Price and Quality Dynamics in Export Markets

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Abstract

This paper investigates the evolution firm-level price and quality choices in export markets. We develop a model of heterogeneous firms who make endogenous entry decisions across distinct international markets. In each year, firms endogenously choose its optimal price and product quality to a build customer base in each market. Consistent with existing research, more productive firms in our model produce higher quality products, charge higher prices, sell more units and achieve higher profits. However, in our model firm-level quality, price and revenues endogenously evolve over time. New exporters optimally charge relatively low prices and produce low quality goods upon initial entry into export markets. As sales grow exporters upgrade product quality and prices to exploit their brand reputation and charge higher prices. We structurally estimate the model using detailed Chinese customs data. Our results indicate that dynamic considerations *reduce* predicted export prices upon initial entry into new markets by 1 percent. However, both product quality and prices are predicted to be 6-7 percent *higher* than that predicted by the static model five years after initial entry into export markets. The estimated model indicates that while new exporters often produce relatively low quality and inexpensive goods, product quality and prices rise among surviving exporters in subsequent years.

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How do firms successfully grow in export markets? While encouraging exporting plays a prominent role in the development plan of many emerging markets, how small, new entrants successfully evolve into large, established exporters remains an open question. This paper investigates the evolution of firm-specific prices, product quality and sales in export markets. In particular, we document that differences in *past* firm performance strongly influence the evolution of *future* firm prices, product quality and sales in a given product market. We build a parsimonious, dynamic model where firms optimally chooses prices and product quality to maximize the long-run growth of the firm. The model is structurally estimated using a rich set of Chinese customs data. Using the structurally estimated model we are able to disentangle static and dynamic pricing incentives. Our preliminary results indicate that dynamic considerations *reduce* predicted export prices upon initial entry into new markets by 1 percent. However, product quality and prices are also predicted to be 6-7 percent *higher* than that predicted by the static model five years after initial entry into export markets. The estimated model suggests that while new exporters often produce relatively low quality and inexpensive goods, product quality and prices rise among surviving exporters in subsequent years.

Our model relies on a rich literature which describes, documents and predicts firm-level input and output quality choices, their relationship with pricing decisions and the impact these have on firm profitability. In fact, our dynamic framework builds directly on the associated static models developed by Verhoogen (2008), Baldwin and Harrigan (2011), and Manova and Zhang (2012a). Not surprisingly, our theoretical structure captures many of same, well-known cross-sectional patterns. However, the dynamic nature of our model allows us to investigate the intertemporal, within-firm tradeoffs associated with entry and growth in new export markets.

There is mounting evidence that idiosyncratic differences in product demand account for a large percentage of sales across markets (Foster et al, 2008; Gervais, 2012; Roberts et al, 2012; Hu et al, 2014). Our model provides a theoretical motivation for the source and growth firm-level demand heterogeneity: brand loyalty. Specifically, in our model firms endogenously choose their initial entry price and product quality to maximize long-run profits. Further, prices, quality and demand evolve together at the firm, product and market-level to reflect both the firm's comparative advantage relative to its competitors and the preferences of consumers in a particular market. Specifically, products which provide "good value" - high quality products for a given price - to consumers tend to have higher initial sales. These firms, in turn, are able to exploit their brand reputation in later years to charge higher prices and markups.

To quantify the dynamic implications of our model we draw on rich firm and product-level information from Chinese customs records. We observe physical sales and output prices of individual firms for every manufacturing export transaction between 2000 and 2006. This is matched with data capturing firm-level imports and import prices. We document three important features of this data. First, positive deviations from long-run average sales in the current year are strongly, positively correlated with positive deviations from long-run average sales in future periods. That is, greater current sales are strongly associated with greater future sales. Second, Chinese exporters initially enter new markets at relatively low prices. As sales grow, however, so do firm-level prices. Increasing prices may be indicative of increasing markups, but it might reflect changes in product quality and input costs. Last, consistent the preceding conjecture, we show that as firms expand into export markets the price paid for imported inputs also rises. We roughly interpret this last finding as suggesting that product quality also improves as exporters gain a foothold in new export markets.

Our work is closely related to the literature which studies the evolution of firms in new markets. The model shares much of the same intuition as that from Foster et al. (2013) even though its structure is substantially different. In both models, new entrants in a given market account for the long-run impact that current pricing decisions will have on future sales and profits. However, in their context they focus on the entry of new firms in the US domestic market, while we study the entry decisions exporters across a diverse set of worldwide export markets. Firm-level turnover in export markets is well known to be much higher than that in domestic markets. In our model the static and dynamic pricing incentives may potentially diverge widely across firms with different expectations of market success and survival. Additionally, in our model, past success not only affects pricing, but also product quality. Together, pricing and product quality, affect the evolution of sales and the markets in which firms enter. Manova and Zhang (2012b) document that not only larger Chinese exporters produce higher quality products, but that high quality producers sell a disproportionate percentage of exports in relatively wealthy and developed countries. In our model, these market-level characteristics in turn affect the evolution of prices, quality and the pattern of sales across countries.

This is work builds on at least three branches of the literature studying firm-level trade. First, it is related to models that study of firm-level heterogeneity and export entry decisions. Similar to the seminal contributions from Eaton and Kortum (2002) and Melitz (2003) our model begins by studying how initial differences in firm-productivity lead to ex-post differences in export behavior. Second, our work is motivated by numerous pieces which extend these frameworks to examine static differences in pricing or markups across firms and countries (Bernard et al., 2003; Melitz and Ottaviano, 2008; Katayama et al., 2009; De Loecker, 2011; Kugler and Verhoogen, 2012; Manova and Zhang, 2012a), firm-level heterogeneity in demand or product quality (Foster et al., 2008; Hallak and Sivadasan, 2009; Khandelwal, 2010; Baldwin and Harrigan, 2011; Manova and Zhang, 2012b; Crozet et al., 2012; Gervais, 2012; Kugler and Verhoogen, 2012; Roberts et al., 2012; Hu et al., 2013), and the impact of exporting on product quality upgrading (Verhoogen, 2008; Flach, 2013; Eslava, Fieler and Xu, 2014).[1]

Finally, our work relates to studies of exporter dynamics and, particularly, the mechanisms

[1] The paper is also related to papers which examine the role of product quality in international trade, including Gabszewicz et al. (1982), Flam and Helpman (1987), Feenstra (1988), Feenstra (1994), Schott (2004), Hummels and Skiba (2004), Hummels and Klenow (2005), Broda and Weinstein (2006), Brooks (2006), Hallak (2006), Mandel (2010), Khandelwal (2010) and, Hallak and Schott (2011).

by which successful entrants grow into large, stable exporters. As such, our work closely relates to that Melitz and Costantini (2008), Atkeson and Burstein (2010) and Arkolakis (2013). Like these papers we allow for differences in productivity across firms, but unlike these papers the key source of firm-level dynamics is not due to active decisions to influence the evolution of productivity. Rather, here the key firm-level dynamics evolve through the active manipulation of price and quality by firms to optimally grow market share given the firm's expected duration in a given market.

Our paper proceeds as follows. Section 1 documents our key stylized facts, while Section 2 develops a model consistent with these facts. Sections 3 and 4 present our empirical model and describe the estimation strategy. Section 5 collects our empirical estimates and reports the model's performance. Section 6 discusses the implications of trade liberalization on firm-level price and quality decisions over time, while Section 7 concludes.

1 Data and Stylized Facts

Our data is collected by the Chinese Customs Office and reports detailed product-level export and import information between 2000 and 2006. Specifically, the data report the f.o.b value, quantity and price from firm-level exports across products and destination countries.[2] These dimensions of the data allow us to study the evolution of firm, product and destination-specific market prices through time. A second advantage of our data set is that it also collects the intermediate material prices for imported inputs at the firm-level. Following Manova and Zhang (2011) we use this as a key determinant of input quality and, for now, a rough proxy of product quality.

Our primary objective here is to provide a simple characterization of the nature of firm-level price and quality dynamics in international markets using the Chinese customs records. To accomplish this goal, we start by presenting two sets of findings. The first set examines the variation in prices and quantities for one quality-differentiated industry, the electric heater industry.[3] We choose to study one particular industry so that we can pinpoint the nature of price and quality differentiation across firms. Further, we will only be able to confidently compute our structural model at the industry level and, as such, it is important verify that we are studying patterns which are robust even within a narrowly defined industry. Second, we also document the same set of findings for the full set of Chinese exporters over the 2000-2006 period. This not only allows us to use our largest possible sample, but also provides us with a sense that the patterns we observe in this industry hold broadly for many traded products. In both cases, we only study privately owned firms which are engaged in "ordinary trade;" that is, we exclude all

[2]Products are recorded at the eight-digit level in the Chinese Harmonized System.

[3]We select this industry using highly disaggregated industry codes. Further disaggregation greatly reduces the number of producers included in our study.

foreign-owned firms, state-owned firms and firms which are involved in processing trade. While this reduces our sample, it allows us to study firms which arguably trade under the same set of market institutions.

Among industries we could choose to focus on, we choose the electric heater industry for four key reasons. First, the electric heater industry is a typical Chinese export-oriented manufacturing industry which exports to a wide set destinations worldwide. Second, by focussing on the set of firms which specialize in electric heaters we are confident that we are comparing firms which are direct competitors across worldwide markets. Third, electric products and appliances in general, and electric heaters in particular, represent a product group with a wide scope for quality differences. Fourth, nearly all of the firms in the electric heater industry, import intermediate inputs from abroad. As such, we will have highly detailed data regarding the inputs used in production among these firms.

Given this data, we document three robust patterns which characterize our data. Specifically, we study on how past performance influences future within-firm changes in sales, output prices and input prices.[4] Our simple exercise is to regress a current firm-level characteristic in a given market (sales, output price, average input price), denoted by x_{ijmt}, on past performance in that market

$$\ln(x_{ijmt}) = \alpha + \beta \ln(Q_{ijm,t-1}) + \Gamma_{ij} + \Gamma_{jmt} + \epsilon_{ijmt} \tag{1}$$

where past performance is measured as past physical sales $Q_{ijm,t-1}$ in that market, Γ_{ij} is a firm-product fixed effect, Γ_{jmt} is a product-destination-year fixed effect, and i, j, m and t index firms, products, destination markets and years, respectively. We include the firm-product fixed effects to capture unobserved differences in productivity and product-destination-year fixed effects to capture shocks to specific export markets.

We expect that firms with larger past sales will be able to enjoy relatively large sales in the future if consumers are loyal to a particular brand. Moreover, if firms recognize that large past sales are indicative of stronger market power in future periods, we predict that past sales and future prices will be positively correlated. Finally, high prices and high past sales may also be indicative of firm-level differences in product quality. We investigate each of these below.

Fact 1: Current sales are positively correlated with future sales.

We find that firms with greater current sales in a given market are more likely to have greater sales in the future. Table 1 documents that the coefficient on current sales, β, is always positive and highly significant. The coefficient ranges between 0.507 in the full sample of Chinese exporters to 0.746 in the electric heater industry.

[4]The cross-sectional relationship between plant-size, output prices and input prices has well established in the literature. See Kugler and Verhoogen (2012) for an example.

Table 1: Correlation Between Current and Past Market Sales

	Electric Heaters		All Exporters	
Past Market Sales	0.647	0.746	0.786	0.507
	[0.014]	[0.017]	[0.002]	[0.002]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Product Fixed Effects	No	Yes	No	Yes
Obs.	2249		93907	

Notes: The above table reports the estimated coefficients from an OLS regression of past sales in a given export market on current sales in the same export market. Robust standard-errors in brackets. Columns 1 and 2 report estimates from the electric heater industry, while columns 3 and 4 report results across all industries. Columns 2 and 4 include firm-product fixed effects, while columns 1 and 3 do not.

A common explanation for this pattern would be that there are large, persistent unobserved differences across firms, such as productivity differences, which largely determine firm performance in any period. We do not dispute this interpretation whatsoever, but rather note that our estimate already controls for persistent unobserved firm-and-product effects, such as productivity. Rather, our intent is to examine how current departures from average sales are correlated with future departures from average sales. That is, even after controlling for persistent firm and product differences we find that firms which experience relatively large current sales in a particular market may reasonably expect to have relatively large future sales in that same market.

Fact 2: Current sales are positively correlated with future output prices.

The second robust empirical pattern we find is that current prices, in a given destination market, are positively correlated to past sales in that same market. Again, we are particularly interested in the correlation between past and future prices within the same firm, rather than across firms. It is well established that there is often a strong positive correlation between measures of firm size and output prices (see Kugler and Verhoogen, 2012, for example).

Table 2: Correlation Between Current Market Prices and Past Market Sales

	Electric Heaters		All Exporters	
Past Market Sales	0.159	0.120	0.035	0.050
	[0.012]	[0.015]	[0.001]	[0.002]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Product Fixed Effects	No	Yes	No	Yes
Obs.	2249		93907	

Notes: The above table reports the estimated coefficients from an OLS regression of past sales in a given export market on current output prices in the same export market. Robust standard-errors in brackets. Columns 1 and 2 report estimates from the electric heater industry, while columns 3 and 4 report results across all industries. Columns 2 and 4 include firm-product fixed effects, while columns 1 and 3 do not.

Examining changes within-firms allows us to consider how departures from average sales are related to future prices. Columns (2) and (4) of Table 2 report that the coefficient on past sales is 0.050 in the electric heater industry and 0.120 in the full sample, after conditioning on firm-product fixed effects. This suggests that firms which saw their sales increase in the past are likely to increase their prices in the next period. One potential interpretation of this pattern is that firms who have successfully gained a foothold in a market exploit consumer loyalty over time by increasing their markups. Alternatively, successful firms with growing sales are likely to be those firms which also actively improving product quality to meet consumer demands. We explore this alternative explanation below.

Fact 3: Current sales are positively correlated with future input prices.

Exploring the correlation between past sales and product quality is inherently difficult since product quality is unobserved. Following a number of papers we will begin by using the average imported input price as a rough proxy of the quality of inputs used in production and, thus, product quality (see Manova and Zhang (2012b) for examples and citations). A first order difficulty with our exercise is that while sales evolve market-by-market, we only observe input prices at the firm-level. Thus, if the firm produces multiple products, or one product with different varieties, we cannot attribute the input price accordingly in our simple regression. In Section 2, we explicitly model the firm's input purchasing decision and use the model's structure to attribute variation in input prices to the quality-level chosen for different markets worldwide. However, without presenting all of the model features we also wish to document some basic correlation between sales and input prices, should it exist. As such, we repeat our experiment using the average the current log imported input price as the dependent variable and regress it on a measure of total past export sales at the firm-level, instead of using a market-specific measure of sales. Likewise, market-year-product dummies are replaced with year-product fixed effects.

