hr. Since there is strong evidence that larger producers are more productive on average, and the model predicts that there is a correlation between productivity and output quality, the effect of market power must be removed from input prices in order to produce suitable instrumental variable candidates. Therefore, only the fraction of locally traded homogenous input prices orthogonal to the plant's market power will be used as instruments for the output price in a two stage least square regression of equation (13).[22] In addition to electricity, two additional inputs satisfy the four conditions: dry milk (SIC 2023) and flour (SIC 2041).[23]

Four important points need to be emphasized. (i) On average, total material cost (including electricity) accounts for about 55 percent of the overall production cost such that changes in input prices should have a substantial effect on the output price.[24] Not surprisingly, flour is by far the most important material input accounting on average for more than a quarter of total material costs – thus about 12.5 percent of the total production costs is attributable to flour; (ii) The dry milk and flour purchased by bread manufacturers are homogenous goods. While it is true that many different types of flour are available, each is characterized by different end use.[25] Generally, rice flour is sold to breakfast cereal manufacturers, corn flour is sold to Mexican food manufacturers and breakfast cereal manufacturers, while wheat flour is sold to industrial bakery

[22] Details on the construction of these instruments are also provided in the appendix. In addition to removing the direct effect of purchasing power, the purging procedure will also break the systematic correlation that might exists between firm size and average input quality. Note that input shares cannot be used since they will be systematically correlated with quality whenever the production technology differs across market segment.

[23] Both material inputs are classified by Rauch (1999) as *not* horizontally differentiated – Bread (SIC 2051) is however.

[24] The rest is divided between payroll (33 percent), and capital (structure and equipment) rental cost (12 percent). These figures are sample averages based on the author's computation.

[25] Wheat flour is the industry's largest product category (more than 50 percent of revenue on average), followed by rice (approx. 20 percent), corn (approx. 10 percent), and malt (approx. 5 percent).

goods manufacturers. Wheat flour can be further categorized according to the type of grain used. For instance, hard wheats are used mainly in breads and rolls, while soft wheats are used in sweet goods, cakes, cookies, crackers, and prepared mixes while durum wheat is used almost solely in pastas. Overall, this implies that the flour purchased by bread producer is much less differentiated then the entire flour industry's output and is thus very homogenous. As for dry milk, the product itself does not allow for significant vertical differentiation; (iii) It is important to note that while electricity accounts for a small fraction of the overall costs (less than 5 percent on average) it will influence the unit cost of production through multiple channels. Obviously, an increase in electricity price will raise electricity expenditure. It should also lead to higher payroll expenditure since the increase in cost of living will have to be factored in the worker's wages. Also, high regional electricity price will increase the production cost of other material inputs and be reflected in their price, thus driving the input cost up. Thus, the small electricity share of total cost most likely underestimates the effect of electricity price on output price; (iv) Homogenous material inputs prices exhibit abundant regional and cross sectional variation. As explained in details Davis et al. (2007), electricity price variation results from difference in utility characteristics and technology. Further, according to the 1993 Commodity Flow Survey (CFS), flour and dry milk are shipped, on average, a distance of 250 miles from there place of production.[26] Therefore, a firm located near a relatively efficient flour producer will, other things equal, pays a lower price for a thousand pound of flour. Even if two plants purchase from the same input producer, if they are not located at the same distance, transport cost variation could lead to different optimal plant behavior. For instance, the plant located further away could find it optimal to buy less frequently and in larger quantity, thus reducing the freshness of its ingredients and, as a result, the quality of its output.[27] The price of flour also greatly fluctuates over time due to changes in consumer taste and industry structure, technological improvement, and other factors. The same is true for the other material input, dry milk.

Before equation (13) can be properly estimated controls for aggregate conditions (λ_t) and market revenue (R_t) must be obtained. The first step is to define the sets of producers that are in direct competition. In essence, markets must be defined. The CFS reveals that on average bread is shipped only 74 miles from its production location. Further, as explained in section 4, the industry

[26] The CFS is a component of the Economic Census series and provides data on the movement of goods within industries (defined by SIC) by mode of transportation. The CFS covers establishments in mining, manufacturing and wholesale trade, and selected retail and service industries.

[27] Since an important quality of the bread is its freshness quality will be higher if production takes place every day. This is less costly to do when suppliers are in close proximity and transport costs can be kept low.

is relatively competitive and characterized by a low level of concentration. The industry is thus composed of a large number of establishments deserving relatively small geographic markets. In other words, the U.S. contains many segmented markets for bread. The obvious approach would be to delimit these markets using state or county borders, however, in addition to being of inadequate sizes, these do not define economically meaningful agglomerations. From an economic standpoint, a better definition of regions is provided by the Bureau of Economic Analysis (BEA) areas. In its latest incarnation, defined in Johnson (1995), the BEA divides the United States in 172 mutually exclusive regions defined by agglomerating counties based on commuting patterns. This is closely related to the behavior of bread producers which tend to locate near important population centers. Therefore, in the empirical analysis, a market will be assumed to be delimited geographically by BEA areas. The market revenue for each year (R_{jt}) is therefore defined as the sum of all plants revenue located in the BEA area and a set of BEA and time fixed effects will be used to control for λ_t.

5.2 Price Elasticity and Product Quality Estimates

All the elements are now in place to begin the econometric analysis. In this subsection, I present results from the following estimating equation:

$$\ln q_{jt} = \boldsymbol{\beta}_{\text{Time}} + \boldsymbol{\beta}_{\text{BEA}} + \ln R_{\text{BEA},t} - \varepsilon \ln p_{jt} + \nu_{jt}, \tag{14}$$

where $\boldsymbol{\beta}_{\text{Time}}$ and $\boldsymbol{\beta}_{\text{BEA}}$ denote a set of time (5 year interval) and BEA area fixed effect respectively, $R_{\text{BEA},t}$ is the market size defined as the total BEA area revenue where the plant is located, p_{jt} is the plant's unit price of output, and v_{jt} is the unobservable demand shock. For reasons explained in details in the previous subsection, the output price will be instrumented using plant level homogenous inputs prices corrected for the plant's market power. Details on the construction of these variables can be found in the data appendix. Descriptive statistics for variables included in equation (14) are presented in table 2. Comparing the two samples reveals that plants are smaller on average in the larger sample but that output and electricity prices are roughly the same. Finally, the larger market size observed in Panel B is explained by the inclusion of 6 additional market and, most importantly, a change in the weights received by the different BEA areas.[28]

The results from estimating regression equation (14) are presented in Table 3. The baseline procedure uses three corrected input prices – electricity, flour, and dry milk (henceforth the EFM

[28] The market size is defined as the average size of the BEA area revenue *faced* by plants. This implies that areas with a large number of plants will receive a larger sampling weight in the computation of the mean.

sample) – to instrument for output price. Since there might be some lingering concerns about the homogeneity of flour and dry milk, I also present results from using only the corrected electricity price (henceforth the Electricity sample). Because there is little doubt about the absence of correlation between output quality and electricity price once the plant's market power in the input market is removed, the latter procedure is relatively conservative. OLS estimation results are presented in column (1) and (3) for the EFM and Electricity samples respectivelly. In both cases, the price elasticity of demand (ε) is negative, larger than unity in absolute value, and statistically significant. It is interesting to note that the point estimate is statistically the same in both samples as would be the case if the absence of flour and milk price information in the EFM sample was random. The overall fit of these regressions is reasonably high as indicated by the R^2 and standard errors of the regressions.

