# Price and Quality Dynamics in Export Markets

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**Abstract**

This paper investigates the evolution of firm-level price and quality decisions in export markets. We develop a model of heterogeneous firms which endogenously choose their optimal price and product quality to build demand in each export market. Consistent with existing research, more productive firms produce higher quality products, charge higher prices, sell more units and achieve higher profits. In our model, however, product quality and prices endogenously evolve over time as firms accumulate demand in each market and maximize the long-run value of the firm. We find that 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 increase prices in response to greater demand. We structurally estimate the model using detailed Chinese customs data. Our results indicate that the incentive to build future demand reduces export prices upon initial entry by 0.5 percent for the average exporter. Over the following five years, export prices and product quality are estimated to grow by 1 and 6 percent, respectively, due to endogenous demand accumulation.

Keywords: productivity, demand, product quality, export price
JEL Classification Numbers: F12, F14

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# 1 Introduction

Determining how firms enter and grow into diverse product-markets worldwide lies at the heart of a number of key economic questions. As formalized in the seminal contributions of Jovanovic (1982), Hopenhayn (1992), Ericson and Pakes (1995) and Melitz (2003), early models often mapped firm and industry evolution to a single dimension of firm-heterogeneity, namely productivity. A number of recent studies, such as Foster et al. (2008) or Roberts et al. (2012) among others, conclude that a single, cost-based dimension of firm heterogeneity is insufficient to fully characterize the firm-level decision to enter markets, to set prices, to upgrade product quality or to invest. This paper extends this literature with two specific objectives. First, we bridge the above literature with research that examines how firms build market share over time and develop a theory which posits the origin and evolution of firm-level demand differences across heterogeneous firms. In this sense we explicitly model where differences in firm demand come from, how demand evolves over time, and evaluate its implications for firm export decisions. Second, we use detailed Chinese customs data to quantify our theory's ability to explain firm-level export growth and study the impact of trade liberalization across heterogeneous exporters. Further, matching our customs data with detailed tariff data across export markets, we use our structural model to characterize the endogenous response of heterogeneous Chinese exporters to potential trade liberalization.

This paper begins by documenting that differences in *past* firm performance among Chinese exporters strongly influences the evolution of their *future* export sales, export prices, and input prices. We highlight three robust patterns in our data. First, greater current performance (e.g. sales) are strongly associated with greater future sales. Second, Chinese exporters initially enter new markets at relatively low prices. As firm sales grow, so do firm-level prices. Increasing prices may be indicative of increasing markups, but it might also reflect changes in product quality and input costs. Third, consistent with the preceding conjecture, we show that as firms expand into export markets the price paid for imported inputs also tends to rise. We interpret this last finding as suggesting that product quality also potentially improves as exporters gain a foothold in new export markets.

Given these stylized facts, we build a dynamic model where firms choose export prices and source quality-differentiated inputs to maximize the long-run profitability of the firm. In particular, the model features an endogenous demand accumulation mechanism where producers optimally choose prices and product quality that build future demand stock at the expense of lower current profits. In our framework firms which sell high quality products for a given price tend to have relatively high initial sales. High sales leads to greater future demand through a mechanism where consumers prefer more recognizable brands. Firms, in turn, are able to exploit greater residual demand in later years by charging higher prices and increasing markups. This mechanism is further reflected in steady-state firm dynamics that are characterized by prices, product quality, markups and sales which endogenously grow over time; each of these are relatively low when a new exporter enters a new market and will grow over time among surviving firms. The model rationalizes how initial firm-specific differences in efficiency interact with

market-specific characteristics to generate differences in pricing and product quality and, in turn, provide a theoretical motivation for the source and evolution of firm-level demand heterogeneity.

The model is structurally estimated using data from Chinese firms which export electric kettles, a quality-differentiated, manufactured product typical of Chinese exports.[1] A key advantage of this industry is that nearly all of the firms in the electric kettle industry import intermediate inputs and, as such, our data provides us with detailed input purchase information among these firms. Together these features allow us to study a setting where we can tractably specify the differences in firm characteristics and market incentives which influence firm pricing and quality choices across a wide set of export markets. Moreover, being specific about the exact product we study we are able to match our exporters to the tariff rates they face in destination markets, use our estimated model to generate counterfactual predictions in each export destination, and disentangle the margins through which electric kettle producers respond to changes in policy-relevant trade costs.