Table 3: Correlation Between Current Import Prices and Past Aggregate Export Sales

	Electric Heaters		All Exporters	
Past Export Sales	-0.029	0.044	-0.066	0.023
	[0.020]	[0.008]	[0.005]	[0.003]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Product Fixed Effects	No	Yes	No	Yes
Obs.	1375		48790	

Notes: The above table reports the estimated coefficients from an OLS regression of past sales across all export markets on the average firm-level import price in the current year. Robust standard-errors in brackets. Columns 1 and 2 report estimates from the electric heater industry, while columns 3 and 4 report results across all industries. Columns 2 and 4 include firm-product fixed effects, while columns 1 and 3 do not.

Table 3 documents that after controlling for firm-product fixed effects there remains positive correlation between current input prices and past sales. The coefficient on past sales ranges between 0.044 in the electric heater industry and 0.023 in the full sample and both are strongly significant. We note that although we have only included firms which import intermediate inputs in this regression, the large majority of firms in our sample do so.[5] Overall, we cannot rule out the possibility that improvements in past performance lead to firms to improve product quality and, thus, charge higher prices in output markets. Disentangling these various effects and quantifying the impact of firm-level behavior will require substantially more structure than provided by our simple regression.

2 A Model of Firm-Level Price and Quality Dynamics

2.1 Consumers

Each country, c, is populated by N_c consumers with identical preferences. Each consumer is endowed with L units of labor which they supply inelastically to produce either a quality differentiated intermediate input ι_c or a non-differentiated, numeraire good k. The consumer's preferences over final goods in period t can be described by the following utility function

$$U_{ct}(k,\omega) = u_{ct}(k) + \theta[Q_{c,t-1}(\omega), \bar{I}_c]q_{ct}(\omega) + \varepsilon_{ct}(\omega)$$

where k is the consumption of a non-differentiated numeraire good, $q_{ct}(\omega)$ is the quality of the differentiated final product ω, and ε_{ct} is random consumer-specific product taste shock. As we show below it is convenient to assume that ε_{ct} is independent and identically distributed across consumers and time by a Type 1 extreme-value distribution. $U_{ct}(k,\omega)$ is the consumer's utility if they consume 1 unit of product ω and k units of the numeraire good.

The function $\theta[Q_{ct-1}(\omega), \bar{I}_{ct}]$ captures consumers' taste for quality, which we assume is a function of $Q_{c,t-1}(\omega)$, past market sales of variety ω by the end of period $t-1$, and $\bar{I}_c$, is the steady state income level in country c which we assume is constant over time. The taste for quality function, θ, is assumed to be increasing in $Q_{c,t-1}(w)$ and $\bar{I}_c$,

$$\theta_1 = \frac{d\theta}{dQ_{c,t-1}} > 0 \text{ and } \theta_2 = \frac{d\theta}{d\bar{I}_c} > 0. \tag{2}$$

The second part of (2) implies that consumers in richer markets place a higher weight on product quality than consumers in poorer destinations, since rich consumers are willing to pay more for a product of the same quality than poor consumers. The first part of (2) implies that the more a firm has previously sold in a given market, the more consumers from that market are willing to pay for the same quality. We refer to this tendency as a "loyalty effect:" firms which

[5]In the electric heater industry 90 percent of firms import intermediate inputs. While many firms also import in the full sample, it is important to note that there is substantial variation across industries.

sell more in a market build their brand reputation. Under the assumption that consumers form loyalties to more recognizable brands, they will also be willing to pay more for the same good as sales grow. It is reasonable to impose an upper bound for this effect; that is, beyond some threshold level of sales we expect that consumer loyalty will not grow any more. Specifically, we modify equation (2) as follows to reflect the threshold level of sales:

$$\begin{aligned}
\theta_1 &= \frac{d\theta}{dQ_{c,t-1}} > 0, \text{ if } Q_{c,t-1} < \overline{Q}_c \\
\theta_1 &= \frac{d\theta}{dQ_{c,t-1}} = 0, \text{ if } Q_{c,t-1} \geq \overline{Q}_c \\
\theta_2 &= \frac{d\theta}{d\bar{I}_c} > 0
\end{aligned} \tag{3}$$

2.2 Non-differentiated production

Entry into the non-differentiated sector is free and these goods are produced solely by labor, $k_{ct} = a_c^k L_{ckt}$ where L_{ckt} is the aggregate amount of labor devoted to producing good k in market c and a_c^k is the productivity of country c in producing k type goods. Perfectly competitive firms will hire labor from consumers up to the point that the value of the marginal product of labor is equal to its wage, w_k: $p_{ckt} MP_L^k = w_{ckt} \Rightarrow p_{ckt} a_c^k = w_{ckt}$. Normalizing the price of non-differentiated goods to 1, we find that a unit of labor can always earn a wage $w_{ckt} = a_c^k$ in the non-differentiated sector, as long as k is produced.[6]

2.3 Intermediate production

Each country also produces a range of country-specific, quality-differentiated, intermediate inputs. Differentiated inputs ι are produced according to $\iota_{ct}(q_\iota) = L_{c\iota t}(q_\iota)/q_\iota$ where $q_\iota \in (0, \infty)$ is an index of the quality of input ι and $L_{c\iota t}(q_\iota)$ is the amount of country c labor devoted to producing input $\iota_{ct}(q_\iota)$. For consumers in any country to be indifferent between supplying labor towards the production of homogeneous good k and input $\iota_{ct}(q_\iota)$ it must that the total earnings from either activity must be the same. Let $L_{ct}^*(1, q_\iota)$ denote the amount of labor required to produce 1 unit of input ι with quality level q_ι in country c: $L_{ct}^* = q_\iota$. Then total earnings from supplying L_{ct}^* units of production to k is $w_{ckt} L_{ct}^* = a_c^k L_{ct}^* = a_c^k q_\iota$ and the total earnings from supplying L_{ct}^* to production of ι is simply $w_{c\iota t}$. Together these imply that the production cost of the intermediate is always proportional to its quality in any country, $w_{c\iota t} = a_c^k q_\iota$. Shipping a unit intermediate good between countries s and c requires paying a iceberg-shipping cost τ_{sc} where $\tau_{sc} \geq 1$ if $s \neq c$ and $\tau_{sc} = 1$ if $s = c$. For now, we will assume that $\tau_{sc} = \tau$ is constant across countries if $s \neq c$.

[6] We only consider situations where the total supply of labor is sufficiently large to guarantee this to be the case.

2.4 Differentiated Production

Consider a set of firms which may be differentiated along multiple dimensions. As in Melitz (2003) we assume that each firm pays a sunk cost S_c upon entry in order to draw a firm-specific productivity level λ from the distribution $G^{\lambda}(\lambda)$ and that this productivity level is constant over time. Although this dimension of productivity is exogenous and constant over time, other dimensions of firm-level differentiation, such as product quality and pricing, evolve endogenously over time. We intentionally suppress productivity dynamics here in order to highlight the effect of past performance on the evolution of firm-level entry, prices, quality and markups over time.

An individual firm produces a single variety $\omega \in \Omega$ where Ω is the set of all varieties. In any year in which the firm chooses to produce, it faces an exogenous death shock which randomly affects any firm with probability δ. Surviving firms can enter a given market by paying a fixed overhead cost, $f_{ct} = \bar{f}_c + \epsilon_{ct}$, and hiring inputs to be used in the production process. The fixed overhead cost has two components: a deterministic, time-invariant component $\bar{f}_c > 0$ and a stochastic component, ϵ_{ct}. For simplicity, we begin by assuming that in each period the stochastic component ϵ_{ct} is an *iid* draw from the distribution $G_c^{\epsilon} \sim N(0, \sigma_{\epsilon}^{c})$.[7] Total firm production h is a constant returns to scale function of composite input ι_t

$$h_t(\omega) = \lambda(\omega)\iota_t(\omega) \tag{4}$$

where λ captures the firm-level productivity level, ι_t is a CES aggregate of domestic and foreign differentiated inputs:

$$\iota_t(\omega) = \left[\int_{c \in C} \iota_{ct}(\omega)^{\frac{\sigma_\iota - 1}{\sigma_\iota}}\right]^{\frac{\sigma_\iota}{\sigma_\iota - 1}} \tag{5}$$

and σ_ι captures the elasticity of substitution across inputs from different countries c. Importantly, our model implies that to produce one unit of output h a firm must hire both domestic and foreign differentiated inputs. This feature is broadly consistent with our data; approximately 90 percent of producers in the electric heater industry import intermediate inputs used for production. Shipping a unit of $h(\omega)$ to market c requires paying the iceberg shipping cost τ.

Given the functional form of $h(\cdot)$ we assume that the firm's product quality depends crucially on the quality of the differentiated inputs hired $q_{\iota 1}, ..., q_{\iota C}$. To map input qualities to output quality we first define an index of input quality $q_{\iota t}$ as

$$q_{\iota t}(\omega) = \min\{q_{\iota 1}(\omega), ..., q_{\iota C}(\omega)\}. \tag{6}$$

We then allow product quality $q_t(\omega)$ to depend on the differentiated input quality index $q_{\iota t}$:

$$q_t(\omega) = \lambda q_{\iota t}(\omega)^{\alpha} \tag{7}$$

[7] We assume that fixed costs are denominated in units of labor and for notational simplicity we absorb the wage term into f_{ct}.

where we assume that product quality level is assumed to be an increasing, concave function of input quality, $\alpha \leq 1$. There are a number of features of equations (6) and (7) which merit comment. First, together equations (6) and (7) imply that a firm's output quality will be determined by the lowest quality input. Second, if $\alpha < 1$ then to increase product quality by fixed amounts the firm must increase input quality at a faster rate.[8] As we show below, this will imply that unit costs are a convex function of output quality. Third, we allow product quality to explicitly depend on productivity, to allow for potential complementarity between these two dimensions of unobserved heterogeneity.[9]

Acquiring a unit of the quality-differentiated input ι_{ct} with quality level q_ι costs $\tau w_{c\iota}$ where $\tau = 1$ if c is the home country. Note that because higher quality inputs will cost more regardless of the country in which they are produced, no firm will optimally choose to vary their input quality across intermediate inputs. Equation (6) implies whatever product quality firm ω optimally chooses, it must be that it is cost minimizing for the input quality to equalized across components $q_{\iota 1}(\omega) = q_{\iota 2}(\omega) = ... = q_{\iota C}(\omega)$.

2.5 Demand

The assumption that each consumer buys one unit of a good from the continuum of differentiated goods indexed by ω in each period t generates the indirect utility function:[10]

$$\tilde{U}_{ct}(\omega) = \theta[\bar{I}_c, Q_{c,t-1}(\omega)]q_{ct}(\omega) - p_{ct}(\omega) + \varepsilon_{ct} \tag{8}$$

Further, under our assumption that the random consumer-product-match term, ε_{ct}, is independent and identically distributed across consumers and time by a Type 1 extreme-value distribution, it is straightforward to write the market demand for product ω at time t as

$$Q_{ct}(\omega) = \frac{N_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1}(\omega), \bar{I}_c)q_{ct}(\omega) - p_{ct}(\omega))\right]}{\int_\Omega \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1}(\omega), \bar{I}_c)q_{ct}(\omega) - p_{ct}(\omega))\right]} \tag{9}$$

where u_c is a parameter of the distribution of ε_{ct} that captures the degree of differentiation between goods.

Although firm-level price and quality choices may be changing over time the market is in a steady state.[11] In each period we expect some firms to enter, some to exit, some to meet the

[8] We maintain this assumption throughout the rest of our model description and verify its validity in Section 5.

[9] Although natural, this assumption is not necessary for most of our results.

[10] The indirect utility function in (8) will hold as long as the consumer's income is sufficiently greater than the price of product ω.

[11] Note that when the firm's output level exceeds $\overline{Q}_c$ and, as such, the consumers' product-specific taste for quality is not growing anymore. Consequently, in the subsequent periods the firm's quality and price choices will be the same after past sales reach the threshold $\overline{Q}_c$.

threshold level of production while others at the threshold level of production will die. This steady state assumption for the whole market gives us a simpler representation of (9)

$$Q_{ct}(\omega) = r_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1}(\omega), \bar{I}_c)q_{ct}(\omega) - p_{ct}(\omega))\right]$$

where $r_c = N_c / \int_{\Omega_c} \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1}(\omega), \bar{I}_c)q_{ct}(\omega) - p_{ct}(\omega))\right]$ is a constant.

2.6 Profit Maximization

We next turn to determining the firm's optimal export, price and quality choices over time. Since the firm's production function exhibits constant returns to scale and we assume that there are no demand spillovers across markets, we focus on the firm-level decisions within one export market since each market is separable. Further, for the purpose of comparison, and to highlight the role of the model's inherent dynamics, we solve for the firm's optimal choices in an environment where the firm makes myopic price and quality decisions in addition to the environment where firms fully internalize the impact that their current decisions will have on the path of profits through time. We show that in both models price and quality will increase over time. However, we find that optimal prices in the dynamic, forward-looking model are generally below (and never greater than) that of the myopic model, while the opposite is true for product quality.