Hausmann's test for exogeneity reveals the presence of correlation between the input price and the residuals. According to the model this is not surprising since the product quality and price are positively related. As expected, removing the omitted variable bias results in statistically larger (in absolute value) elasticity of substitution as can be seen from columns (2) and (4), which present the result from the IV estimation for the EFM and Electricity sample respectivelly. In fact, in the case of the electricity sample, the elasticity is much larger. Nevertheless, as for every other elasticity estimates, it remains in reasonable range. It states that, holding quality fix, a one percentage point increase in price will result in a ten percentage point decrease in quantity demanded. As usual, the IV estimation is less precise than the OLS. Table 3 also reports two measures of the instrument's quality. In both case, the first stage F is high enough that the instrumental variable procedure should be considered adequate according to criteria developed by Staiger and Stock (1997). Further, the first stage R^2 for the EFM sample is 0.22 (not shown in the table) while Shea's R square is 0.04 – see Shea (1997) for a definition of the latter. This implies that out of the 22 percent of variation explained by the regressors, about a fifth is explained by the instruments. In the electricity sample only a small fraction (about 1 percent) of the variation is explained by the corrected electricity price. Finally, in the EFM procedure an overidentifying restriction test suggests the presence of superfluous instruments. This provides an additional rational to consider the electricity sample as the better estimation technique. Overall these results indicate that the IV procedure is recommended.

As explained earlier, an estimate for average product quality can be obtained from the residual of the demand regression. Precisely, I define the estimated log quality as follow $\ln \hat{\omega}_{jt} \equiv \hat{\nu}_{jt}$. The presence of time and BEA fixed effects in regression equation (14) implies that the estimated quality is a measure of idiosyncratic plant-level demand shocks. In other words, regional or aggregate intertemporal variation does not drive any of the results. By construction the sample average of these estimates is zero (up to an approximation error) and the standard errors are about 1.5 and 3 for the EFM and Electricity sample respectively.[29] For plants included in both samples the correlation between the two quality estimates is large, positive, and statistically significant. This explains why, overall, the results presented in the next section are generally unaffected by the choice of procedure. Finally, the quality estimates are very persistent over time. Regressing quality on its own (5 years) lag, controlling for regional and time fixed effect, yields a point estimate of 0.63 with a standard error of 0.04. This implies an annualized persistence rate of 0.91.[30] Hence the quality estimates are unlikely to only capture transitional random shocks.[31]

6. QUALITY AND PLANT CHARACTERISTICS

Equipped with plant-level product quality estimates, I investigate the empirical validity of the model's main predictions. First, I look at the correlation between quality and production costs and provide some evidence that the estimated demand shocks do in fact capture voluntary actions by the plant aimed at increasing the quality of its output. Second, I explore the relationship between firm characteristics, export status, and product quality. Third, I present evidence supporting the hypothesis that, in addition to productivity, product quality is an important determinant of industry dynamics. Finally, I go over a series of robustness checks.

6.1 Test of Prediction 1: Cost, Price, Productivity, and Quality

If incurring greater costs in an attempt to increase product quality – or more generally to raise consumer willingness to pay – is ineffective, profit-maximizing plants will not incur them. Thus, the reliability of the quality estimate could be evaluated by computing its correlation with different indicators of the plant's investment in quality – such as advertising or R&D expenditures. Unfortunately this type of information is not available in the data. However, evidence that firms voluntarily invest in quality enhancing activity can be obtained by looking at overall unit cost patterns. Precisely, if the quality estimates are purely random shocks, they will not be systematically related to the unit cost of production – in line with the theory, this argument

[29] Only one estimate in the EFM sample and 3 in the electricity sample do not fall within the 10 median range. While I remove these outliers from the samples, results are not sensitive to their inclusion.

[30] The implied one-year persistence rate is defined as the 5 year persistence to the one-fifth power.

[31] It is possible however that a random idiosyncratic demand shock leads the plant to invest in quality such that there is a positive correlation between past random shocks and current product quality. Unfortunately, this hypothesis is not testable since I cannot separate the random (shock) and deterministic (quality) components of the residuals.

implicitly assumes that plant cannot costlessly and instantaneously adjust the quality of their output as would be the case for price. To formally evaluate the relationship between production costs and quality, I regress the unit production cost on quality, controlling for the effect of productivity as well as regional and aggregate shocks. Precisely, I estimate the following equation:

$$\ln c_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + \beta_1 \ln \hat{\omega}_{jt} + \beta_2 \ln \hat{\varphi}_{jt} + e_{jt}, \tag{15}$$

where unit production costs are defined as the sum of real capital, energy, labor, and material expenditures divided by the quantity produced.[32] The productivity estimates ($\hat{\varphi}$) are computed as in Foster, Haltiwanger, and Syverson (2008). Basically, I obtain the difference between the log quantity and the log of a constant return to scale Cobb-Douglas production function where the capital, labor, electricity, and material shares of expenditure are estimated by sample averages.[33] Finally, time and BEA fixed effects are included as control for regional and aggregate exogenous shocks uncorrelated with quality that could influence the production cost.

The results from estimating regression equation (15) are presented in columns (1) and (4) of Table 4. Recall that, since I use only specialized plants to compute productivity, the sample sizes are now smaller. In both sample the quality elasticity of unit production costs is positive and statistically significant as predicted. The magnitude of the point estimates are difficult to interpret since it is not clear what a one percentage change in the quality of the bread actually means. To resolve that problem I create a quality indicator. To follow the theory I divide the plants in two segments. Plants with quality estimates above the median quality are classified as high, the others as low quality.[34] An additional advantage of this measure is that it is very constant across sample and therefore facilitates the comparison of the results. When they appear in both samples, 80 percent of the plants are classified in the same category and most of the misclassification occurs at the margin between the two qualities. Results using that measure of quality are presented in columns (2) and (5). Again, an increase in average product quality leads to a statistically significant increase the unit production costs. According to the point estimates, a plant that upgrades the quality of its output from low to high will experience an average cost increase of

[32] See the data appendix for detailed definitions.

[33] The model assumes that only one input enters the production process. However in reality capital, labor, energy, and material are combined to produce the final good. Since there is no reason to expect that the factor intensities are the same across goods of different quality I allow them to vary. To follow the theory I divide the plants in two segments. Plants with quality estimates above the median quality are classified as high, the others as low quality. In the two segments case, the factor shares are almost identical across quality. Finally, as explained in the robustness section, the results are not sensitive to the number of segments or the constant returns to scale assumptions.