We map the parallel evolution of prices, product quality, markups, and sales through time and decompose the impact of static and dynamic incentives on the evolution of firm characteristics across export markets. For the average exporter we find that dynamic considerations *reduce* prices and increase sales upon initial entry into new markets by 0.5 and 4 percent, respectively. Over time, prices, product quality and sales endogenously rise. Five years after entry, prices and product quality are predicted to increase by 1 and 6 percent, while sales endogenously grow by 39-48 percent, conditional on survival. Further, our research suggests that a reduction in tariffs faced by Chinese electric kettle exporters rarely leads to large reductions in the average export prices of products sold to any export market. Rather, we find that product quality improves in response to trade liberalization, which mitigates the price depressing effect of tariff cuts.

Research examining firm and industry export dynamics have regularly found that new exporters are smaller than established exporters in the same market although the size gap closes gradually as the firm gains experience in new markets.[2] A number of recent theoretical contributions suggest that new exporters are small because demand for their product is low in a given market due to informational or reputational frictions, among other mechanisms. To the extent that these frictions diminish over time, demand and firm-sales grow, should the firm survive in that product market. Nonetheless, it remains unclear how firms manipulate product characteristics and pricing over time to gain a foothold in new export markets, grow sales, and maximize long-run profits.

This paper relies on an extensive 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. Our framework builds directly on the associated static models developed by Verhoogen

[1] Our sample includes electric kettles along with electric coffee makers, tea makers and other electric appliances used to heat water. For brevity, we group these together and refer to them simply as electric kettles.

[2] This finding mirrors that in industrial organization, macroeconomics and finance. See Caminal and Vives (1999), Klepper (2002), Cabral and Mata (2003), Radner (2003), Fishman and Rob (2003, 2005), Bar-Isaac and Tadelis (2008), Arkolakis (2010), Luttmer (2011), Dinlersoz and Yorukoglu (2012), Drozd and Nosal (2012), Perla (2013), and Gourio and Rudanko (2014) for examples.

(2008), Baldwin and Harrigan (2011), and Manova and Zhang (2012a). Not surprisingly, the theoretical structure captures many of same, well-known cross-sectional patterns. Allowing current demand to be a direct function of past performance, we show that this class of models can be extended to capture internal firm pricing, product quality and sales dynamics. The key departure of our model is that the firm's residual demand is a function of its past market share in a given destination country. In this sense our work is also broadly related to papers which study the impact of external habits on economic behavior as in Ravn et al. (2006), Ravina (2007) and Gilchrist et al. (2015).

Our model likewise shares intuition with Foster et al. (2015) 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 through demand accumulation. While Foster et al. (2015) focus on the US domestic market, we study the exporter decisions across a diverse set of worldwide export markets. It is well known that firm-level turnover in export markets is much higher than that in domestic markets. In our setting the static and dynamic pricing incentives diverge across firms with different expectations of sales and survival. Additionally, Foster et al. (2015) focus on a setting where there is little room for product differentiation, but our work studies firms where product differentiation and endogenous quality upgrading play a central role. In turn, we allow market-level characteristics to affect the evolution of prices, quality and the pattern of sales across countries. Our findings are consistent with Manova and Zhang (2012b) which documents that not only do larger Chinese exporters produce higher quality products, but that high quality producers sell a disproportionate percentage of exports in relatively wealthy and developed countries.

This work builds on the literature which studies firm-level trade. Similar to the seminal contributions from Eaton and Kortum (2002), Melitz (2003), and Eaton et al. (2011), our model begins by studying how initial differences in firm-productivity lead to ex-post differences in export behavior. Further, 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 (Sutton, 2007; Foster et al., 2008; Hallak and Sivadasan, 2009; Khandelwal, 2010; Baldwin and Harrigan, 2011; Manova and Zhang, 2012b; Crozet et al., 2012; Kugler and Verhoogen, 2012; Roberts et al., 2012; Gervais, 2015; Hu et al., 2015), and the impact of trade on product quality upgrading (Verhoogen, 2008; Amiti and Khandelwal, 2013; Flach, 2014; Eslava et al, 2015; Fan et al., 2015).[3]

Our empirical exercise likewise has several similarities with Roberts et al. (2012), though there are at least four substantial differences. Largely, the key differences arise from the manner in which demand is modeled and reflect an important difference in the underlying question investigated in each framework. While Roberts et al. (2012) document the important role that demand differences play