2.6.1 Price and Quality in a Myopic Environment

In the myopic model we assume that firms will choose price and quality in each period to maximize current profits rather than discounted stream of all future profits. To determine this result we first solve the firm's within-period cost minimization problem, conditional on the firm wanting to achieve quality level q. Given this result we proceed to solve for the profit maximizing choices of price and product quality.[12]

The cost of producing and shipping one unit of output at quality level q_{ct} is

$$C(q_{ct}, \lambda) = \tau_{cp}\left(\sum_{s \in C} \tau_{ps} w_s(q_\iota)\iota_s(q_\iota)\right) = \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta \tag{10}$$

where p indexes the country of final production, s indexes the source country of each input and $\eta = \tau\left(1 + \frac{M-1}{\tau^{\sigma_\iota}-1}\right)^{\frac{1}{1-\sigma_\iota}}$. Note that the cost function is a strictly increasing function of quality and a strictly decreasing function of productivity. Given the unit cost function in (10) we write

[12] We suppress the variety index ω hereafter for notational convenience since the following derivations will hold equally well for all firms with the same productivity level.

the firm's *myopic* profit maximization problem as

$$\max_{p_{ct},q_{ct}} \pi(p_{ct},q_{ct}) = Q(p_{ct},q_{ct}) \left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta\right] - f_{ct}$$

where $Q(p_{ct},q_{ct})$ is the firm-level demand function (9). By *myopic* we intend to imply that the firm ignores the impact of its current decision on the discounted value of future profits and denote decisions made under this assumption using the index m. Specifically, the first order conditions from the firm's profit maximization problem imply that the firm's myopic quality and price decisions are

$$q_{ct}^m = \lambda \left[\frac{\alpha\theta\lambda^2}{\eta}\right]^{\frac{\alpha}{1-\alpha}} = \lambda^{\frac{1+\alpha}{1-\alpha}} \left[\frac{\alpha\theta}{\eta}\right]^{\frac{\alpha}{1-\alpha}} \tag{11}$$

$$p_{ct}^m = \eta \left(\frac{q_{ct}^m}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} + u_c = \lambda^{\frac{1+\alpha}{1-\alpha}} \left(\frac{\alpha\theta}{\eta^\alpha}\right)^{\frac{1}{1-\alpha}} + u_c \tag{12}$$

Equation (11) implies that more productive firms will optimally choose higher levels of quality as long as $\alpha < 1$. Firm-level quality choices are also increasing in θ, the consumers' taste for quality, and, as such, both average income, $\bar{I}_c$, and past sales in that market $Q_{c,t-1}$. This suggests that among new entrants we should expect that both price and quality will grow over time since $Q_{c,t-1} = 0$ for all new entrants. Finally, under the assumption that $\alpha < 1$ we observe that our model implies that more productive firms will tend to charge higher prices, due to the higher costs of production.

Although unit costs are increasing in productivity, prices depend on both costs and markups. We write the myopic firm's markup as

$$\mu_{ct}^m = \frac{p_{ct}}{C_{ct}} = \frac{C_{ct}+u_c}{C_{ct}} = 1 + u_c \left(\frac{\lambda^{1+\alpha}}{q_{ct}^m}\right)^{1/\alpha} = 1 + u_c \left(\frac{\eta}{\alpha\theta(Q_{c,t-1},\bar{I}_c)\lambda^{1+\alpha}}\right)^{\frac{1}{1-\alpha}}. \tag{13}$$

Similar to models without quality differentiation, equation (13) indicates that among firms which have the same product quality, markups are positively correlated with productivity.[13] However, once insert the firm's optimal quality choice into the markup equation we see that this is largely driven by the fact that these firms must differ in some other dimension. In our case, if two firms produce products of the same quality, but one is more productive than the other, then the less productive firm must have greater demand (a higher $\theta(\cdot)$). Once we condition on demand-level differences, the opposite pattern presents itself in our model. Although highly productive firms incur higher costs and charge higher prices, they are also willing to absorb lower markups to achieve higher sales. As we document below, this predicted correlation is less clear once we consider the firm's full dynamic problem.

[13] See Bernard, Eaton, Jensen and Kortum (2003), Melitz and Ottaviano (2008), De Loecker (2011) for examples.

2.6.2 Price and Quality in a Dynamic Environment

In the dynamic model firms choose price and quality in each period to maximize the discounted stream of future profits. In each period, the incumbent firm first observes its shock to fixed overhead costs, ϵ_{ct}, and decides whether or not to produce:

$$V(Q_{c,t-1}, f_{ct}) = \max[0, W(Q_{c,t-1}, f_{ct})] \tag{14}$$

where $W(Q_{c,t-1}, f_{ct})$ is continuation value of the firm with $Q_{c,t-1}$ cumulative sales and the overhead cost draw f_{ct}[14]

$$\begin{aligned} W(Q_{c,t-1}, f_{ct}) &= \max_{p_{ct}, q_{ct}} \pi(p_{ct}, q_{ct}) + \rho \int V(Q_{ct}, f_{c,t+1}(\epsilon_{c,t+1}))G^{\epsilon}(\epsilon_{c,t+1})d\epsilon_{t+1} \qquad (15) \\ &= \max_{q_{ct},\, p_{ct}} r_c \exp\left[\frac{1}{u_c}\left(\theta(Q_{c,t-1}, \bar{I}_c)q_{ct} - p_{ct}\right)\right]\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_c\right] - f_{ct} + \rho EV(Q_{ct}, f_{c,t+1}) \end{aligned}$$

where $\rho = (1-\delta)\tilde{\rho}$ and $\tilde{\rho}$ is the discount factor. We proceed analogously to the myopic model and solve for the firms optimal price and quality choices at any point in time. To do so we will need to differentiate the value function; however, given the kink in the value function induced by the firm's exit decision it is not obvious that we can use first order conditions from (14) and (15) to characterize the firm's optimal pricing and product quality decisions. We rely on the results from Clausen and Strub (2013) which, given our model's structure, allow us to proceed by differentiating the value function for any continuing firm and characterizing their optimal price and product quality choices accordingly. We document that our model satisfies the conditions in Clausen and Strub (2013), but since the results are broadly tangential to our primary objective here, we relegate these results and discussion to the Appendix. The remaining key results for the firm's price and quality choices are summarized below.

Lemma 1 *$V_1'(Q_{ct}, f_{ct}) \equiv \frac{dV(Q_{ct}, f_{ct})}{dQ_{ct}} \geq 0$, if $\theta_1 \geq 0$. For continuing firms the inequality holds strictly if $Q_{ct} < \overline{Q}_c$.*

Proposition 1 implies that the value of the firm is increasing in the volume of previous sales if and only if consumers' taste for quality is increasing with the volume the firm sold. The increasing relationship between past sales and the value of the firm holds until the volume sold reaches the threshold value of sales $\overline{Q}_c$, at which point further sales no longer have any effect on the firm's reputation. Alternatively, we may interpret this proposition as demonstrating that the marginal benefit of consumer loyalty on firm value is positive. Then, using the results from Clausen and Strub (2013) we take the derivative of (14) with respect to q_{ct}, p_{ct}, and $Q_{c,t-1}$,

[14]With a slight abuse of notation, we do not include productivity as a state variable since it does not change over time.

respectively, to determine the optimal conditions for quality and price at any time t. These are formulated in the following proposition where we let the index d denote the solution to the firm's dynamic profit maximization problem.

Proposition 1 *In the dynamic environment the optimal quality at time t is*

$$q_{ct}^d = q_{ct}^m = \lambda^{\frac{1+\alpha}{1-\alpha}} \left[\frac{\alpha\theta}{\eta}\right]^{\frac{\alpha}{1-\alpha}} \tag{16}$$

and the optimal price at t is

$$p_{ct}^d = \left(\frac{q_{ct}^d}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta + u_c - \rho E V_1'(Q_{ct}, f_{ct}) \tag{17}$$

From Proposition 1, we observe that the optimal quality, q_{ct}^d, is identical to its myopic counterpart, q_{ct}^m, conditional on the same past sales. The optimal price p_{ct}^d, conditional on quality, is always lower in the dynamic model than in the myopic model before the firm threshold level of sales $\bar{Q}_c$. Beyond the threshold level of sales $\bar{Q}_c$ the difference between the myopic model and the dynamic model disappears.[15] The intuition is straightforward: because of the loyalty effect, forward looking firms have an incentive to sell more in early periods to enhance profitability in the subsequent periods. The increased incentive to sell a higher volume encourages firms to depress the current price relative to the myopic model.

As in the myopic model, equation (17) further implies that product quality will increase over time. To the extent that sales increase faster in the dynamic model because firms choose lower prices, quality will also increase faster. Price dynamics are less clear in the dynamic model since the optimal price depends on how the current choice will affect the future value of the firm. However, we can show that the optimal price in the dynamic model will tend to increase over time, under certain conditions.

Proposition 2 *A sufficient condition for* $V_{11}'' \equiv \frac{\partial^2 V(Q_{ct}, f_{ct})}{\partial Q_{ct}^2} \leq 0$ *is*

$$\left\{ \underbrace{\left(\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \theta(Q_{ct}, \bar{I}_c)^{\frac{2\alpha-1}{1-\alpha}}\right) \left(\frac{\partial\theta}{\partial Q_{ct}}\right)^2}_{Term\ A} + \underbrace{\left(\frac{\alpha}{1-\alpha}\theta(Q_{ct}, \bar{I}_c)^{\frac{\alpha}{1-\alpha}}\right) \left(\frac{\partial^2\theta}{\partial Q_{ct}^2}\right)}_{Term\ B} \right\} \times (u_c - \rho E V_1'(Q_{c,t+1}, f_{c,t+1})) \leq 0 \tag{18}$$

[15] This is because $V'(Q) > 0$ for all $Q < \overline{Q}$, and $V'(Q) = 0$ for Q$\geq \overline{Q}$.

The right-most term in brackets, $u_c - \rho EV_1'$, captures unit profit and will be positive for any incumbent firm. The sign condition is thus determined by Term A, which is positive, and Term B, which is negative, in the above inequality. To ensure that (19) is negative it must be that Term B dominates Term A. Fundamentally what the condition is stating is that the intertemporal spillover of past sales on future profits cannot be too big.[16] Proposition 2 allows us to further characterize the evolution of sales in a given market.

Lemma 2 *If condition (19) holds, then* $\frac{\partial Q_{ct}}{\partial Q_{c,t-1}} > 0$*. This result further implies that firm-level sales will grow over time until they reach* $Q^*(\bar{Q}_c)$ *where* $Q^*(Q_c)$ *is the quantity demanded in the current period given that the last period's sales were* $\bar{Q}_c$ *(or larger).*

With the above results in hand, we can now characterize the evolution of firm-level prices in the dynamic environment. First, using (12) and (17) we observe that conditional on quality, the optimal price level in the dynamic environment is always lower than the optimal price in the myopic environment.

$$p_{ct}^d = \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta + u_c - \rho EV_1'(Q_{ct}, f_{ct}) \leq \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta + u_c = p_{ct}^m$$

since $\rho EV_1'(Q_{ct}, f_{ct}) \geq 0$. Sales, Q_{ct}, increase over time and, as such, so does product quality, q_{ct}. Since $V_1'(Q_{ct}, f_{ct}) > V_1'(Q_{c,t+1}, f_{ct})$, the firm's price p_{ct} will also increase over time. We find that dynamic considerations tend to offset the firms myopic markup rule across heterogeneous firms. To see this first note we can write the firm's dynamic markup as

$$\mu_{ct}^d = \frac{p_{ct}^d}{C_{ct}} = \mu_{ct}^m - \frac{\rho}{\lambda^{\frac{1+\alpha}{1-\alpha}}[\alpha\theta(Q_{c,t-1}, \bar{I}_c)]^{\frac{1}{1-\alpha}}} EV_1'(Q_{ct}, f_{ct}) = 1 + \frac{u_c - \rho EV'(Q_{ct}, f_{ct})}{\lambda^{\frac{1+\alpha}{1-\alpha}}[\alpha\theta(Q_{c,t-1}, \bar{I}_c)]^{\frac{1}{1-\alpha}}}. \quad (19)$$

Differentiating (19) with respect to productivity we find

$$\begin{aligned} \frac{d\mu_t^d}{d\lambda} = & \frac{-\rho EV_{11}''(Q_{ct}, f_{ct})}{\lambda^{\frac{1+\alpha}{1-\alpha}}[\alpha\theta(Q_{c,t-1}, \bar{I}_c)]^{\frac{1}{1-\alpha}}} \frac{dQ_{ct}}{d\lambda} - \frac{u_c - \rho EV_1'(Q_{ct}, f_{ct})}{\lambda^{\frac{\alpha}{1-\alpha}}[\alpha\theta(Q_{c,t-1}, \bar{I}_c)]^{\frac{1}{1-\alpha}}} \left(\frac{1+\alpha}{1-\alpha}\right) \\ & - \frac{u_c - \rho EV_1'(Q_{ct}, f_{ct})}{\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{1}{1-\alpha}}\theta(Q_{c,t-1}, \bar{I}_c)^{\frac{\alpha-2}{1-\alpha}}} \left(\frac{1}{1-\alpha}\right) \frac{dQ_{c,t-1}}{d\lambda} \end{aligned} \quad (20)$$

[16] If we put a little more structure on our problem we can make this somewhat more obvious. For instance, if we assume that

$$\theta(Q_{c,t-1}, \bar{I}_c) = \theta_0 + \theta_1 \ln(1 + Q_{c,t-1}) + \theta_2 \ln \bar{I}_c$$

then we can reduce our condition further since $-\theta_1 \frac{\partial^2\theta}{\partial Q_{ct}^2} = \left(\frac{\partial\theta}{\partial Q_{ct}}\right)^2$ in this case. Under this assumption, condition (19) will be satisfied as long as θ_1 is sufficiently small and the values of $\frac{\partial^2\theta}{\partial Q_{ct}^2}$ and $\left(\frac{\partial\theta}{\partial Q_{ct}}\right)^2$ are bounded. That is, as long as the future gain from past sales isn't too big, the value function will be concave. More generally, as long as equation (19) holds the marginal benefit of higher current sales on the future value of the firm declines.

If Proposition 2 holds then the first term in equation (20) is necessarily positive since $EV''_{11}(Q_{ct}, f_{ct}) < 0$ and $\frac{\partial Q_{ct}}{\partial \lambda} > 0$, while the second and third terms are negative.[17] If unit profit, $u_c - \rho EV'_1(Q_{ct})$, is small, then the second and third terms in equation (21) are also small and, thus, markups will rise with productivity. Note that this is driven by the fact that more productive firms will achieve higher sales faster than their less productive counterparts, reducing the incentive to keep markups small in the future.

Proposition 2 also allows us to characterize the evolution of markups over time. Consider how the firm's myopic markup changes over time as sales grow

$$\frac{d\mu^m_{ct}}{dt} = -\left(\frac{1}{1-\alpha}\right) \frac{u_c\theta_1}{\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{2-\alpha}{1-\alpha}}} \frac{dQ_{t-1}}{dt} \leq 0 \tag{21}$$

As past sales grow, firms have an increased incentive to exploit the quality-reputation tradeoff and reach more consumers. Again, dynamic incentives can offset the myopic markup incentives:

$$\frac{d\mu^d_{ct}}{dt} = \frac{-\rho V''_{11}(Q_{ct})\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}} \frac{dQ_t}{dt}}{\left(\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}}\right)^2} - \frac{(u_c - \rho V'_1(Q_{ct}))\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \theta(Q_{ct}, \bar{I}_c)^{\frac{\alpha}{1-\alpha}} \frac{dQ_{c,t-1}}{dt}}{(1-\alpha)\left(\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}}\right)^2} \tag{22}$$

The first term in equation (22) is positive, while the second is negative. If current unit profit is small, the second term will be small. In that case, we expect that the dynamic pricing incentives will dominate and markups will increase over time.