[34] The question of whether or not increasing the number of segments affects the results is addressed in the robustness section.

about 8 to 10 percent. While economically significant this magnitude is perhaps lower than one would expect. This is explained by a “dilution” effect. Suppose that a plant producing a low quality variety introduces a high quality variety that is 10 times as costly to produce. If the plant produces and sells only 10 percent as much units of the high quality as the low quality variety the average cost will increase by less than 20 percent. Yet this small change in output composition could be enough to move the plant from a low to a high quality plant.

The results presented so far are strong evidence that the overall production cost is increasing in quality. It would also be interesting to know if the variable component of cost is increasing in quality. Amongst the different cost components the most likely to be purely variable is the material component.[35] Columns (3) and (6) uses the unit material cost and the dummy quality variable in regressions of the form of (15). Again, holding productivity fixed, the unit costs are increasing in quality. According to the coefficients, a plant that upgrade the quality of its output from low to high will experience an average material cost increase of about 15 percent. There are many potential explanations for this finding. First, high quality goods can be made with higher quality material input. Second, if quality is related to freshness high quality goods may be produce using similar inputs but delivered more often and in smaller batch thus increasing transport cost. Finally, high quality goods may contain additional ingredients such as vitamins, supplements, or preservative agents.

As can be further seen from Table 4, the impact of productivity is substantial. A one percentage point increase in productivity results in a one percentage point decrease in unit cost. A final interesting point to note is that, as should be expected, the included regressors account for an important fraction of the cost variation in the samples. In every unit cost regressions, the R^2 is above 0.8 and the standard errors are below 0.35. This is not surprising but nevertheless confirms that product quality, plant productivity, and aggregate conditions are the most important determinants of unit cost. Overall, the results present in Table 4 confirm the theory’s fundamental hypothesis that, controlling for productivity, an increase in product quality leads to an increase in unit cost of production.

Quality and productivity are also important determinants of output price. Precisely, the markup pricing rule defined in equation (5) implies that plants will shift the increase in production costs associated with producing high quality goods to the consumer. Conversely, any gain in productivity will be reflected by a proportional decrease in price. To formally evaluate the

[35] Recall that the bread industry is heavily mechanized such that labor might not be very responsive to a (not too large) change in output.

relationship between price and quality, I regress price on quality and productivity estimates controlling for regional and intertemporal variation. I estimate the following:

$$\ln p_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + \beta_1 \ln \hat{\omega}_{jt} + \beta_2 \ln \hat{\varphi}_{jt} + e_{jt} \,. \tag{16}$$

Results are presented in Panel A of Table 5. Only the results using the quality dummy variable are presented since they are easier to interpret. The qualitative properties of the results are unchanged when the continuous quality variable is used. As expected, the impact of quality on price is large, positive, and statistically significant in both samples. The coefficients state that a plant that sells high quality varieties will, on average, charge a price that is about thirty percent higher than a plant that sells low quality varieties. Further, in all cases, productivity as a large, negative, and significant effect on price. A one percentage point increase in productivity results in a one-third to one-half percentage point decrease in price. As is the case of homogenous goods, once vertical differentiation is taken into account, the more productive firms will charge lower prices. Importantly, since the model predicts that productivity and quality are positively related, omitting product quality could lead to an underestimation of the effect of production on price. In fact, unreported results provide empirical evidence of this downward bias: when only a productivity measure is regressed on price, controlling for regional and aggregate effects, the estimated coefficient are generally smaller in absolute value then in a richer specification that also includes quality. Finally, the overall fit of Panel A's regression is high according to both the R^2 and standard error of regression. This suggests that product quality, plant productivity, and local and aggregate conditions are the main determinants of the plant's average unit price.

Given the complexity of the procedure obtaining an estimate for product quality will not be feasible in general. Therefore it is interesting to evaluate the soundness of using unit value (i.e. average price) as a proxy for average product quality. While not common, price is often available and many studies mention in the introduction do in fact use it as a proxy for quality. To evaluate the validity of price as an indicator of product quality, I regress the continuous quality measure on price controlling for time and BEA fixed effect – results are not affected by the choice of quality measure. The results are presented in Panel B of Table 5. In both samples the coefficient on price is large, positive, and significant. Precisely, a one percentage point increase in price leads to a 2.6 to 8.4 percentage point increase in quality. According to these results, plant level cross sectional and time series variation in price is a good indicator of variation in plant product quality. This is encouraging both for existing and future studies of product quality.

The model also predicts that relatively productive firms should produce higher quality goods. This can be tested by estimating the following equation:

$$\ln \hat{\omega}_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + \beta \ln \hat{\varphi}_{jt} + e_{jt} . \quad (17)$$

The results are presented in Table 6. Up to now only results using quantity productivity have been presented in part because, as explained in the robustness section below, these are not sensitive to the use of other measures. However, this is not always the case when looking at the impact of productivity on plant sorting along product quality. Hence, in table 6, I also present results using revenue productivity, a more standard measure than the quantity productivity measure used so far. As can be seen in columns (1) and (2) in the case of the EFM sample both measures yield the same expected result: an increase in productivity leads to a large, positive, and statistically significant increase in average product quality. However, when the larger Electricity sample is considered an increase in quantity productivity leads to a decrease in quality while an increase in revenue productivity leads to an increase in quality. This results might not be so surprising however if we think about the exact nature of the two productivity estimators. If producing a unit of high quality is more costly in terms of all inputs then plants producing high quality goods will produce fewer units using a given amount of inputs and thus appear less efficient to the econometrician.[36] In contrast these same firms are likely to generate larger revenue from a given amount of inputs. These considerations imply that the coefficients on the quantity productivity estimates are biased downward. Consistent with this interpretation, the coefficient on quantity productivity is much smaller than that on revenue productivity in the EFM sample. Finally note that the qualitative properties of all coefficients are the same when the dummy quality measure is used as the dependent variable. Since they do not help in the interpretation of the results, they are omitted for space consideration.

6.2 Test of Prediction 2: Quality and Plant Size

A robust empirical finding in the literature is the strong correlation between productivity and size: large producers are generally more productive – see for instance Bernard and Jensen (1995). As the theory developed in section 2 shows, productivity is a strong competitive advantage that allows the firm to produce goods of a certain quality at lower price. Hence productivity directly affects production volume by providing a price advantage. However, it was also shown that productivity leads firms to increase the quality of their products which, holding price fixed, increases demand. This section's goal is to decompose changes in revenues and quantity into a

[36] As explained earlier in footnote 32, I attempt to control for this by allowing factor input intensities to vary across both quality segments. However, this adjustment is unlikely to capture the complexity of the actual evolution of the production processes across quality – especially in the current case where plants produce multiple products.

productivity and a quality component. From the equilibrium revenue given in (11), I define the following regression equation:

$$\ln r_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + \beta_1 \ln R_{BEA,t} + \beta_2 \ln \hat{\omega}_{jt} + \beta_3 \ln \varphi_{jt} + e_{jt} . \qquad (18)$$

where $\boldsymbol{\beta}_{Time}$ and $\boldsymbol{\beta}_{BEA}$ denote a set of time and BEA area fixed effect respectively and serve as a control for the export conditions $(1+n\tau^{-\varepsilon})$, the markup (ρ), and the local market's aggregate price index (P_t). Similarly, from the equilibrium supply equation given in (12), I define:

$$\ln q_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + \beta_1 \ln R_{BEA,t} + \beta_2 \ln \hat{\omega}_{jt} + \beta_3 \ln \varphi_{jt} + e_{jt} \qquad (19)$$

where the fixed effects are controls for the export conditions $(1+n\tau^{-\varepsilon})$, the markup (ρ), the elasticity (ε), the term $(f_o / c_o)\varphi_o^{1-\varepsilon}$, and the local market's aggregate price index (P_t).