[3]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, 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).

in explaining export market selection, we are primarily interested in characterizing the intertemporal evolution of firm-level pricing and product quality. Specifically, Roberts et al. (2012) model demand as an exogenous firm-specific unobservable. Although they allow for a difference between first year demand and that in subsequent years, the growth in demand is identical for all exporters. In our model firms endogenously affect the evolution of firm-specific demand in every year through their pricing and product quality choices. Second, there are substantial conceptual differences in what each paper refers to as 'demand.' In Roberts et al. (2012) the demand unobservable acts as an exogenous cost shifter, which is justified on the basis that their demand measure captures differences in product quality. In our case, we explicitly model endogenous product quality decisions and measure product quality differences across firms using input prices. In this sense, our measure of firm-specific demand captures differences across firms other than current product quality, such as brand reputation, consumer loyalty or similar demand accumulation mechanisms. Third, we theoretically examine how differences across firms, markets and trade costs influence firm-specific pricing and product quality through time. This difference is distinctly reflected in our model's optimal pricing equation which directly depends on the firm's future expected value function. Last, these features of our model result in a structure that endogenously explains the short average duration of exporting, the rapid growth of surviving exporters and the intertemporal variation in prices and product quality among exporters.

Finally, our work relates to studies of exporter dynamics and, particularly, the mechanisms by which successful entrants grow into large, stable exporters. As such, our work closely relates to that of Costantini and Melitz (2008), Atkeson and Burstein (2010) and Arkolakis (2015). 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 firm decisions which influence the evolution of productivity. Rather, firm-level dynamics in our model evolve through a firm's active manipulation of price and quality to optimally grow future demand given the firm's expected duration in a given export market.

A particular complication for model estimation is that the firm's pricing decision in any period directly depends on the shape of the firm's expected value function. Solving the firm's dynamic problem in our context requires consistently guessing at both the expected function itself and its first derivative. We adapt modern value function approximation methods as described in Keane and Wolpin (1997) and Gallant et al (2011) to quantify the Chinese exporter's intertemporal incentive to accumulate demand across destination markets. Although a straightforward extension of existing approaches to value function iteration, we demonstrate that our extension of these methods provides researchers with a tractable approach to the estimation of high dimensional dynamic problems with non-trivial intertemporal spillovers. In this sense, our research contributes to the literature which follows the pioneering work of Das et al. (2007) and empirically characterizes the dynamic entry, duration and sales decisions of exporting firms.

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

time, while Section 8 concludes.

# 2 Three Stylized Facts from Chinese Customs Data

## 2.1 The Data

Our primary objective here is to provide a simple characterization of the nature of firm-level price and quality dynamics in export markets. The data we use 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.[4] 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 Kugler and Verhoogen (2009, 2012), Bastos, Silva and Verhoogen (2014), and Manova and Zhang (2011), we use this as a reasonable proxy for product quality.

Much of our work in this paper will focus on variation in prices and quantities for one quality-differentiated industry, the electric kettle industry. 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 to verify that we are studying patterns which are robust even within a narrowly defined industry. That said, 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 of whether 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 foreign-owned firms, state-owned firms, export intermediaries, and firms which are involved in processing trade. While this reduces our sample, it allows us to focus on firms which arguably trade under the same set of market institutions.[5]

Among industries we could choose to focus on, we chose the electric kettle industry for four key reasons. First, the electric kettle industry is a typical Chinese export-oriented manufacturing industry which exports to a wide set of destinations worldwide. Second, by focussing on the set of firms which specialize in electric kettles we are confident that we are comparing firms which are direct competitors across worldwide markets. Third, electric appliances in general, and electric kettles in particular, represent a product group with a wide scope for quality differences.[6] Fourth, nearly all of the firms in the electric kettle industry import intermediate inputs from abroad. This provides us with highly detailed

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

[5] We make this restriction to avoid issues of transfer pricing, unobserved tax differences or differential import allowances, for example.

[6] A search on google.com or amazon.com, for instance, will deliver a wide set of quality differentiated examples of electric kettles.

data regarding the inputs used in production among these firms.

Since our study will only investigate the evolution of real prices, we first convert all nominal prices to real prices by constructing price deflators. Specifically, for each HS code we calculate the average export price for each product using a revenue-weighted geometric mean. We then convert observed prices and revenues to a common year (2000) using the average annual price as a deflator. We then repeat this exercise for import prices. Further description of the data along with summary statistics can be found in the Data Appendix. Instead of discussing broad features of the data here, we highlight three key empirical patterns around which our model is constructed.