2.7 Quality, Pricing and Sales Across Countries

We now consider how quality and pricing decisions may vary across countries at the time of entry and, likewise, what impact these initial differences have on the future evolution of prices and quality in export markets. We allow markets to vary on four dimensions. First, destinations vary in consumer income, $\bar{I}_c$, market size, r_c, and the degree of competition, u_c. Second, we also extend our above framework to allow for differences in transport costs τ_{pc}. This last feature will cause η to vary by destination country. We will denote this by η_c and note that η_c is increasing

[17] Note that $\frac{dQ_{ct}}{d\lambda} > 0$ since $Q_{ct} = re^{A(\lambda)}$ where

$$A(\lambda) = \frac{1}{u_c}\left[\lambda^{\frac{1+\alpha}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) - u_c + \rho EV'_1(Q_{ct}, f_{ct})\right].$$

Differentiating Q_{ct} with respect to λ we find

$$\frac{dQ_{ct}}{d\lambda} = r_c e^{A(\lambda)} \frac{1}{u_c}\left[\frac{1+\alpha}{1-\alpha}\lambda^{\frac{2}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) - u_c + \rho EV''_{11}(Q_{ct})\frac{dQ_{ct}}{d\lambda}\right]$$

$$\frac{dQ_{ct}}{d\lambda} = \frac{\frac{1}{u_c}\frac{1+\alpha}{1-\alpha}\lambda^{\frac{2}{1-\alpha}} \theta(Q_{c,t-1}, \bar{I}_c)^{\frac{1}{1-\alpha}}(1-\alpha) r_c e^{A(\lambda)}}{1 - \frac{\rho}{u_c} EV''_{11}(Q_{ct}) r e^{A(\lambda)}} > 0$$

since $EV''_{11}(Q_{ct}) \leq 0$.

in the shipping cost between the country of production p and the country of consumption c. To facilitate our analysis we assume that each firm can produce a unique quality level of their product for each market in which it enters.

First, we examine the impact of differences in income $\bar{I}_c$ across countries. Since the taste parameter θ is assumed to be increasing in income per capita, the model predicts that, conditional on past sales, firms will export higher quality products to richer countries. Because firm productivity does not vary by export destination, firms will charge higher prices in richer countries as long as the country-specific markup parameters, u_c, are sufficiently close. It is less clear how quality and price vary with trade costs.

Consider a firm which exports two distinct markets c and c'. Further, suppose each country is of the same size, competitiveness, and has the same average income, but varies in the distance from the exporting country. If past sales in each market are identical, $Q_{c,t-1} = Q_{c',t-1}$, then the firm will produce higher quality products for the closer market. Specifically, if $\tau_{pc} < \tau_{pc'}$ then

$$q_{ct}/q_{c't} = (\eta_{c'}/\eta_c)^{\alpha} = (\tau_{pc'}/\tau_{pc})^{\alpha} > 1 \tag{23}$$

and the firm will sell higher quality products to consumers in country c relative to those in country c' in period t. In general, we would not expect that for any firm which enters two markets that $Q_{c,t-1} = Q_{c',t-1}$, except when an exporter enters two new markets in the same year. In this particular case, we can straightforwardly characterize the evolution of sales across markets and time.

Proposition 3 *If a firm enters two similar markets for the first time in the same year, then the firm's sales will be larger in the closer country in any subsequent period. Specifically, if $u_c = u'_c$, $r_c = r'_c$, $\bar{I}_c = \bar{I}_{c'}$ and $\tau_{pc} < \tau_{pc'}$ then*

$$Q_{ct} > Q_{ct'} \text{ and } \frac{dQ_{ct}}{d\tau_{pc}} < 0 \tag{24}$$

Proposition 3 indicates that an exporting firm will, all else equal, have greater sales in closer (or less costly) markets which will in turn reinforce both quality and sales differences across markets in later time periods. For instance, it is straightforward to show that

$$\frac{dq_{ct}}{d\tau_{pc}} = -\frac{q_{ct}}{1-\alpha}\left(\frac{\alpha}{\eta_c}\frac{\partial \eta_c}{\partial \tau_{pc}} - \frac{1}{\theta(Q_{ct}, \bar{I}_c)}\frac{\partial \theta(Q_{ct}, \bar{I}_c)}{\partial Q_{c,t-1}}\frac{\partial Q_{c,t-1}}{\partial \tau_{pc}}\right) < 0 \tag{25}$$

That is, among the set of profitable export destinations the firm will sell the highest quality products in the markets least costly to enter, *ceteris paribus.* Because exporting firms are already relatively low cost suppliers to closer destinations, there is a larger incentive to increase profits by producing higher quality products and build a larger customer base. It would premature to conclude, however, that lower quality products are generally exported to more distant destinations in aggregate. Since more distant destinations will only be reached by the most productive firms, it is quite possible, that the aggregate exports to distant locations are generally of a higher quality than those to closer markets. Our current results only apply to within-firm differences.

Similar analysis can be applied to firm-level pricing decisions across countries. We find, surprisingly, that prices are generally *decreasing* in τ_{pc}:

$$\frac{dp_{ct}}{d\tau_{pc}} = \frac{\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{1}{1-\alpha}} \tau_{pc}^{\frac{-1}{1-\alpha}} \theta(Q_{ct-1}, \bar{I}_c)^{\frac{1}{1-\alpha}}}{1-\alpha} \left(\frac{\tau_{pc}}{\theta(Q_{ct-1}, \bar{I}_c)} \frac{\partial Q_{ct-1}}{\partial \tau_{pc}} - \alpha \right) - \rho V_{11}''(Q_{ct}, f_{ct}) \frac{\partial Q_{ct}}{\partial \tau_{pc}} < 0 \tag{26}$$

Somewhat counterintuitively our model implies that we would expect that initially prices are *declining* with the cost of exporting. This result is due to the fact if past sales are identical across similar markets, the firm optimally chooses to produce higher quality products in the markets in which it has a greater comparative advantage.

2.8 The Distribution of Productivity Over Time

Index the age of different cohorts of firms in market c by a and consider a cohort of firms which has been in the market for a years. The distribution of productivity for cohort a in year t can then be determined recursively

$$\chi_{ct}^{a}(\lambda) = \int_{\epsilon_{ct}} \tilde{\chi}_{ct}^{a}(\lambda|\epsilon_{ct}) G^{\epsilon}(\epsilon_{ct})$$

where

$$\tilde{\chi}_{ct}^{a}(\lambda|\epsilon_{ct}) = \begin{cases} \frac{\chi_{c,t-1}^{a}(\lambda)}{1-\chi_{c,t-1}^{a}(\lambda^*(\epsilon_{ct}))} & \text{if } \lambda \geq \lambda_c^*(\epsilon_{ct}) \\ 0 & \text{otherwise} \end{cases}$$

where $\lambda_c^*(\epsilon_{ct})$ is implicitly defined for each value ϵ_{ct} at the productivity level where the firm with shock ϵ is indifferent between producing and exiting the market altogether:

$$W_{ct}(\lambda^*(\epsilon_{ct}), Q_{c,t-1}(\lambda^*), f_{ct}(\epsilon_{ct})) = 0.$$

This above structure has a number of implications for the composition of new cohort's over time. These are summarized in the following propositions.

Proposition 4 *Consider a set of firms with productivity level λ. The probability of exit from the market is falling over time.*

This result is natural to expect given the dynamic evolution of sales and firm-value over time. The longer firms exist in a given market, the more entrenched they become: higher sales generate greater loyalty and higher profits. This, in turn, increases the value of the firm and discourages exit. We expect, therefore, that exit rates across otherwise similar firms will be highest in the first year of entry and then decline thereafter.

Proposition 5 *The expected duration (survival) of a firm in the market is an increasing function of productivity.*

As we would expect more productive firms enter new markets with greater sales and higher profits. This, in turn, reduces their sensitivity to fixed cost shocks and encourages repeated sales in a given market.

3 Empirical Model

This section describes the empirical model which we take to the customs-level trade data. We begin by defining the taste for quality equation, $\theta(Q_{c,t-1}, \bar{I}_c)$, since it is not given a specific functional form in the theoretical model. We assume that it is log linear in past sales and income per capita:

$$\theta(Q_{c,t-1}, \bar{I}_c) = \theta_0 + \theta_1 \Big[\ln(1+Q_{c,t-1}) \cdot 1[Q_{c,t-1} < \bar{Q}_c] + \ln(1+\bar{Q}_c) \cdot 1[Q_{c,t-1} \geq \bar{Q}_c] \Big] + \theta_2 \ln \bar{I}_c \quad (27)$$

The parameters θ_0, θ_1 and θ_2 play a particularly important role in our analysis since they govern the impact of past sales on future firm performance and the extent to which this varies across rich and poor countries. However, these are not the only parameters to estimate in equation (27). In fact, we must also pin down the threshold level of sales after which there are no further gains to consumer loyalty, $\bar{Q}_c$. If there are $C-1$ export destinations, equation (27) has $C+2$ parameters to estimate.

Similarly, since we do not observe the trade costs between China and any given destination we assume that we can write trade costs as simple function of the observed tariff between China and the destination countries and the geographic distance between countries

$$\ln \eta_c = \ln(1 + \text{tariff}_{pc}) + \gamma_\tau \ln(d_{pc})$$

where d_{pc} is measured as the distance between Beijing and the capital city in any given destination market.

Given the above structure our model provides us with four sets of equations on which we base our estimation. First, note that equations (3)-(6) imply that the average price of imported inputs, $\bar{w}_{ict}$, is directly related to product quality for a single-destination exporter i to market c in year t:

$$\ln \bar{w}_{it} = \gamma_w + \frac{1}{1-\alpha}\big(\ln(\alpha) + 2\ln\lambda_i + \ln\theta(Q_{t-1}, I_t) - \gamma_\tau \ln(d_{pc}) - \ln(\text{tariff}_{pc})\big) + \varepsilon^q_{ict} \qquad (28)$$

where $\gamma_w = \sum_{s \in C} \tau_{sc}/C$ and ε^q_{ict} is treated as *iid* measurement error. We measure the average import price for each firm in each year to capture $\bar{w}_{ict}$. However, many exporters export to more than one destination. Unfortunately, the data do not not distinguish the import price for products shipped to different countries. Fortunately, the model implies that the average import price among multiple exporters can be written as a quantity-weighted average of the import price used to export the product to each destination

$$\bar{w}_{it} = \frac{\sum_c Q_{ict} \bar{w}_{ict}}{\sum_c Q_{ict}} \tag{29}$$

Equation (29) implies that although in practice we do not generally observe $\bar{w}_{ict}$ for multiple destination exporters we can still relate the observed variation in import prices to differences using the firm-level entry and sales outcomes across destinations in a given year, Q_{ict}.

The second key equation is the firm's pricing equation in a given market

$$\ln p_{ict} = \ln \left[\left(\frac{\widehat{q}_{ict}}{\lambda_i^{1+\alpha}} \right)^{\frac{1}{\alpha}} \eta_c + u_c - \rho E V_c'(Q_{ict}, f_{c,t+1}) \right] + \varepsilon^p_{ict} \tag{30}$$

where $\widehat{q}_{ict}$ is the model-implied product quality of exports from firm i to destination c in year t and ε^p_{ict} is *iid* measurement error in the pricing equation. A key challenge for our empirical exercise is most clearly presented in equation (30). Given an estimate of product quality, $\widehat{q}_{ict}$, the process governing the relationship between input and output quality, α, market-competitiveness, u_c, and firm-productivity, λ, output prices depend on the first derivative of the value function with respect to past sales. However, the value function itself is unobserved, let alone its first derivative. Recovering the profit function, and the thus value function, will in turn depend on the firm's price. Breaking the circular nature of this problem is discussed at length in the next section.

Our third estimating equation relates observed firm sales in the current period to predicted prices and product qualities across markets:

$$\ln Q_{ict} = \ln r_c + \frac{1}{u_c} [\theta(Q_{ic,t-1}, \bar{I}_c) \widehat{q}_{ict} - \widehat{p}_{ict}] + \varepsilon^Q_{ict} \tag{31}$$

A guess at $\widehat{q}_{ict}$, $\widehat{p}_{ict}$ and u_c, allows equation (31) to identify parameters r_c, $\bar{Q}_c$, θ_0, θ_1 and θ_2. Given (r_c, $\bar{Q}_c$, θ_0, θ_1, θ_2) equations (28), (29) and (30) in turn identify the remaining parameters α, u_c and firm-specific productivity λ.

Although the key parameters governing the evolution of price and quality can be identified from equations (28)-(31) alone, they do not allow us to recover the entry cost in any particular market. These are key parameters, particularly for our counterfactual exercises, since past sales depend crucially on whether the firm chooses to export in any market. Fortunately, the extended model allows us to write down a model-consistent binary choice model for exporting to any given market in any year

$$\Pr[D_{ict} = 1 | Q_{c,t-1}, f_{ct}, \lambda_i] = \Pr[\epsilon_{ict} < W(Q_{c,t-1}, f_{ct}, \lambda_i | D_{ict} = 1)]. \tag{32}$$

For computational ease we assume that the fixed export cost shock, ϵ_{ict}, is exponentially distributed.

4 Estimation

As noted in Section 2, we focus our empirical exercise on the Chinese exporters from the electric heater industry engaged in ordinary trade. We consider 8 distinct export destinations for each Chinese exporter in the electrical heater industry: (1) Canada and the US, (2) Europe, (3) Japan and Korea, (4) Australia and New Zealand, (5) South America and Mexico, (6) Africa, and (7) the Rest of Asia. Average income in each region is measured using average, population-weighted GDP per capita. Similarly, our measure of distance is a population weighted measure as the distance between Beijing and each capital city in a particular region.[18]

Given the generalized type II Tobit likelihood function in our model, classical estimation techniques such as Maximum Likelihood Estimation often do not perform well. Hence we choose to use Bayesian MCMC methods to estimate the model parameters.[19] The estimation algorithm proceeds in two steps with an inner routine, which solves the firm's dynamic problem, and an outer routine, which updates the parameters. We briefly describe each step below.