Results from estimating these equations are presented in Table 7. Since they are easier to interpret, only results using the quality dummy variable are reported. All the qualitative properties are the same using the continuous quality variable. As expected, the coefficients on quality are large, positive, and statistically significant in both samples. The coefficient in columns (1) and (3) imply that a plant that increases the average quality of its output from low to high will experience a 75 percent increase in demand. Furthermore, from columns (2) and (4), the same plant would see its revenue more than double. In all regressions productivity as a large, positive, and significant impact. A one percentage point increase in productivity results in a 1.6 to 2.3 percentage point increase in size. Finally the results confirm the prediction that, holding productivity and quality fixed, a plant operating in a large market will be larger on average than a plant in a small market. Overall, the results presented in this table are strong evidence that product quality is an important determinant of plant size in addition to productivity and market size.

6.3 Test of Prediction 3: Quality and Export Status

Starting in 1987, the CM contains plant level information on the nominal value of export. It is therefore possible to classify a plant as either an exporter or a non exporter. However, it is not possible to know with certainty if the plant exports bread or another of the product that it manufactures. For the empirical implementation I therefore construct two indicator variables. The first dichotomous variable, X, will take a value of one if the plant reports a positive export value and zero otherwise. The second indicator, XS, will take the value one if, in addition to report positive export value, the plant is a specialized establishment and will be equal to zero otherwise. The idea is that an exporting plant that obtains at least fifty percent of its revenue from bread is likely to export bread products. By definition, the set of plants for which XS takes a value of one is a subsample of the plants for which X takes a value of one.

Table 8 uses the first criterion X and compares the characteristics of exporters and non exporters. The table would be almost identical if XS was used instead. As the model predicts, exporters produce higher quality goods on average. Furthermore, exporters earn greater revenues than non exporters on charge on average a higher price for a unit of output. The results for productivity and quantity are mixed. In the larger Electricity sample exporters are one average more productive and produce more units. The converse is true in the EFM sample.[37] Overall these patterns are consistent with the predictions of the model. A major drawback however is the sensitivity of means to extreme values.

More compelling evidence can be obtained by estimating a series of regressions of plant characteristics on export status. Basically, equations of the form:

$$\ln Z_{jt} = \boldsymbol{\beta}_{Time} + \boldsymbol{\beta}_{BEA} + EX_{jt} + e_{jt}, \qquad (20)$$

where the dependent variable (Z) will, in turn, be quality, price, productivity, revenue, and quantity produced and EX is can be defined as X or XS. The results are presented in Table 9. Note that each cell presents the result of a different linear probability regression model.[38] There are many important points to highlight. First, overall the signs of the coefficients are has expect and support the predictions of the model. The only exceptions are when the XS criterion is used in the Electricity sample. In that case quality is negative but not significant and price is negative and significant. Overall these results indicate that: (i) the average quality of varieties produced by exporters is generally higher than that produced by non exporters;[39] (ii) Exporters are generally more productive. (iii) Exporters are on average larger than non-exporters; (iv) The price pattern is unclear. Second, the pattern of statistical significance is almost the same within sample across the two different measures of export status but very different for both measures across samples. For instance, the EFM sample finds that exporters have higher quality and price but are not different in terms of productivity and size. The converse is true according to the Electricity sample. Finally, these results are not really surprising given the specific characteristics of the bread

[37] The model does not have any prediction about the pattern of cost across export status. However, for the sake of completeness, I report a few basic results. Regressing unit cost on an exporter dummy as well as regional and time series fixed effect and progressively adding productivity and quality controls reveals that exporter do not face a systematically different production cost schedule.

[38] I do not present the results from Probit regressions because of disclosure issues related to changes in sample size. Importantly however, note that the qualitative properties when a Probit estimation is used are the same as those of the linear probability estimators.

[39] It is impossible to make inference about the quality of exported product since only the overall production is observed. In other words I have no information on the characteristics of goods produce for exportation versus goods produced for the domestic market.

industry. While quality and productivity are likely to be important determinant of export status in general, location is likely to be the driving factor in the bread industry. All else equal, plants located close to the Canadian or Mexican border have an enormous advantage over plants located in the middle of the United States. Furthermore, since exporting plants are generally part of large multi-establishment firms and within firm plants are likely to be similar, the explanatory power of plant characteristics across exporting status is greatly reduced. Basically, similar plants belonging to the firm will show up in both the exporter and the non-exporter subset.

6.4 Test of Prediction 4: Quality and Exit Probability

As in many other industries plant turnover is substantial in the bread industry. The simple statistics presented in Table 10 reveal that on average the life expectancy of an establishment is about 15 to 20 years – Recall that periods are 5 years interval. Moreover, while substantial the exit rate is relatively stable over time and across sample.

According to the model, since high quality producer are more profitable, they should be less affected by exogenous aggregate random shocks such as a recession or a change in policy that affects the structure of the industry (e.g. a change in trade policy). In terms of the model, since they are further away from the profitability threshold they are less likely to exit following a change that would increase that threshold. I test this hypothesis by estimating the following regression equation:

$$\Pr\{\text{Exit}\} = \Phi(\boldsymbol{\beta}_{\text{Time}} + \boldsymbol{\beta}_{\text{BEA}} + \beta_1 \ln \hat{\omega}_{jt} + \beta_2 \ln \varphi_{jt}), \tag{20}$$

where $\Phi(\cdot)$ is the c.d.f of the standard normal distribution. The results are presented in Table 11. Column (1) and (4) shows that quality significantly decreases the probability of exit. However it could be the case that quality in fact captures the underlying productivity of the firm. Thus in columns (2) and (5) a measure of productivity is added to the regression. The coefficients' magnitudes are almost identical indicating that quality captures a dimension of market selection distinct from productivity that contributes significantly to explaining the dynamics of the industry. The coefficients on productivity are also large, negative, and statistically significant as expected. Finally, to control for the long term component of survival and focus on the short-run determinants of selection, I include a measure of capital stock. As explained in Olley and Pakes (1996) the later embodies the accumulated effect of plant's past probability draws. As can be seen from columns (3) and (6) including capital as almost no effect on the estimated quality and productivity coefficient. All remain large, negative, and statistically significant. Overall these results support the hypothesis that, in addition to productivity, quality is an important determinant of survival.

6.5 Robustness

In this section I evaluate the sensitivity of the results to some of the assumptions I made during the course of the empirical implementation. First, I look at the impact of changing the geographic size of the market. If the US is a single market and all plants compete against each other, market size (R) is the same for all firms and only controls for aggregate conditions are required. Thus I reestimate every regression equation using only time fixed effects. In another experiment I divide the markets according to state lines. In that case I used a set of time-state fixed effects and define market revenue as the sum of all plant revenue within the state in which the plant is located. Overall the results were qualitatively the same in both cases. Hence changing the geographic size of the market does not have a substantial impact on the conclusions of the analysis.

Second, I look at the impact of changing different aspect of the productivity estimation procedure. Since this is a rather involved component of the analysis I conduct a number of tests. I first reestimate every equation using the more common revenue productivity measure instead of quantity productivity. Further, while the structure of the industry and the description of the actual production process suggests low, if any, degree of economies of scale it is important to assess the impact of the constant returns to scale assumption. This is done by rescaling the factor intensities so that they sum to a constant smaller than one if there is decreasing returns to scale and greater than one if there is increasing returns to scale. I reestimate both the quantity and revenue productivity assuming returns to scale of 0.9 and 1.1. Finally, the degree of specialization – defined as the share of overall revenue a plant obtains from bread products – is set at 50 percent in the baseline specification. Of course this is a rather arbitrary choice. Therefore I reestimate every equation using a threshold of 70 percent. While these amendments are relatively drastic they have surprisingly little effect on the overall results and all the main conclusions remain the same.

Third, in the baseline estimation of the price elasticity of demand I use input prices corrected for the plant's market power. These are defined as the residuals from a regression of input price on a second order polynomial in input quantity purchased. I also construct corrected price using a first, third and higher order polynomial – Powers above the third are sometimes statistically significant but have a negligible magnitude, as a result, I ignore them. I reestimate the equations using the first and third order corrected prices. In both case the results are qualitatively the same. The only notable difference is that the overidentifying restriction tests do not provide evidence of superfluous instruments. Finally, I remove about a hundred plants that produce only roll type bread such as croissants or bagels from the sample. This has no effect on the results.

7. CONCLUSION

The paper test assumptions and predictions of a rigorous general equilibrium model in which heterogeneous firms endogenously choose the quality of their output. In order to deal with endogeneity of output price, the model is implemented using the fraction of locally traded homogenous input prices orthogonal to the plant's market power will be used as instruments for the output price in a 2SLS IV estimation of a demand equation. The estimated price elasticity of demand is then used to infer product quality. The latter is used to confront the predictions of the model to the data. Overall strong support for the model is found using detailed US Census microdata on bread manufactures. The main results are as follow: (i) All else equal, increasing product quality is costly and higher quality goods sell at higher prices; (ii) Once quality is taken into account, an increase in productivity decreases the unit cost of production and leads to lower price; (iii) In addition to being larger and more productive, exporting firms produce higher quality goods on average; (iv) Finally, an increase in product quality, controlling for productivity, reduces the probability of exit.

Overall the analysis demonstrates that, in addition to productivity, taking product quality into account is important to understand many aspects of the firm's behavior such as production, pricing, export, and exit decisions. Further, it brings to the fore an important weakness of widely used productivity estimation procedure. Developing a procedure immune to this quality bias seems a promising avenue for future research.

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9. THEORY APPENDIX

Entry in the differentiated market is assumed to be costly as product development and production start up costs must be disbursed. The entry cost is the same for all potential entrants and is denoted f_e. Prior to entering the industry the plant does not know its productivity. Thus, the value of the investment opportunity is learned only once the fixed entry cost is sunk and the plant learns its productivity φ, which is assumed to be a random draw from the distribution $G(\varphi)$ on support $\Phi \subseteq [1,\infty)$. After learning its productivity, the plant can decide to exit the industry immediately or develop and produce a variety in its preferred market segment. Since profits are increasing in productivity and plants stay in the industry only if profits are non-negative, free entry determines a productivity threshold below which plants will decide to exit the industry. Given the assumption on technology, in a partitioned equilibrium, less profitable plants will choose to produce low quality varieties. The equilibrium *profitability threshold* is therefore the equilibrium zero-profit productivity cutoff for the lowest segment φ_o^*. The zero-profit condition that determines this threshold is given by:

$$\pi_o(\varphi_o^*) = 0 \quad \Leftrightarrow \quad r_o(\varphi_o^*) = \varepsilon f_o . \tag{A.1}$$

Plants that draw an ability below the profitability threshold will exit the industry. Those drawing ability above will engage in profitable production.

Each period producing plants face a probability δ of being hit by an exogenous shock that will force them to exit the industry. Hence, the value of the plant is zero if it draws a productivity below the profitability threshold and exits, and equal to the stream of future profits discounted by the probability of "death" if it draws an ability above the cutoff value and produces. Since profit is the same in every period, the value of the plant, conditional on its productivity, can be expressed as:

$$V(\varphi) = \max\left\{0, \sum_{t=0}^{\infty}(1-\delta)^t \pi(\varphi)\right\} = \max\left\{0, \frac{\pi(\varphi)}{\delta}\right\},$$

where $\pi_i(\varphi) = \pi_i(\varphi) + \max\{0, n\,\pi_i^x(\varphi)\}$ and t is the time index.

The ex-post probability density function for plant productivity, $\mu(\varphi)$ is conditional on successful entry and is truncated at the zero-profit productivity cutoff. Following the literature productivity is assumed to be Pareto distributed.[40] The ex-ante cumulative distribution function of productivity is thus given by $G(\varphi) = 1 - \varphi^{-\sigma}$ where $\sigma > \max\{2, \varepsilon - 1\}$ is a parameter that affects the shape of the distribution.[41] Under these conditions, the conditional ex-post distribution is given by:

$$\mu(\varphi) = \begin{cases} \sigma\varphi_o^{\sigma}\varphi^{-(1+\sigma)} & \text{if } \varphi > \varphi_o \\ 0 & \text{otherwise,} \end{cases}$$

while the ex-ante probability of successful entry in the differentiated industry is given by $\zeta_e \equiv 1 - G(\varphi_o) = \varphi_o^{-\sigma}$. The characteristics of the ex-ante distribution of productivity $G(\varphi)$ are assumed to be common knowledge such that the expected value of entry is identical for all potential entrants and given by the product of the average incumbent's value $(\bar{\pi}/\delta)$ and the ex-

[40] In addition to being tractable, the Pareto distribution provides a reasonable approximation of productivity distribution, see from instance Cabral and Mata (2003). In particular, Helpman, Melitz, and Yeaple (2004) and Helpman, Melitz, and Rubinstein (2007) also assume that productivity is distributed Pareto.