4.1 Inner Routine

The inner routine solves the Bellman equation for each firm in each destination given a set of destination and firm-specific parameters, $s_{ict} = \{\lambda_i, \ln Q_{c,t-1}, \ln \bar{I}_c\}$. The key difficulty in this context is that the optimal pricing decision (16) and, thus both current profits and the future value of the firm, depend the unknown derivative of the value function (14). Because of this feature of the firm's problem, we cannot standard value function solution methods. Our approach instead extends well-established value-function approximation methods, so that we develop consistently guess the expected value function EV_c and it's derivative EV_c' and then directly iterate upon the value function and it's first derivative until they both converge.

We approximate the value function for each destination by a third order polynomial of productivity (λ_i), the log of past sales ($\ln Q_{c,t-1}$), the log of average income ($\ln \bar{I}_c$), and an unknown parameter vector. Specifically, let X_{ict} denote a third order sieve of s_{ict} then value

[18] GDP and population data are taken from the Penn World Tables. The distance data are obtained from CEPII, available at www.cepii.fr.

[19] Das, Roberts and Tybout (2007) for a related discussion.

function is approximated as

$$V_c(s_{ict}) = b^* + B^* \cdot X_{ict}$$

where b^* is a constant vector and B^* is a coefficient matrix. This approach is similar to that used elsewhere in the dynamic games literature (see Gallant, Hong and Khwaja (2011), for example). However, in our context, given the parameters b^* and B^* we can immediately calculate a consistent guess of the derivative of value function with respect to Q_t by taking the derivative of the approximated value function, $\frac{\partial V_c^*(s_{ict})}{\partial Q_{ict}} = \frac{\partial (B^k \cdot X_{ict})}{\partial Q_{ict}}$. This in turn allows us to calculate current profits for the firm in any market.

Finally, we must determine the parameters b^* and B^* at the steady-state. To do this we initialize the inner routine by setting all parameters $\{b^0, B^0\}$ to 0 and calculating consistent measures of current profits ($\pi_{ict}(s_{ict})$), the continuation value ($W_c(s_{ict})$) and the value function ($V_c(s_{ict})$). We can then regress the computed $V(s_{ict})$ on a constant and X_{ict} to recover new parameter estimates, b^1 and B^1. We repeat this process until the coefficients become stable, $\max\{|b^k - b^{k-1}|, |B^k - B^{k-1}|\} < \epsilon$, where ϵ is an arbitrarily tolerance level. Last, the fixed point of the value function is then computed as $V_c^*(s_{ict}) = b^k + B^k \cdot X_{ict}$. A detailed description of is reported in the Appendix.

4.2 Outer Routine

For the outer routine, MCMC methods are used to draw parameters from a one-move-at-a-time random walk proposal density. Let the parameter vector be denoted by $\Theta = \{\lambda_i, \ln \bar{Q}_c\, \alpha, r_1, ...r_7, u_1, ..., u_2, \bar{f}_1, ..., \bar{f}_7, \theta_1, \theta_2, \theta_3\}$. Given the old draw Θ^o, a new draw is made from a conditional distribution $q(\Theta^*|\Theta^o)$. To facilitate the outer routine computation Θ^* is drawn from a normal distribution with mean Θ^o. Then we follow a standard Metropolis-Hastings algorithm to update model parameters.[20]

5 Results

In this section we document the parameter estimates from the structurally estimated model. We then evaluate the model's performance in replicating key moments of the data across countries and over time.

[20]Denote likelihood by $L(\Theta)$, the prior by $\varphi(\Theta)$ and let $a = \min\{1, \frac{L(\Theta^*)\varphi(\Theta^*)q(\Theta^o|\Theta^*)}{L(\Theta^o)\varphi(\Theta^o)q(\Theta^o|\Theta^*)}\}$. With probability a we set $\Theta' = \Theta^*$, and with probability $(1-a)$ set $\Theta' = \Theta^o$. In practice, we break the parameters in four blocks and update each block successively. Further, the joint distribution of errors for equations (28)-(31) are drawn from an inverse Wishart distribution. Details can be found in the Appendix.

5.1 Parameter Estimates

Table 4 reports the means and standard deviations of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2)$, quality transformation process, α, and the trade cost parameter, γ_τ. The key model parameter is θ_1 which maps past performance into future profits. We find a small, but robustly positive estimate of θ_1 which implies that firms which have recently experienced past success in export markets are more likely to charge higher prices and produce higher quality products next year. We also find that θ_2 is positive. Consistent with existing research, this implies that richer countries have a stronger taste for quality. However, in our context, this also implies that the quality of exports will evolve differently across rich and poor countries. Unfortunately, the parameter estimates themselves do not tell us whether the magnitude of these effects, however, is of economic significance. In the following sections we investigate the extent to which the estimated dynamic process influences the evolution of prices and quality in export markets.

Table 4: Parameter Estimates

	Coefficient	
Parameter	Mean	Std. Dev
θ_0 (Taste for Quality - Intercept)	0.791	(0.121)
θ_1 (Taste for Quality - Reputation Parameter)	0.213	(0.071)
θ_2 (Taste for Quality - Income Parameter)	0.027	(0.013)
α (Quality Transformation Parameter)	0.106	(0.020)
γ_τ (Trade Cost Parameter)	0.039	(0.010)

Notes: Table 4 reports the means and standard deviations of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2)$, quality transformation process, α, and the trade cost parameters, γ_τ.

The positive coefficient on α indicates that firms which choose higher quality inputs produce higher quality products. However, because it is estimated to be less than 1, to repeatedly increase product quality by fixed increments, our model implies that the firm will need to improve input quality by increasingly large steps. Finally, the positive coefficient trade costs indicates it is more costly to export to more distant destinations.

Table 5 reports country-specific parameters. In particular, we observe substantial differences across countries. Consistent with our expectations, the largest and richest markets, (e.g. US, Europe or Japan), are estimated to be substantially larger and have higher markups when compared to clearly smaller or poorer markets (e.g. Africa or South America). There is also substantial variation across markets, with Japan, US and the Rest of Asia are estimated to be the most costly markets to enter while South America and Europe are the least costly. This, in part, reflects differences in turnover rates as documented in the subsequent section. Last, we also observe large differences in threshold sales in each market. While the parameter estimates are

Table 5: Country-Specific Parameter Estimates

	Size r_c	Markup u_c	Entry Costs, $\bar{f}_c$	Threshold Sales, $\ln \bar{Q}_c$
USA/Canada	3.636	1.252	5.998	13.989
	(0.079)	(0.030)	(0.087)	(0.866)
Japan/Korea	2.863	0.993	6.499	12.801
	(0.064)	(0.025)	(0.087)	(0.085)
Europe	7.503	1.527	1.800	12.208
	(0.122)	(0.039)	(0.087)	(0.856)
Australia/New Zealand	0.976	1.290	3.999	11.700
	(0.020)	(0.049)	(0.086)	(0.859)
South America/Mexico	1.242	0.879	0.502	10.799
	(0.035)	(0.007)	(0.086)	(0.866)
Africa	0.346	0.502	4.401	10.310
	(0.016)	(0.011)	(0.086)	(0.869)
Rest of Asia	4.147	1.352	7.699	11.289
	(0.136)	(0.034)	(0.087)	(0.753)

The above table will report the means and standard deviations (in parentheses) of the posterior distribution for the parameters for country size, r_c, country competitiveness/markups, u_c, average export entry costs, $\bar{f}_c$, and threshold sales, $\bar{Q}_c$.

not drastically different, it is important to note that the estimated thresholds are in logarithms. After exponentiating, we naturally observe much larger differences across regions.

Although the parameter estimates are broadly in line with our expectations, they do not reveal the implications for quality or pricing strategy across countries in a straightforward manner. Moreover, while the standard deviations on all parameters appear to be relatively small these do not in and of themselves indicate that the estimated is capturing the key patterns in the data. We turn to these issues next.

5.2 Model Performance

To determine how well the model replicates key features of the data, we simulate model at the mean estimate of each parameter and collect simulated prices, qualities, sales and entry and exit decisions for every plant in every destination market. After repeating this exercise 100 times, we then proceed to compare key moments of the simulated data with their empirical counterparts from the Chinese customs data. For instance, Tables 6 and 7 document how well the model matches average firm-level prices and sales across regions.

Table 6: Log Export Prices Across Countries

Market	US/CAN	JAP/KOR	EU	AUS/NZ	SA/MEX	AFR	ASIA
Data	0.284	0.398	0.300	0.358	-0.410	0.181	0.337
Model	0.255	0.378	0.343	0.300	-0.450	0.206	0.309

Notes: The above table reports the average log export sales for electric heaters producers in each region, along with the same moments from the simulated data.

Table 7: Log Export Sales Across Countries

Market	US/CAN	JAP/KOR	EU	AUS/NZ	SA/MEX	AFR	ASIA
Data	9.513	9.185	10.228	8.414	9.550	9.343	9.224
Model	9.364	9.248	10.007	8.526	9.659	9.100	9.243

Notes: The above table reports the average log price for electric heaters producers in each region, along with the same moments from the simulated data.

We find that the model generally captures the pattern of price differences across regions very well. High (low) price regions in the data are predicted to be high (low) price regions in the model, likewise, high (low) sales regions in the data are predicted to be high (low) sales regions in the model. We also predict the average log import price using the model's structure. On this dimension the model does produce quite as well; the model predict's an average log import price of -3.10 while the corresponding moment in the data is -4.84.

Table 8: Market-Specific Entry and Exit Rates

Market	US/CAN	JAP/KOR	EU	AUS/NZ	SA/MEX	AFR	ASIA
				Entry Rates (%)			
Data	0.411	0.436	0.484	0.382	0.389	0.565	0.459
Model	0.435	0.436	0.475	0.375	0.361	0.522	0.459
				Exit Rates (%)			
Data	0.589	0.564	0.516	0.618	0.611	0.435	0.541
Model	0.566	0.563	0.525	0.625	0.639	0.478	0.541

Notes: The above table reports the average entry and exit rates or electric heaters producers in each region, along with the same moments from the simulated data.

We further examine the model's ability to capture the turnover of export producers across diverse export markets. Table 8 reports the actual and simulated entry and exit rates in each region. Again, the model is very successful in replicating the degree of turnover in the data where we observe that entry is highest in Africa, Europe and Asia, while exit is largest in Australia, South America and the US. The turnover differences across regions, relative to region size and competitiveness, pin down the differences in fixed export costs across countries.

Although Table 8 suggests that the model fits dynamic entry and exit decisions relatively well, it does not reveal whether the model captures within-firm and market evolution of prices and quality as documented in Section 1. To evaluate the model's performance on this dimension, we repeat the regression exercises outlined by equation (1) on the simulated data. Specifically, we regress a current firm-level characteristic in a given market (sales, output price, average input price) on past performance in that market, firm-product fixed effects, and product-destination-year fixed effects. We can then evaluate whether the empirical model captures the inherent export price, export sales and import price dynamics which motivate our study. Analogous regression coefficients to those reported in Section 1, but produced using simulated data, are reported in Table 9 along with original regression coefficients for comparison.

Table 9: Replicating Export Sales, Export Price and Import Price Dynamics

Dependent Variable					
Export Sales		Export Prices		Import Prices	
Data	Model	Data	Model	Data	Model
0.746	0.406	0.120	0.188	0.044	0.290
[0.017]	[0.064]	[0.015]	[0.091]	[0.008]	[0.024]

Notes: The above results are OLS estimates of β in equation (1), $\ln(x_{ijmt}) = \alpha + \beta \ln(Q_{ijm,t-1}) + \Gamma_{ij} + \Gamma_{jmt} + \epsilon_{ijmt}$, where Γ_{ij} is a firm-product fixed effect, Γ_{jmt} is a product-destination-year fixed effect, and i, j, m and t index firms, products, destination markets and years, respectively. Standard errors are in brackets. Lagged total sales are used in place of lagged market-specific sales in the import price regression. Product-destination-year fixed effects are replaced by product-year fixed effects in the import price regression.

Overall, the simulated data data replicates the dynamics qualitative patterns in the actual data well, though it does not perfectly replicate the actual data. This is not completely surprising given that this structure is not used to estimate the model. However, we find it striking that the simulated again predicts a relatively high persistence coefficient on export sales. Moreover, the estimated coefficient of simulated lagged sales when regressed on simulated export prices is very close to that from the actual data. Again, the simulated data capture the qualitative relationship past sales and future import prices similarly to the data, there is a small gap but important gap in the estimated regression coefficients. Consistent with cross-sectional results on simulated import prices, the model tends to predict a stronger relationship between past sales and future import prices. In the final section, we briefly outline the improvements we are currently working on to improve the fit of the model along these dimensions.

5.3 Dynamic Implications

In this section, we consider further simulating the estimated model to illustrate the model's implications over time. Specifically we simulate the model in two different scenarios. In the first case, we simulate the model under the benchmark parameter estimates for the median firm (median productivity) in the average export market (average size, markup, entry cost, income, trade costs and tariff rate). We then repeat this exercise under the restriction that the intertemporal spillover effect is zero, $\theta_1 = 0$. We then compute the percentage difference in output prices, input prices and and sales to highlight the relationship between these three key variables.

The left panel of Figure 1 documents the impact of the consumer loyalty effect on product quality over time. The first year of the figure is the year of entry and, as such, past sales are zero by construction. Because θ_1 will not affect the firm's quality choice differentially across our two simulations in the year of initial entry, there is no difference across models. After the year of entry, past sales improve the firm's future demand which in turn drives an increase in product quality in the model with intertemporal spillovers. Specifically, product quality improves rapidly after the first year, peaks 4 years after entry, and remains constant thereafter. Five years after entry the intertemporal accounts for a 6 percent increase in product quality relative to the model without intertemporal spillovers.

Although quality choices are identical in the year of entry, output prices are slightly lower in the initial period when we include the consumer loyalty effect. In fact, we find that the initial output price is 1 percent lower than that charged by the firm in which there is no consumer loyalty. This reflects the fact that firms care about the impact that current choices have on future profits in the export market. This, in turn, leads to higher initial sales even if it comes at the cost of lower initial profits. In fact, initial sales are 5 percent higher in the model with consumer loyalty in the year of entry as documented in the right panel of Figure 1.