[41] By definition of the Pareto distribution, an increase in the shape parameter σ decreases both the mean and the variance of the productivity and $\sigma > 2$ is required to ensure a finite variance. The assumption that $\sigma > \varepsilon - 1$ is required to ensure well behaved results. For instance, when it is not satisfied average revenue, defined in the Theory Appendix, is negative.

ante probability of successful entry ζ_e. There exists an unbounded set of potential entrants in the differentiated industry. Plants will attempt entry in the industry as long as the expected value from entry is greater then the sunk entry cost f_e. Therefore, the *free entry condition* can be written:

$$V^E \equiv \frac{\zeta_e(\bar{\pi}+\zeta_x n\bar{\pi}^x)}{\delta} = f_e \quad \text{with } \bar{\pi} = \int_{\varphi_o}^{\infty} \pi(\varphi)\mu(\varphi)\,d\varphi \quad \text{and } \bar{\pi}^x = \int_{\varphi_x}^{\infty} \pi^x(\varphi)\mu_x(\varphi)\,d\varphi,$$

where $\mu_x(\varphi) \equiv (\xi_e/\xi_x)\mu(\varphi)$ denotes the probability density function of productivity conditional on exporting and $\xi_x \equiv [1-G(\varphi_x)]/[1-G(\varphi_o)]$ denote the probability of exporting conditional on producing.[42] Given the assumption on the productivity distribution and technologies, the average domestic and export profit are independent of the zero-profit productivity cutoff and can be expressed as a function of preferences, technology and distribution parameters alone. Hence the free entry condition alone pins down the equilibrium value of the threshold as a function of the parameters of the model.

Since all countries are identical, trade is balanced and the share of the total revenue in each country is equal to the income in each country. The equilibrium mass of producing plants in the differentiated industry (M) can be obtained by dividing total revenue $R=(1-\alpha)L$, by the average revenue ($\bar{r}$). The equilibrium threshold and mass of incumbents can be used to obtain an expression for the equilibrium price index defined in (3). By definition, in a stationary equilibrium, every aggregate variable must remain constant over time. This requires a mass of new entrants (M_e) in each period, such that the mass of successful entrants ($\zeta_e M_e$), exactly replaces the mass of incumbents (δM) hit by the exogenous shock and forced to exit. This aggregate stability condition requires $\zeta_e M_e = \delta M$. Finally, it can be shown that:

Proposition. *There exists a unique costly trade open economy equilibrium.*

The zero-profit condition that determines the threshold is given by $\pi(\varphi_0,\omega_0)=0$. From (A.1) this implies that: $r(\varphi_0,\omega_0)=\varepsilon f_0$. Further, from (8), the ratio of revenue functions for plants with different productivity can be expressed as $r(\varphi,\omega_0)/r(\varphi',\omega_0)=(\varphi/\varphi_0')^{\varepsilon-1}$, if they are both produce goods quality of quality ω_0 and $r_i(\varphi)/r_0(\varphi')=(\Omega_i/\Omega_0)(\varphi/\varphi')^{\varepsilon-1}$ if one produce quality ω_i goods while the other produces quality ω_0 goods. These relations can be used to express revenue as a function of the parameters and the equilibrium threshold only. Replacing $\varphi'=\varphi_0$ it follows that:

$$r_0(\varphi)=\varepsilon f_0(\varphi/\varphi_0)^{\varepsilon-1} \text{ and } r(\varphi,\omega_i)=\varepsilon f_0(\Omega_i/\Omega_0)(\varphi/\varphi_0)^{\varepsilon-1}.$$

The average revenue can be obtained by calculating the value of:

$$\bar{r}=\int_{\varphi_o}^{\infty} r(\varphi)\mu(\varphi)d\varphi=\int_{\varphi_o}^{\Delta\varphi_o} r_o(\varphi)\mu(\varphi)d\varphi+\int_{\Delta\varphi_o}^{\infty} r_H(\varphi)\mu(\varphi)d\varphi=\left(\frac{\sigma}{1+\sigma-\varepsilon}\right)\left[1+\left(\frac{\Omega_H-\Omega_o}{\Omega_o}\right)\Delta^{\varepsilon-1-\sigma}\right]\varepsilon f_o,$$

where the second equality follows by definition of average revenue and the last from the expression previously defined and from the properties of the Pareto distribution. From the profit functions defined in (7) it must be the case that $\bar{\pi}=\bar{r}/\varepsilon-\bar{f}$. The average fixed production cost can be obtained by calculating the value of:

$$\bar{f}=f_o\int_{\varphi_o}^{\Delta\varphi_o}\varphi^{-1-\sigma}\,d\varphi+f_H\int_{\Delta\varphi_o}^{\infty}\varphi^{-1-\sigma}\,d\varphi=(1-\Delta^{-\sigma})f_o+\Delta^{-\sigma}f_H.$$

[42] Also note that, by definition, $\xi_e\xi_x = 1-G(\varphi_x)$ is the unconditional probability of exporting.

The average extra profit from the export market, average (overall) revenue and average export price are obtained by evaluating:

$$\bar{\pi}_x = \int_{\varphi_o^x}^{\infty} \pi^x(\varphi)\,\mu_x(\varphi)\,d\varphi = \int_{\Delta_x \varphi_o^x}^{\Delta\varphi_o} \left[\frac{\tau^{1-\varepsilon} r_o(\varphi)}{\varepsilon} - f_x\right]\mu_x(\varphi)\,d\varphi + \int_{\Delta\varphi_o}^{\infty} \left[\frac{\tau^{1-\varepsilon} r_H(\varphi)}{\varepsilon} - f_x\right]\mu_x(\varphi)\,d\varphi,$$

$$\bar{r} = \int_{\varphi_o}^{\infty} r(\varphi)\,\mu(\varphi)\,d\varphi$$

$$= \int_{\varphi_o}^{\Delta_x\varphi_o} r_o(\varphi)\,\mu(\varphi)\,d\varphi + \int_{\Delta_x\varphi_o}^{\Delta\varphi_o} (1+n\tau^{1-\varepsilon}) r_o(\varphi)\,\mu(\varphi)\,d\varphi + \int_{\Delta\varphi_o}^{\infty} (1+n\tau^{1-\varepsilon}) r_H(\varphi)\,\mu_x(\varphi)\,d\varphi.$$

By definition of the revenue function, in equilibrium it must be the case that: $r_o(\varphi_o) \equiv p_o(\varphi_o) q(\varphi_o) = \varepsilon f_o$, where the equality follows from (9.1). This implies that the optimal quantity of low variety produced by the marginal entrant is given by: $q_o(\varphi_o) = \varepsilon f_o \rho\, \varphi_o / c(\omega_o)$. From the optimal demand (3), and the pricing rule (5), it can be shown that:

$$q_o(\varphi)/q_o(\varphi') = (\varphi/\varphi')^{\varepsilon} \text{ and } q_i(\varphi)/q_0(\varphi') = (\varphi'/\varphi)^{\varepsilon}(\Omega_i/\Omega_0).$$

Since, by definition $r_i^x(\varphi) = \tau^{1-\varepsilon} r_i(\varphi)$ and it must be the case that $p_o^x(\varphi) q_o^x(\varphi) = \tau^{1-\varepsilon} p_o(\varphi) q_o(\varphi)$ which implies that $q_o^x(\varphi) = \varepsilon\rho f_o \varphi_o^{1-\varepsilon} \tau^{-\varepsilon} c(\omega_o)^{-1} \varphi^{\varepsilon}$. Using this result and the fact that the plant-level production of high quality is given by $q_H^x(\varphi) = (\Omega_H/\Omega_o) q_o^x(\varphi)$ it is possible to calculate the output per segment for domestic and foreign sales defined as follow: $O_o^D \equiv M\int_{\varphi_o}^{\Delta\varphi_o} q_o(\varphi)\,\mu(\varphi)\,d\varphi$, $O_H^D \equiv M\int_{\Delta\varphi_o}^{\infty} q_H(\varphi)\,\mu(\varphi)\,d\varphi$, $O_o^x \equiv M\int_{\Delta_x\varphi_o}^{\Delta\varphi_o} n\, q_o^x(\varphi)\,\mu(\varphi)\,d\varphi$, and $O_H^X \equiv M\int_{\Delta\varphi_o}^{\infty} n\, q_H^x(\varphi)\,\mu(\varphi)\,d\varphi$. Finally note that $q_i^x(\varphi) = \tau^{-\varepsilon} q_i(\varphi)$, such that $s_i^x(\varphi) \equiv n q_i^x(\varphi) / [q_i(\varphi) + n q_i^x(\varphi)]$ leads to the result in the text.

10. DATA APPENDIX

The CM contains two measures of *quantity produced (q).* The product quantity shipped (PQS) records the quantity produced by the firm at the 7 digit level. For product with typically wide fluctuations in finished good inventories the CM also reports the product quantity produced (PQP). I use the latter when available. The *real revenue (r)* is the sum of the establishment's product value (PV) across all products within the industry deflated using the shipment deflator (PISHIP) from the NBER productivity data base for the corresponding year. The *real output price (p)* is measured by dividing the real revenue by the number of units produced. The *real market revenue (R)* is obtain by taking the sum over real revenue (r) across all plants – not only those in the samples.[43] This implies that the real revenue is the same across both samples.

The plant level real price of energy is defined as the energy expenditure (EE) divided by the purchased energy (PE) adjusted to obtain a real variable using an energy deflator (PIEN). For each state-year pair in the sample I run a regression of this real price on a polynomial in the quantity purchased. The residual from that regression is used as the instrument for the *price of electricity*. The real material prices are obtain in a similar fashion. First I obtain the unit cost of a specific 4 Digit SIC input (dry milk 2023 and flour 2041) by dividing the total cost by the quantity purchased (TVMC/MQDC) using information from the material trailer of the CM. Then use the PISHIP deflator from the NBER CES to obtain a real price of input. I then regress this real price on the quantity purchased to obtain the real price of material that will be used as an instrument. Note that since the sample is relatively small I cannot run separate regressions for each year, BEA area. However I include controls for regional variation. Finally, note that all plants in the CM are used to calculate the impact of market power not only plants in the bread industry.

The *Specialization* is evaluated by dividing the reported nominal value of total shipment (TVS) by the reported nominal product value of shipment (PV) in the bread industry (2051) – I sum over all PV within an establishment. This provides a concentration ratio. Establishments for which the concentration ration is more than 50% are considered specialized. The real capital stock is the plants' reported book values for their structure and equipment capital stocks deflated to 1987 levels using sector-specific deflators from the Bureau of Economic multiplied by the concentration ratio. The cost of capital is constructed by multiplying real capital stock value by the capital rental rates for the plant's respective two-digit industry. These rental rates are from unpublished data constructed and used by the Bureau of Labor Statistics in computing their Multifactor Productivity series – See Foster, Haltiwanger, and Syverson (2008) for additional details and sources. Labor inputs are measured as plants' reported production-worker hours (TH) multiplied by the ratio of total payroll to payroll for production workers and the concentration ratio. The real cost of labor is obtained by multiplying the employment by the real wage. The later is defined at the BEA area level as the average reported wage in for all plant in the bread industry (SIC 2041) in 1987. Materials and energy inputs are plants' reported expenditures on each deflated using the corresponding input price indices from the NBER Productivity Database multiplied by the concentration ratio. Finally, the *real unit cost (c)* is defined as real total cost divided by quantity, where the total real cost is defined as the sum of real labor cost, real capital cost and real material costs.

[43] I remove AR and other observations with imputed value.

Table 1. Sample Characteristics

Year	*Electricity,Flour, and Milk Sample*			*Electricity Sample*		
	Plants	Share of Revenue	Share of Output	Plants	Share of Revenue	Share of Output
1972	549	0.16	0.15	869	0.14	0.13
1977	432	0.15	0.14	691	0.13	0.12
1982	397	0.20	0.19	671	0.19	0.18
1987	326	0.19	0.19	590	0.20	0.20
1992	303	0.15	0.18	621	0.17	0.19
1997	240	0.14	0.15	603	0.17	0.19
Total	2,247	1	1	4,045	1	1

Notes: This table shows the number of plants per year in each samples as well as the year's share of total revenue and quantity in the sample (pooled across years). When only specialized plants are considered the shares are almost the same and the number of plants is also decreasing over time.

Table 2. Descriptive Statistics

Panel A. Electricity, Flour, and Milk Sample (N = 2,247)					
Quantity Produced	Output Price	Electricity Price	Flour Price	Milk Price	Market Size
25,118	0.59	0.04	0.22	3.22	125,473
(26,104)	(0.24)	(0.03)	(0.29)	(4.92)	(180,968)
Panel B. Electricity Sample (N = 4,045)					
Quantity Produced	Output Price	Electricity Price	Market Size		
20,034	0.62	0.05	151,787		
(25,274)	(0.29)	(0.03)	(196,914)		

Notes: This table present mean and standard deviation (in parenthesis) of the demand equation variables. Quantity is measured in 1,000 pounds of bread (baked weight). Output, flour and milk price are measured in real (1987) dollar per pound, while the electricity price is measured in real dollar per KW/hr. The Market size is defined as the total real revenue measured in thousands of real dollars in the BEA area where the plant is located. The average market size varies across samples due to variation in the number of BEA areas present. There are respectively 164 and 170 areas in Panel A and B out of a possible 172. The number of plants in each sample (N) is indicated in parenthesis at the top of each panel.

Table 3. Price Elasticities

	Electricity, Flour, and Milk Sample		Electricity Sample	
Estimation:	OLS	IV	OLS	IV
	(1)	(2)	(3)	(4)
Elasticity (ε)	-2.35	-3.74	-2.24	-10.1
	(0.15)***	(0.66)***	(0.10)***	(2.06)***
Market Size (lnR)	0.30	0.30	0.37	0.42
	(0.07)***	(0.07)***	(0.05)***	(0.13)***
Sample Size	2,247	2,247	4,045	4,045
R^2	0.34		0.34	
S.E of reg.	1.42	1.42	1.57	3.15
1st stage F		14.59		21.97
Shea's R^2		0.04		0.01

Notes: The dependent variable is log quantity produced (lnq). In addition to the reported variables, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.

Table 4. The Impact of Quality on Cost

	Elect., Flour, Milk Sample			Electricity Sample		
Dependent:	Cost (lnc)		Material	Cost (lnc)		Material
	(1)	(2)	(3)	(4)	(5)	(6)
Quality (lnω)	0.05			0.02		
	(0.01)***			(0.003)***		
Quality Dummy		0.10	0.15		0.08	0.15
		(0.02)***	(0.01)***		(0.02)***	(0.01)***
Productivity (lnφ)	-1.04	-1.03	-0.62	-1.00	-1.01	-0.58
	(0.03)***	(0.03)***	(0.02)***	(0.02)***	(0.02)***	(0.02)***
Sample Size	1,517	1,517	1,517	2,815	2,815	2,815
R^2	0.83	0.83	0.71	0.85	0.85	0.64
S.E of reg.	0.33	0.32	0.19	0.34	0.34	0.25

Notes: In addition to the reported variables, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.