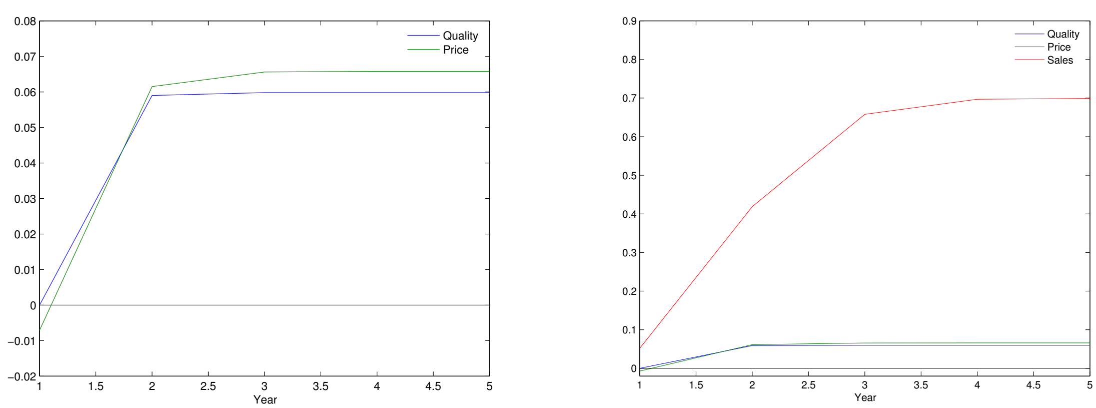

Figure 1: Impact of Consumer Loyalty on Model Performance

While the model without consumer loyalty predicts the prices, product quality and sales are constant over time for the average firm, the model predicts strong growth in prices, quality and sales when we include consumer loyalty. In fact, by the second year export prices 6.1 percent higher than those in to the model without consumer loyalty and sales are 38.0 percent higher. After five years of exporting all three dimensions, product quality, output prices and sales, level off and do not grow any further. After five years, prices are 6.6 percent higher and sales are 39.4 percent higher in the dynamic model with intertemporal spillovers.

6 Trade Liberalization

In this section, we consider the quantitative implications of trade liberalization in our context. In particular, we first set the tariffs faced by Chinese electric heater exporters in destination markets to 0 in all markets. We then repeat the above simulation exercises described in Sections 5.1 and 5.2 under this alternative assumption and compute the implied changes in pricing and product quality across countries and over time.

6.1 Price and Quality Dynamics

We begin by considering the simple exercise of evaluating the median firm's performance in the average export market before trade liberalization. The average tariff in our hypothetical setting is 7 percent, which is precisely the average tariff observed in the data. We then compare this with the choices the median firm makes after unilateral trade liberalization in the same market. Note that this is a strictly partial equilibrium experiment, we do not adjust any aggregate equilibrium variables. The upper diagrams in Figure 2 plots the dynamic path of export product quality and export prices over time, where the benchmark product quality and export price are normalized to 1 in the year of entry. Likewise, with bottom two figures plot the path of sales and operating profits[21] for the median firm.

[21]We refer to operating profits at the total profits of the firm, π_c, net of the fixed cost, f_c.

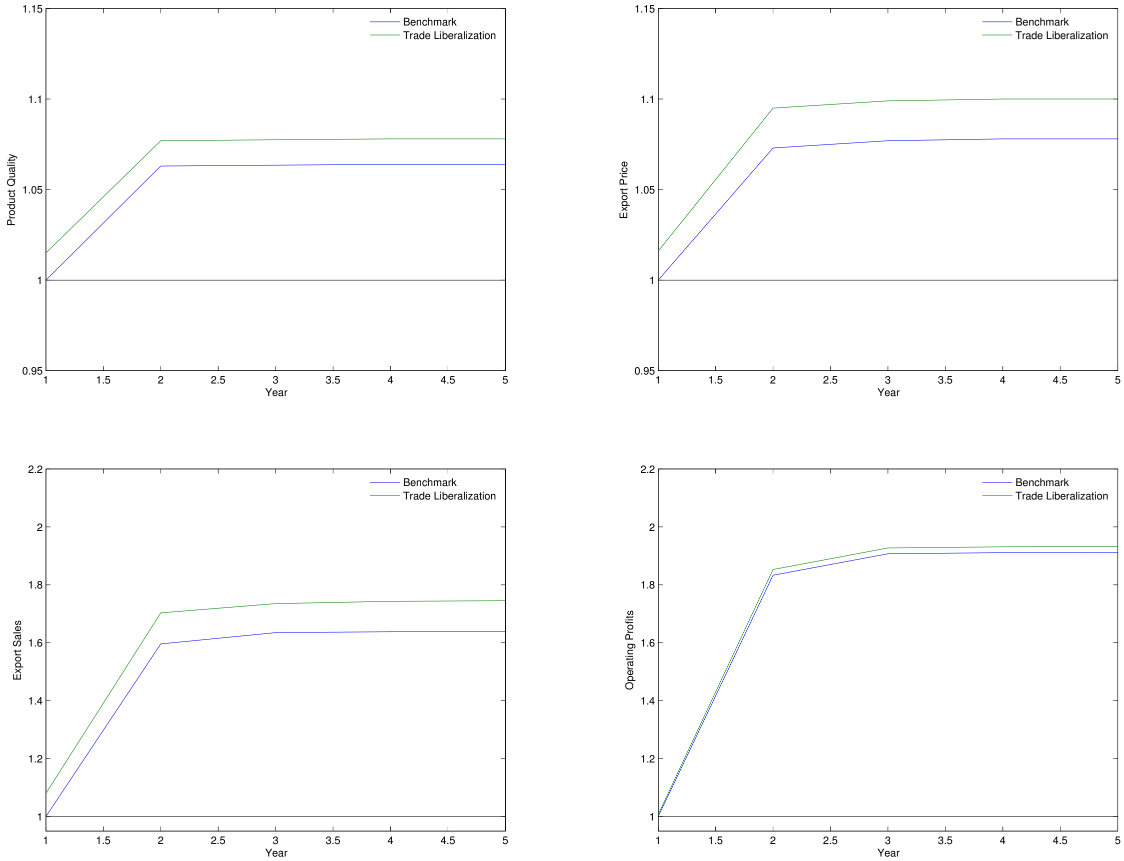

Figure 2: Impact of Trade Liberalization on Price and Quality Dynamics

Consistent with Proposition 3, we observe that trade liberalization increases export sales and product quality in the year of entry and over time. In fact, trade liberalization increases the median firm's sales by 8 percent in the year of entry. The gap between the benchmark evolution of export sales and the counterfactual path increases to 11 percent after 5 years and is constant thereafter. Similarly, product quality and export prices 1.5 and 1.6 percent *higher* after the elimination of tariffs. While these differences maybe relatively small, we note that it is striking that export prices *rose* after tariffs were eliminated. We further find that the gap between the benchmark evolution of export prices and the counterfactual path increases to 2.2 percent after 5 years. Overall, the reduction of tariffs increases profitability by 2 percent after accounting for the endogenous product quality and pricing decisions of the firm.

6.2 Trade Liberalization Across Countries

We proceed to repeating our simulation exercise across countries and time. We then examine the predicted impact on sales and prices across markets in Table 10. In this exercise, the predicted changes depend on the full set of country-specific parameters, but, in particular, depend on the observed variation in tariff rates in our data. Specifically, as listed in the last row of Table 10, we observe that Chinese electric heater exporters face a great degree of heterogeneity in tariffs are regions worldwide; tariffs range from a high of 26.4 percent in Africa to a low of 2.4 percent in the US.

Table 10: Trade Liberalization: Export Prices and Sales Across Countries

Market	US/CAN	JAP/KOR	EU	AUS/NZ	SA/MEX	AFR	ASIA
			Export Product Quality				
Benchmark	0.363	0.371	0.367	0.360	0.359	0.362	0.371
Trade Liberalization	0.366	0.374	0.370	0.364	0.368	0.375	0.377
% Change	0.8	0.9	0.8	1.0	2.5	3.4	1.6
			Log Export Prices				
Benchmark	0.255	0.378	0.343	0.300	-0.450	0.206	0.309
Trade Liberalization	0.256	0.389	0.344	0.308	-0.348	0.296	0.344
% Change	0.1	1.1	0.1	0.8	10.2	9.0	3.5
			Log Export Sales				
Benchmark	9.364	9.248	10.007	8.526	9.659	9.100	9.243
Trade Liberalization	9.429	9.257	10.073	8.581	9.832	9.116	9.300
% Change	6.5	0.9	6.6	5.5	17.3	1.6	5.7
			Benchmark Tariff Rates (%)				
Tariff Rate	2.394	4.070	3.929	3.929	17.315	26.445	9.677

Notes: The above table reports the average log pricesand log sales for electric heaters producers in the simulated benchmark model, along with the same moments from the simulated model after tariffs are set to 0 in all markets.

Across all markets we observe that tariff reductions again lead to an improvement in product quality and export price increases in all markets. This reflects the increase in product quality; across all firms and markets, the reduction in tariffs are predicted to improve product quality by 1 to 3 percent. Consistent with observed changes in tariff rates we observe relatively large changes in prices in locations which were initially subject to relatively large tariffs. In Africa and South America, where tariffs rates were 26 and 17 percent, respectively, we observe a relatively large increase in product quality and a 9-10 percent increase in export prices. In contrast, in the US, Europe, Japan, or Australia, where benchmark tariffs are low, product quality and export prices increase by 1 percent at most. Changes in total sales reflect both the change in tariffs, but also other market level characteristics. For instance, in South America, export sales are predicted to increase by 17 percent, but in Africa our predictions suggest that sales will only grow by 1.6 percent. These differences are largely attributable to substantial differences in market size (r_c) and average entry costs (f_c).

7 Concluding Remarks

This paper develops a dynamic model of heterogeneous firms which make endogenous price and product quality decisions across export markets and over time. Consistent with previous research we find that more productive firms choose to export higher quality products, charge higher prices, achieve higher sales, and record larger profits, *ceteris paribus*. The focus of our paper, however, is how these dimensions of firm heterogeneity evolve over time. We find that new exporters will tend to enter export markets at low prices and producing low quality goods, compared to their later sales. Over time we find that as firms grow into export markets and develop a loyal customer base they will tend to improve product quality, and charge higher prices.

We estimate our model using detailed Chinese customs data. We find that the year of entry the dynamic consumer loyalty spillover reduces firm-level export prices by 1 percent and increases firm-level sales by 5 percent. Over time quality, prices and sales grow. Our dynamic model predicts that the consumer loyalty intertemporal spillover would increase the export product quality and prices by 6 and 7 percent, respectively, after 5 years of continuous exporting for the median exporter.

We believe that these preliminary results are striking, but warrant a great deal of caution. We have collected a detailed series of export tariffs faced by Chinese exporters in destination markets. We intend use this data to study the impact of trade liberalization on price and quality decisions across export markets. Further, we are working on testing the robustness of our assumption on the functional form of the equation which maps previous performance in the firm's current state variable. In particular, we are considering structures which more closely resemble an autoregressive process rather than one which uses last year's sales as the current state variable.

References

Arkolakis, Costas. 2013. "A Unified Theory of Firm Selection and Growth," NBER Working Paper 17553.

Atkeson, Andrew and Ariel Burstein. 2009. "Innovation, Firm Dynamics, and International Trade," *Journal of Political Economy,* 118(3): 433-484.

Baldwin, Richard and James Harrigan. 2011. "Zeros, Quality, and Space: Trade Theory and Trade Evidence," *American Economic Journal: Microeconomics*, 3(5):60-88.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum. 2003. "Plants and Productivity in International Trade," *American Economic Review*, 93(4): 1268-1290.

Broda, Christian and David E. Weinstein. 2006. "Globalization and the Gains from Variety," *Quarterly Journal of Economics*, 121(2): 541-585.

Brooks, Eileen L. 2006. Why Dont Firms Export More? Product Quality and Colombian Plants, *Journal of Development Economics*, 80: 160-178.

Clausen, Andrew and Carlo Strub. 2013. "A General and Intuitive Envelope Theorem," mimeo, University of Edinburgh.

Costantini, James A., and Marc J. Melitz. 2008. "The Dynamics of Firm-Level Adjustment to Trade Liberalization," in *The Organization of Firms in a Global Economy*, E. Helpman, D. Marin, and T. Verdier (eds.), Cambridge: Harvard University Press.

Crozet, Mattheiu, Keith Head and Thierry Mayer. 2012. "Quality Sorting and Trade: Firm-level Evidence for French Wine," *Review of Economic Studies,* 79(2): 609-644.

Das, Sanghamitra, Mark J. Roberts, and James R. Tybout. 2007. "Market Entry Costs, Producer Heterogeneity, and Export Dynamics," *Econometrica* 75(3): 837-873.

De Loecker, Jan. 2011. "Product Differentiation, Multi-Product Firms and Estimating the Impact of Trade Liberalization on Productivity," *Econometrica*, 79(5): 1407-1451.

Eaton, J. and S. Kortum. 2002. "Technology, Geography and Trade," *Econometrica,* 70: 1741-1779.

Eslava, M., A.C. Fieler and D. Xu. 2014. "Trade, Skills and Quality Upgrading," mimeo, University of Pennsylvania.

Feenstra, Robert C. 1988 "Quality Change under Trade Restraints in Japanese Autos," *Quarterly Journal of Economics*, 103: 131-146.

Feenstra, Robert C. 1994. "New Product Varieties and the Measurement of International Prices," *American Economic Review*, 84:157-177.

Flach, Lisandra. 2013. "Quality Upgrading and Price Heterogeneity: Evidence from Brazilian Exporters," University of Munich, Working Paper.

Flam, Harry, and Elhanan Helpman. 1987. "Vertical Product Differentiation and North-South Trade," *American Economic Review*, 77: 810-822.

Foster, Lucia, John Haltiwanger and Chad Syverson. 2008. "Reallocation, Firm Turnover and Efficiency: Selection on Productivity or Profitability?" *American Economic Review*, 98(1): 394-425.

Foster, Lucia, John Haltiwanger and Chad Syverson. 2013. "The Slow Growth of New Plants: Learning about Demand," University of Chicago, Working Paper.

Gabszewicz, J. Jaskold, Avner Shaked, John Sutton, and Jacques-Francois Thisse. 1982. "International Trade in Differentiated Products," *International Economic Review*, 22: 527535.

Gervais, Antoine. 2012. “Product Quality and Firm Heterogeneity in International Trade,” University of Notre Dame, Working Paper.