Table 5. The Impact of Quality on Price

Panel A.	*E, F, M*	*Electricity*
	(1)	(2)
Quality Dummy	0.29	0.34
	(0.01)***	(0.01)***
Productivity (lnφ)	-0.48	-0.37
	(0.02)***	(0.02)***
Sample Size	1,517	2,815
R^2	0.73	0.76
S.E of reg.	0.17	0.18
Panel B.	*E, F, M*	*Electricity*
	(3)	(4)
Price (lnp)	0.71	0.99
	(0.05)***	(0.03)***
Sample Size	1,517	2,815
R^2	0.26	0.46
S.E of reg.	0.45	0.38

Notes: In addition to the reported variables, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.

Table 6. Product Quality and Sorting

	E, F, and M Sample		*Electricity Sample*	
	(1)	(2)	(3)	(4)
Quantity Productivity	0.56		-2.48	
	(0.13)***		(0.19)***	
Revenue Productivity		2.69		2.51
		(0.10)***		(0.23)***
Sample Size	1,517	1,517	2,815	2,815
R^2	0.10	0.55	0.17	0.11
S.E of reg.	1.19	0.84	2.82	2.93

Notes: The dependent variable is log quality produced (lnω). In addition to the reported variable, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.

Table 7. The Impact of Product Quality on Plant Size

	E, F, and M Sample		*Electricity Sample*	
Dependent:	Quantity (lnq)	Revenue (lnr)	Quantity (lnq)	Revenue (lnr)
	(1)	(2)	(3)	(4)
Quality Dummy	0.73	1.02	0.75	1.09
	(0.04)***	(0.04)***	(0.03)***	(0.04)***
Productivity (lnφ)	2.04	1.56	2.29	1.92
	(0.05)***	(0.05)***	(0.05)***	(0.05)***
Market Size (lnR)	0.11	0.16	0.09	0.13
	(0.03)***	(0.04)***	(0.03)***	(0.03)***
Sample Size	1,517	1,517	2,815	2,815
R^2	0.83	0.79	0.76	0.69
S.E of reg.	0.51	0.53	0.73	0.75

Notes: In addition to the reported variables, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.

Table 8. Exporters v.s Non exporters Characteristics

Panel A.	*Electricity, Flour, and Milk Sample*				
	Quality	Price	Productivity	Revenue	Quantity
	(1)	(2)	(3)	(4)	(5)
Non Exporter	-0.04	0.57	3.87	16,433	33,465
	(1.62)	(0.30)	(0.54)	(17,572)	(33,915)
N	819	819	632	819	819
Exporter	0.73	0.72	3.85	19,825	32,618
	(1.93)	(0.35)	(0.50)	(18,497)	(28,651)
N	50	50	32	50	50
Panel B.	*Electricity Sample*				
	Quality	Price	Productivity	Revenue	Quantity
	(6)	(7)	(8)	(9)	(10)
Non Exporter	-0.22	0.60	3.74	12,264	25,670
	(3.55)	(0.34)	(0.61)	(15,553)	(31,842)
N	1,709	1,709	1,353	1,709	1,709
Exporter	0.61	0.64	3.9	14,510	26,251
	(4.36)	(0.31)	(0.51)	(15,647)	(25,914)
N	102	102	69	102	102

Notes: This table presents the mean and standard deviation (in parenthesis) of some plant characteristics. The sample sizes are smaller than in previous table because the export information in the CM is available only from 1987 to 1997. Quality and productivity are in logs, while price, revenue, and quantity are in level. The output price is measured in real (1987) dollar per pound, revenue is measured in thousand of real dollar, and quantity is measured in 1,000 pounds of bread (baked weight). The number of plant observation (N) is lower for productivity because of the specialization criterion.

Table 9. Export Status and Firm Characteristics

	EFM Sample		Electricity Sample	
Independent:	X	XS	X	XS
	(1)	(2)	(3)	(4)
Quality (lnω)	0.89	0.98	0.59	-0.32
	(0.31)***	(0.37)***	(0.50)	(0.57)
Price (lnp)	0.19	0.05	0.01	-0.14
	(0.07)***	(0.09)	(0.05)	(0.06)**
Productivity (lnφ)	0.01	0.01	0.26	0.26
	(0.11)	(0.11)	(0.08)***	(0.08)***
Revenue (lnr)	0.39	0.85	0.54	0.95
	(0.27)	(0.25)***	(0.20)***	(0.19)***
Quantity (lnq)	0.20	0.80	0.53	1.08
	(0.29)	(0.25)***	(0.21)**	(0.20)***

Notes: The independent variable X is a binary variable equal to 1 if the plant is classified as an exporter and 0 otherwise. The variable XS further requires that the plant be specialized in the production of bread – this increases the probability that the plant does export bread and not some other product(s). Each cell the result of a separate linear probability regression whose dependent variable is listed on the left hand side of the table. Every regression includes both Year and BEA fixed effects. Robust standard errors are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively. The sample sizes are respectively 869 and 1811 for the EFM and Electricity samples. The number of observation drops to 664 and 1422 respectively for the productivity regressions because of the additional specialization criterion.

Table 10. Exit Rates

	E, F, and M Sample		Electricity Sample	
Year	Exit	Exit Rate	Exit	Exit Rate
1972	72	0.24	171	0.35
1977	57	0.24	124	0.33
1982	85	0.28	193	0.36
1987	52	0.20	116	0.24
1992	65	0.29	162	0.34
Total	329	0.25	766	0.33

Notes: This table present the number of plant included in the samples that exit the industry in each period as well as the exit rate defined as the number of plant in the sample that exit the industry in a period divided by the number of plant in the sample.

Table 11. Product Quality and Exit Probability

	E, F, and M Sample			*Electricity Sample*		
	(1)	(2)	(3)	(4)	(5)	(6)
Quality (lnω)	-0.34	-0.32	-0.32	-0.07	-0.11	-0.11
	(0.04)***	(0.04)***	(0.04)***	(0.01)***	(0.01)***	(0.01)***
Productivity (lnφ)		-0.39	-0.38		-0.81	-0.79
		(0.12)***	(0.12)***		(0.07)***	(0.07)***
Capital Stock (lnk)			0.24			0.30
			(0.24)			(0.15)*
Sample Size	1,208	1,208	1,208	2,226	2,226	2,226
log Likelihood	-612	-607	-606	-1312	-1245	-1243

Notes: The dependent variable is a binary variable equal to 1 if the plant exits the industry during the period and 0 otherwise. Each column presents the result from a probit regression. In addition to the reported variables, every regression includes both Year and BEA fixed effects. Robust standard errors (clustered by plants) are in parenthesis. The ***, **, and * sign denote p-values lower than 0.01, 0.05, and 0.1 respectively.