Hallak, Juan Carlos, “Product Quality and the Direction of Trade,” *Journal of International Economics*, 68: 238-265.

Hallak, Juan Carlos and Peter K. Schott. 2011. “Estimating Cross-Country Differences in Product Quality,” *Quarterly Journal of Economics*, 126(1): 417-474.

Hallak, Juan Carlos and Jagadeesh Sivadasan. 2009. “Firms’ Exporting Behavior under Quality Constraints,” NBER Working Paper 14928.

Hummels, David and Peter J. Klenow. 2005. “The Variety and Quality of a Nation’s Exports,” *American Economic Review*, 95(3): 704-723.

Hummels, David and Alexandre Skiba. 2004. “Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture,” *Journal of Political Economy*, 112(6): 1384-1402.

Hu, Zhongzhong, Joel Rodrigue, Yong Tan and Chunhai Yu. 2013. “Firm Selection Across International Markets: Evidence from Chinese Exporters,” Vanderbilt University, Working Paper.

Katayama, Hajime, Shihua Lu and James R. Tybout. 2009. “Firm-Level Productivity Studies: Illusions and a Solution,” *International Journal of Industrial Organization*, 27(3): 403-413.

Khandelwal, Amit. 2010. “The Long and Short (of) Quality Ladders,” *Review of Economic Studies*, 77(4): 1450-1476.

Kugler, Maurice and Eric Verhoogen. 2012. “Prices, Plant Size, and Product Quality,” *Review of Economic Studies*, 79(1): 307-339.

Mandel, Benjamin. 2010. “Heterogeneous Firms and Import Quality: Evidence from Transaction-Level Prices,” International Finance Discussion Papers No. 991.

Manova, Kalina and Zhiwei Zhang. 2012a. “Multi-Product Firms and Product Quality,” NBER Working Paper w18637.

Manova, Kalina and Zhiwei Zhang. 2012b. “Export Prices across Firms and Destinations,” *Quarterly Journal of Economics*, 127: 379-436.

Melitz, Marc J. 2003. “The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity,” *Econometrica*, 71: 1695-1725.

Melitz, Marc J. and Gianmarco I.P. Ottaviano. 2008. “Market Size, Trade and Productivity,” *Review of Economic Studies*, 75: 295-316.

Roberts, Mark J., Yi Xu, Xiaoyan Fan, Shengxing Zhang. 2012. “A Structural Model of Demand, Cost, and Export Market Selection for Chinese Footwear Producers,” NBER Working Paper 17725.

Schott, Peter. 2004. "Across-Product versus Within-Product Specialization in International Trade," *Quarterly Journal of Economics*, 119: 647-678.

Verhoogen, Eric. 2008. "Trade, Quality Upgrading, and Wage Inequality in the Mexican Manufacturing Sector," *Quarterly Journal of Economics*, 123(2): 489-530.

A Proofs

Differentiability Proof

This proof relies on the results in Clausen and Strub (2013). Specifically, we begin reformulating our problem by making three simplifications. First, let the firm's exit decision be denoted by χ_{ct} which takes a value of 1 if the firm produces in period t and 0 otherwise. Second, since f_{ct} is *iid*, the firm's exit decision is characterized by a cut-off rule $y(\cdot)$ so that the firm only chooses to produce at state $(\lambda, Q_{c,t-1}, f_{ct})$ if $f_{ct} \leq y(\lambda, Q_{c,t-1})$. Third, we rewrite the firm's Bellman equations as

$$\begin{aligned}\tilde{V}(\lambda, Q_{c,t-1}) \quad = \quad & \max_{p_{ct}, q_{ct}, \chi_{ct}} \left\{ r_c \exp\left[\frac{1}{u_c}\left(\theta(Q_{c,t-1}, \bar{I}_c) q_{ct} - p_{ct}\right)\right]\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta\right] - f_{ct} \right. \\ & \left. + \rho \int_{f_{ct} \in y(\lambda, Q_{c,t-1})} \tilde{V}(Q_{ct}) g_c(f_{ct}) df_{ct} \right\} \chi_{ct} \qquad (33)\end{aligned}$$

The value function has downward kinks at states of indifference between exiting and continuing. We then proceed by showing that this decision problem satisfies the conditions of Theorem 1 in Clausen and Strub (2013) which, in turn, implies that the first order conditions from the firm's optimization problem hold for any continuing firm. Specifically, we show we can construct

1. A differentiable lower support function for any price and quality combination which a continuing firm might consider.
2. A differentiable upper support function for any price and quality combination which a continuing firm might consider.

Differentiable Lower Support Function. We again follow Clausen and Strub (2013) in constructing a differentiable lower support function for the value function $\tilde{V}(\cdot)$. Specifically, we consider the a 'lazy' manager that - as a consequence of his laziness - undervalues exit, and hence never chooses to exit regardless of the size of fixed export cost. The value function of this firm with a lazy manager is

$$\begin{aligned}L(\lambda, Q_{c,t-1}, f_{ct}) \quad = \quad & \max_{p_{ct}, q_{ct}} r_c \exp\left[\frac{1}{u_c}\left(\theta(Q_{c,t-1}, \bar{I}_c) q_{ct} - p_{ct}\right)\right]\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta\right] - f_{ct} \\ & + \rho \tilde{V}(Q_{ct}) \qquad (34)\end{aligned}$$

We note that it is not obvious that our differentiable lower support function is concave in past sales at the firm's optimal choice of price or quality. For now, we will assume that this is the case and verify under what conditions it is locally true below.

Assumption 1. The differentiable lower support function (34) satisfies

$$\frac{\partial L}{\partial Q_{c,t-1}} > 0 \text{ and } \frac{\partial^2 L}{\partial Q_{c,t-1}^2} < 0$$

if $Q_{c,t-1} < \bar{Q}_c$.

Differentiable Upper Support Function. We then turn to showing that there exists a differentiable upper support function $U(\lambda, Q_{c,t-1})$ at any interior optimal choice of price and quantity. Let $\phi(p_{ct}, q_{ct})$ be any continuous, differentiable function such that $\frac{\partial \phi(\cdot)}{\partial p_{ct}} = 0$ and $\frac{\partial \phi(\cdot)}{\partial q_{ct}} = 0$. Then any function $\phi(p_{ct}, q_{ct})$ will suffice as an upper bound function at the optimal choice of price and quality,

$$U(\lambda, Q_{c,t-1}) = \phi(p_{ct}, q_{ct}) \tag{35}$$

.

Given the differentiable upper and lower support functions in equations (34) and (35) our problem then satisfies all of the conditions of Theorem 1 from Clausen and Strub (2013). We refer the reader to this paper for further details.

Lemma 1

Proof. The proof is completed in two parts. Suppose first that $Q_{ct} = \bar{Q}_c$. In this case $\frac{dV(Q_{ct})}{Q_{ct}} = 0$ if $\theta_1 \geq 0$. To see this note that once sales have reached $\bar{Q}_{ct}$ further increases in sales will no longer affect the consumer's taste for the good and there is no further complementarity with product quality. As such, once firms reach the threshold $\bar{Q}_c$, current sales, Q_{ct}, have no impact on future profitability.

Second, consider the proposition when $Q_{ct} < \bar{Q}_c$. To establish the proposition we compare $V(Q_{c,t-1})$ and $V(Q'_{c,t-1})$ when $Q_{c,t-1} < Q'_{c,t-1} < \bar{Q}_c$. Denote the optimal quality and price sequence as $\{q_{ct}, p_{ct}\}_t$ when past sales are $Q_{c,t-1}$. Observe that if past sales are $Q'_{c,t-1}$ and the firm followed the same sequence of quality and price choices $\{q_t, p_t\}_t$, then in any period $\tilde{t} \geq t$ the current profits of the firm with past sales $Q'_{c,t-1}$ would be greater than those of the firm with past sales $Q_{c,t-1}$ if $\theta_1 > 0$:

$$\pi(\lambda, Q_{c,\tilde{t}-1}, q_{c\tilde{t}}, p_{c\tilde{t}}) \leq \pi(\lambda, Q'_{c,\tilde{t}-1}, q_{c\tilde{t}}, p_{c\tilde{t}},)$$

$$r_c \exp\left\{\frac{1}{u_c}[(\theta(Q_{c,\tilde{t}-1}, \bar{I}_c)q_{c\tilde{t}} - p_{c\tilde{t}}]\right\}\left[p_{c\tilde{t}} - \frac{\eta q_{c\tilde{t}}^{\frac{1}{\alpha}}}{\lambda^{1+\frac{1}{\alpha}}}\right] \leq r_c \exp\left\{\frac{1}{u_c}[(\theta(Q'_{c,\tilde{t}-1}, \bar{I}_c)q_{c\tilde{t}} - p_{c\tilde{t}}]\right\}\left[p_{c\tilde{t}} - \frac{\eta q_{c\tilde{t}}^{\frac{1}{\alpha}}}{\lambda^{1+\frac{1}{\alpha}}}\right]$$

where $\tilde{t} > t-1$ and $Q_{\tilde{t}-1} < Q'_{\tilde{t}-1}$. Since θ, and hence current demand, is strictly increasing in past sales, $Q_{c,t-1}$, a firm achieves a greater discounted profit stream relative to an identical firm with smaller past sales by choosing the same quality and price sequence even it is not optimal. As such, $V(Q'_{c,t-1}) > V(Q_{c,t-1})$. This implies that $V(Q'_{c,t-1}) \geq V(Q_{c,t-1})$ for all incumbent firms. ■

Proposition 1

Proof. To establish this proposition we take the derivative of equation (**??**) with respect to q_{ct}, p_{ct} and $Q_{c,t-1}$, respectively.

$$
\begin{aligned}
\frac{\partial V(Q_{c,t-1})}{\partial q_{ct}} &= \left\{\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta + \rho V'(Q_{ct})\right]\frac{\theta(Q_{c,t-1},\bar{I}_c)}{u_c} - \frac{1}{\alpha}\left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}}\eta\lambda^{1+\alpha}\right\} \\
&\quad \times r_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1},\bar{I}_c)q_{ct} - p_{ct})\right] = 0 \\
&\quad \Rightarrow p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta + \rho V'(Q_{ct}) - \frac{u_c\eta\lambda^{1+\alpha}}{\alpha\theta(Q_{c,t-1},\bar{I}_c)}\left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}} = 0
\end{aligned} \tag{A1}
$$

$$
\begin{aligned}
\frac{\partial V(Q_{c,t-1})}{\partial p_{ct}} &= \left\{1 - \frac{1}{u_c}\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta + \rho V'(Q_{ct})\right]\right\} r_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1},\bar{I}_c)q_{ct} - p_{ct})\right] = 0 \\
&\Rightarrow p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta + \rho V'(Q_{ct}) - u_c = 0
\end{aligned} \tag{A2}
$$

$$
\begin{aligned}
\frac{\partial V(Q_{c,t-1})}{\partial Q_{c,t-1}} &= r_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1},\bar{I}_c)q_{ct} - p_{ct})\right]\left[p_{ct} - \left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta\right]\frac{\theta_1 q_{ct}}{u_c} \\
&\quad + \left[1 + r_c \exp\left\{\frac{1}{u_c}\left(\theta(Q_{c,t-1},\bar{I}_c)q_{ct} - p_{ct}\right)\right\}\frac{\theta_1 q_{ct}}{u_c}\right]\rho V'(Q_{ct}) = 0
\end{aligned} \tag{A3}
$$

From (A1) and (A2) we find

$$
\frac{u_c\eta\lambda^{1+\alpha}}{\alpha\theta(Q_{c,t-1},\bar{I}_c)}\left(\frac{q_{ct}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}} = u_c \Rightarrow q_{ct} = \left[\frac{\alpha\theta(Q_{c,t-1},\bar{I}_c)}{\eta}\right]^{\frac{\alpha}{1-\alpha}}\lambda^{\frac{1+\alpha}{1-\alpha}} = \lambda^{\frac{1+\alpha}{1-\alpha}}\left(\frac{\tilde{\nu}\tilde{\theta}}{\eta}\right)^{\alpha} \tag{A4}
$$

Inserting optimal quality (A4) into (A2) we find

$$
\begin{aligned}
p^d_{ct} &= \frac{\eta}{\lambda^{1+\frac{1}{\alpha}}}q_{ct}^{\frac{1}{\alpha}} + u_c - \rho V'(Q_{ct}) \\
&= \tilde{\nu}\tilde{\theta}\lambda^{\frac{1+\alpha}{1-\alpha}} + u_c - \rho V'(Q_{ct})
\end{aligned} \tag{A5}
$$

■

Proposition 2

Proof.

A sufficient condition to guarantee that $V(Q_{ct})$ is concave is that the current profit function is concave:

$$\frac{\partial \pi}{\partial Q_t} = [u_c - \rho V'(Q_{c,t+1})]Q_{c,t+1}\left[\lambda^{\frac{1-\alpha}{1+\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(Q_{ct}, I_c)^{\frac{\alpha}{1-\alpha}}\right]\frac{\partial \theta}{\partial Q_{ct}} \tag{A6}$$

$$\begin{aligned}\frac{\partial^2 \pi}{\partial Q_t^2} &= [u_c - \rho V'(Q_{c,t+1})]Q_{c,t+1}\left[\lambda^{\frac{1-\alpha}{1+\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(Q_{ct}, I_c)^{\frac{\alpha}{1-\alpha}}\right]^2\left(\frac{\partial \theta}{\partial Q_{ct}}\right)^2 \\ &+ [u_c - \rho V'(Q_{c,t+1})]Q_{c,t+1}\left[\lambda^{\frac{1-\alpha}{1+\alpha}}\frac{\alpha^{\frac{1}{1-\alpha}}}{1-\alpha}\theta(Q_{ct}, I_c)^{\frac{2\alpha-1}{1-\alpha}}\right]\left(\frac{\partial \theta}{\partial Q_{ct}}\right)^2 \\ &+ [u_c - \rho V'(Q_{c,t+1})]Q_{c,t+1}\left[\lambda^{\frac{1-\alpha}{1+\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(Q_{ct}, I_c)^{\frac{\alpha}{1-\alpha}}\right]\frac{\partial^2 \theta}{\partial Q_{ct}^2}\end{aligned} \tag{A7}$$

From equation (A7) a sufficient condition for $\pi(Q_{ct})$ to be concave is

$$\left\{\left(\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(Q_{ct}, \bar{I}_c)^{\frac{2\alpha-1}{1-\alpha}}\right)\left(\frac{\partial \theta}{\partial Q_{ct}}\right)^2 + \left(\frac{\alpha}{1-\alpha}\theta(Q_{ct}, \bar{I}_c)^{\frac{\alpha}{1-\alpha}}\right)\left(\frac{\partial^2 \theta}{\partial Q_{ct}^2}\right)\right\}(u_c - \rho V'(Q_{c,t+1})) \leq 0 \tag{A8}$$

■

Although condition (A8) is sufficient to guarantee the concavity of $\pi(Q_{ct})$ and thus $V(Q_{ct})$ it is regrettably cumbersome and difficult to interpret. Note that fundamentally what the condition is stating is that the intertemporal spillover of past sales on future profits cannot be too big. If we put a little more structure on our problem we can make even stronger claims. For instance, if we assume that

$$\theta(Q_{c,t-1}, \bar{I}_c) = \theta_0 + \theta_1 \ln(Q_{c,t-1}) + \theta_2 \ln I_c$$

then we can reduce our condition further since $-\theta_1 \frac{\partial^2 \theta}{\partial Q_{ct}^2} = \left(\frac{\partial \theta}{\partial Q_{ct}}\right)^2$ in this case. Under this assumption, condition (A8) will be satisfied as long as α is sufficiently small; that is, as long as it is relatively costly to turn input quality into final product quality.

Lemma 2

Proof. Recall, that total sales in market c in year t can be expressed as

$$Q_{ct} = r_c \exp\left[\frac{1}{u_c}(\theta(Q_{c,t-1}, \bar{I}_c)q_{ct} - p_{ct})\right]$$

Then using equations (16) and (17) it must be that

$$\frac{\partial Q_{ct}}{\partial Q_{c,t-1}} = \frac{Q_{ct}\frac{1}{u_c}\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(Q_{c,t-1}, \bar{I}_c)^{\frac{\alpha}{1-\alpha}}}{1 - \frac{Q_{ct}}{u_c}}\rho V'' > 0$$

if condition (19) holds. ■

Proposition 3

Consider the firm-level sales to destinations c and c' where $\tau_{pc} < \tau_{pc'}$. Under the assumption that $Q_{c,t-1} \leq Q_{c',t-1}$ it must be that

$$Q_{c't} \leq \tilde{Q}_{ct} \equiv r_c' \exp\left[\frac{1}{u_{c'}}\left(\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)\theta(Q_{c,t-1}, \bar{I}_{c'})^{\frac{1}{1-\alpha}}\eta_{c'} - u_{c'} + \rho V'(Q_{c't})\right)\right]$$

where the only difference between $Q_{c't}$ and $\tilde{Q}_{ct}$ is that we use $Q_{c,t-1}$ in pace of $Q_{c',t-1}$ inside of $\theta(\cdot)$. Now suppose that Q_{ct} is an increasing function of τ_{pc}, which implies $Q_{c't} > Q_{ct}$. Then, it must also be that

$$\tilde{Q}_{ct} < \hat{Q}_{ct} \equiv r_c' \exp\left[\frac{1}{u_{c'}}\left(\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)\theta(Q_{c,t-1}, \bar{I}_{c'})^{\frac{1}{1-\alpha}}\eta_{c'} - u_{c'} + \rho V'(Q_{ct})\right)\right]$$

since $Q_{ct} < Q_{c't}$ and condition (19) holds. The derivative of $\hat{Q}_{ct}$ with respect to $\tau_{pc'}$ is

$$\begin{aligned}
\frac{d\hat{Q}_{ct}}{d\tau_{pc'}} &= \hat{Q}_{ct}\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)\theta(Q_{c,t-1}\bar{I}_{c't})^{\frac{1}{1-\alpha}}\left(-\frac{\alpha}{1-\alpha}\frac{1}{\eta_{c'}^{\frac{1}{1-\alpha}}}\frac{\partial\eta_{c'}}{\partial\tau_{pc'}}\right) < 0 \\
&\Rightarrow \hat{Q}_{ct}(\tau_{pc'}) < \hat{Q}_{ct}(\tau_{pc}) = Q_{ct} \\
&\Rightarrow Q_{c't}(\tau_{pc'}) \leq \tilde{Q}_{ct}(\tau_{pc'}) < \hat{Q}_{ct}(\tau_{pc'}) < Q_{ct}(\tau_{pc})
\end{aligned}$$

The last inequality contradicts our initial assumption that $Q_{c't} > Q_{ct}$. Therefore, given that $Q_{c,t-1} > Q_{c',t-1}$ it must be that Q_{ct} is a decreasing function of τ_{pc}. As such, we expect that firms will have larger sales in closer markets.

Proposition 4

Proof. Recall that the firm is indifferent between exiting the market or continuing to produce when $V^C(\lambda, Q_{c,t-1}, f_{ct}(\epsilon_{ct})) = 0$. Denote the fixed cost shock which causes the firm to be indifferent between exiting and continuing as ϵ^*_{ct}. Since V^C is strictly increasing in $Q_{c,t-1}$ and strictly decreasing in f_{ct} it must be that

$$f^*_{c,t+1} > f_{ct} \Rightarrow \epsilon^*_{c,t+1} > \epsilon^*_{ct} \Rightarrow G^\epsilon_c(\epsilon^*_{c,t+1}) < G^\epsilon_c(\epsilon^*_{ct})$$

The last implication follows from the assumption that the cost shocks are *iid* over time. ■

Proposition 5

Proof. Let ϵ^*_{ct} and $\epsilon^{*\prime}_{ct}$ denote the fixed cost shocks which induce exit from firms with productivity levels λ and λ' where we assume that $\epsilon^*_{ct} > \epsilon^{*\prime}_{ct}$ without loss of generality. Since quality, price and past sales are unaffected by fixed cost shocks in any period, past sales are only a function of productivity. This implies

$$V^C(\lambda, Q_{c,t-1}(\lambda), \epsilon^*_{ct}) = V^C(\lambda', Q_{c,t-1}(\lambda'), \epsilon'^*_{ct}) = 0 \Rightarrow \lambda > \lambda'$$

Since $G_c^\epsilon(\epsilon_{ct}'^*) > G_c^\epsilon(\epsilon_{ct}^*)$ the firm with productivity draw λ is more likely to survive in any period. ■

B Computational Details

This section documents the computational procedure used to estimate the model's parameters. As described in the manuscript, the estimation proceeds in two steps. The inner routine reports the methods used for computing the firm's value function, while the routine documents the details of the Bayesian MCMC methods employed for estimating model parameters.

B.1 Inner Routine

Specifically, given a set of destination and firm-specific state parameters $s_{ict} = \{\lambda_i, \ln Q_{c,t-1}, \ln \bar{I}_c\}$, the value function is solved as follows:

1. Let X_{ict} denote a third order sieve of s_{ict}. We approximate the value function at each year by a third order polynomial of firm productivity (λ_i), the log of past sales ($\ln Q_{c,t-1}$), and the log of destination income ($\ln \bar{I}_c$): $V_c(s_{ict}) = b^* + B^* \cdot X_{ict}$, where b^* is a constant vector, and B^* is a coefficient matrix.

2. Search for the fixed point of $V_c^*(s_{ict})$ by initializing the value function $V_c^0(s_{ict}) = 0 + 0 \cdot X_{ict}$, where the superscript indicates the number of iterations. Here the search starts with $\{b^0, B^0\}$ being set to 0.

3. We can then find the derivative of value function with respect to Q_t by taking the derivative of the approximated value function, $\frac{\partial V_c^*(s_{ict})}{\partial Q_{ict}} = \frac{\partial (B^k \cdot X_{ict})}{\partial Q_{ict}}$. Given the estimated derivative we can compute the firm's optimal price, profits and update its continuation value as $W_c(s_{ict}) = \pi_{ict}(s_{ict}) + \rho E V_c(s_{ict})$. Compute the value function using $V_c(s_{ict}) = \max\{0, W_c(s_{ict})\}$, where $W_c(s_{ict})$ is the firm's value function if they continue export.

4. Regress $V_c(s_{ict})$ on a constant and X_{ict} to recover b^1 and B^1. The new $\{b^1, B^1\}$ is an update of $\{b^0, B^0\}$.

5. Iterate steps 3 and 4 to find the new value function under new coefficients $\{b^1, B^1\}$, and update $\{b^1, B^1\}$ to $\{b^2, B^2\}$. Keep doing this until the coefficients become stable, $\max\{|b^k - b^{k-1}|, |B^k - B^{k-1}|\} < \epsilon$.

6. The fixed point of the value function is then computed as $V_c^*(s_{ict}) = b^k + B^k \cdot X_{ict}$.

Step 3 is the key step in our algorithm. Effectively, we extend value function approximation methods to allow us capture the derivative of the value function and determine the optimal pricing decision of the firm. This in turn allows us to pin down profits and directly iterate on the value function. While simple, this method allows us to tractably capture prices which are a direct function of the value function itself.

B.2 Outer Routine

For the outer routine, MCMC methods are used to draw parameters from a one-move-at-a-time random walk proposal density. Given the old draw Θ^o, a new draw is made from a conditional distribution $q(\Theta^*|\Theta^o)$. Denote likelihood by $L(\Theta)$, and the prior by $\varphi(\Theta)$. The parameters for each successive iteration, Θ', are generated as follows:

1. Separate the parameters into 4 blocks: $\Theta_1 = \{\lambda_i\}$, $\Theta_2 = \left\{\ln \bar{Q}_c\right\}$, $\Theta_3 = \{\alpha, r_1, ...r_7, u_1, ..., u_2,$ $\bar{f}_1, ..., \bar{f}_7\}$, and $\Theta_4 = \{\theta_1, \theta_2, \theta_3\}$.

2. Estimate firm-specific productivity, λ_i.

   (a) Draw λ_i for each firm according to $q(\Theta_1^*|\Theta_1^o)$.

   (b) Let $a_1 = \min\{1, \frac{L(\Theta_1^*)\varphi(\Theta_1^*)q(\Theta_1^o|\Theta_1^*)}{L(\Theta_1^o)\varphi(\Theta_1^o)q(\Theta_1^o|\Theta_1^*)}\}$. With probability a_1 set $\Theta_1' = \Theta_1^*$, and with probability $(1 - a_1)$ set $\Theta_1' = \Theta_1^o$.

3. Estimate the sales threshold in each market, $\bar{Q}_c$.

   (a) Draw Θ_2 according to $q(\Theta_2^*|\Theta_2^o)$.

   (b) Let $a_2 = \min\{1, \frac{L(\Theta_2^*)\varphi(\Theta_2^*)q(\Theta_2^*|\Theta_2^o)}{L(\Theta_2^o)\varphi(\Theta_2^o)q(\Theta_2^o|\Theta_2^*)}\}$. With probability a_2 set $\Theta_2' = \Theta_2^*$, and with probability $(1 - a_2)$ set $\Theta_2' = \Theta_2^o$.

4. Repeat step (3) for Θ_3 and Θ_4 using $q(\Theta_3^*|\Theta_3^o)$, $q(\Theta_4^*|\Theta_4^o)$, $a_3 = \min\{1, \frac{L(\Theta_3^*)\varphi(\Theta_3^*)q(\Theta_3^*|\Theta_3^o)}{L(\Theta_3^o)\varphi(\Theta_3^o)q(\Theta_3^o|\Theta_3^*)}\}$ and $a_4 = \min\{1, \frac{L(\Theta_4^*)\varphi(\Theta_4^*)q(\Theta_4^*|\Theta_4^o)}{L(\Theta_4^o)\varphi(\Theta_4^o)q(\Theta_4^o|\Theta_4^*)}\}$, respectively.

5. Update the variance-covariance matrix of errors. Using equations (28)-(31): Draw a new variance-covariance matrix of the errors, Σ, for equations (28)-(31) from an inverse Wishart distribution, $IW(V', v')$, where $V' = V + (e_1'; e_2'; e_3') \cdot (e_1, e_2, e_3)$, is the variance covariance matrix, $v' = v + n$, and n is the number of observations in the data set.

We set $q(\Theta^*|\Theta^o)$ to be a conditional normal distribution, in which Θ^* is drawn from a normal distribution with mean Θ^o, so as to facilitate the outer routine computation. In this way, $q(\Theta^*|\Theta^o) = q(\Theta^o|\Theta^*)$, and the acceptance probability in any block $j = 1, ..., 4$ can be written as $a_j = \min\{1, \frac{L(\Theta^*)\varphi(\Theta^*)}{L(\Theta^o)\varphi(\Theta^o)}\}$.

C Assumed Prior Distributions

We choose very diffuse prior distributions for all parameters estimated by Bayesian Markov Chain Monte Carlo. Our specific assumptions are collected in Table 11.

Table 11: Prior Distributions

Variable	Description	Assumption
$\ln(r_c)$	Market Size	$\ln(r_c) \sim N(0, 10)$
$\ln(u_c)$	Markup/Competitiveness	$\ln(u_c) \sim N(0, 2)$
$\ln(\bar{Q}_c)$	Sales Threshold	$\ln(\bar{Q}_c) \sim N(0, 10)$
f_c	Fixed Export Cost	$f_c \sim EXP(10)$
$\ln(\gamma_\tau)$	Transportation Cost Parameter	$\ln(\gamma_\tau) \sim N(0, 10)$
α	Quality Transformation Parameter	$\alpha \sim U[0, 1]$
θ_0	Taste for Quality Constant	$\theta_0 \sim U[-20, 20]$
θ_1	Taste for Quality Loyalty Parameter	$\theta_0 \sim U[-20, 20]$
θ_2	Taste for Quality Income Parameter	$\theta_0 \sim U[-20, 20]$
$\ln(\lambda_i)$	Firm Productivity	$\ln(\lambda) \sim N(0, 4)$

The first four rows correspond to region-specific parameters. In each region, the prior assumptions are identical. We note that the fixed cost draws are assumed to be drawn from an exponential distribution for parsimony; the exponential distribution can be described by parameter. The fifth row corresponds to the shipping cost parameter, while the sixth corresponds to the quality transformation parameter. Note that the quality transformation parameter is assumed to lie between 0 and 1, which is consistent with our theory. The parameters which govern the taste for quality are reported in rows 7, 8 and 9, and represent the key parameters in our estimation. As such, we assume a very diffuse uniform prior. The last row reports for the assumption for firm productivity, which is identical across all firms in our data.