## 2.2 The Evolution of Prices and Sales: Three Stylized Facts

We document three robust patterns which characterize our data. Specifically, we study the relationship between past performance and future changes in sales, output prices and input prices.[7] Our simple exercise is to regress a current firm-level characteristic in a given destination country (sales, output price, average input price), denoted by $x_{ijkt}$, on past performance in that same country:

$$\ln(x_{ijkt}) = \alpha + \beta \ln(Q_{ijk,t-1}) + \Gamma_{ik} + \Gamma_{jkt} + \epsilon_{ijkt} \tag{1}$$

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

### 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, $\beta$, is always positive and highly significant. The coefficient ranges between 0.685 in the full sample of Chinese exporters to 0.402 in the electric kettle industry.

[7] The cross-sectional relationship between plant-size, output prices and input prices is well established in the literature. See Kugler and Verhoogen (2012) or Fan et al (2013) for examples.

Table 1: Correlation Between Current and Past Market Sales

| | Electric Kettles | | All Exporters | |
|---|---|---|---|---|
| Past Market Sales | 0.642*** | 0.402*** | 0.686*** | 0.685*** |
| | [0.014] | [0.017] | [0.001] | [0.001] |
| Destination-Product-Year Fixed Effects | Yes | Yes | Yes | Yes |
| Firm/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 are in brackets. The first two columns report estimates from the electric kettle industry, while the last two columns report results across all industries. Columns 2 and 4 include firm-product fixed effects, while the others do not. *** p<0.01, ** p<0.05, * p<0.1.

A common explanation for the persistence in firm, product and destination-specific sales 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 note that our estimate already controls for persistent unobserved firm effects, such as productivity, in the first two columns (electric kettles only) or firm-and-product effects in the last two columns (all exporters). 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.

One possible interpretation of the above result is that firms with larger past sales may be able to enjoy relatively large sales in the future if consumers[8] are loyal to a particular brand or variety.[9] In any case, we would expect that if purchasing behavior displays a strong degree of persistence, whether through consumer loyalty, brand reputation, or similar mechanisms, then changes in current performance should also affect other firm decisions, such as pricing strategy.

### 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 with past sales in that same market. Again, we are particularly interested in the correlation between past sales and future prices within the same firm-product-destination triplet, rather than across a cross-section of firms. It is already well established that there is often a strong positive

[8] We interpret consumers in a very broad sense here. For instance, recent work examining buyer and seller networks in international trade (Eaton et al. 2014; Monarch, 2015) suggest strong sales growth among exporters which maintain a relationship with an importer over time.

[9] In particular, it would be difficult to reconcile the positive correlation in columns (2) and (4) with a simple AR(1) process for an unobservable, such as productivity. For this to be the case, we would need the AR(1) productivity process to deliver unanticipated shocks which were biased upwards since any trend growth or exchange-rate induced changes would be accounted for in the firm-product-destination fixed effects. Nonetheless, we revisit this issue in Section 3.7, Section 4.1 and in the Supplemental Appendix where we consider setting which allows a stochastic productivity process to compete with our demand accumulation process as an alternative mechanism for our stylized facts.

correlation between measures of firm size and output prices.

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 0.057 in the electric kettle industry and 0.281 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 which gain 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 are also actively improving product quality to meet consumer demands. Improvements in output prices may thus reflect changes in input costs, if high quality products are more costly to produce. We explore this alternative explanation below.

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

| | Electric Kettles | | All Exporters | |
|---|---|---|---|---|
| Past Market Sales | 0.148*** | 0.057*** | 0.281*** | 0.281*** |
| | [0.011] | [0.012] | [0.001] | [0.001] |
| Destination-Product-Year Fixed Effects | Yes | Yes | Yes | Yes |
| Firm/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 are in brackets. The first two columns report estimates from the electric kettle industry, while the last two columns report results across all industries. Columns 2 and 4 include firm-product fixed effects, while the others do not. *** p<0.01, ** p<0.05, * p<0.1.

### 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 Kugler and Verhoogen (2009, 2012), Manova and Zhang (2011), and Bastos, Silva and Verhoogen (2014), among others, we use the average imported input price as a proxy of the quality of inputs used in production and, thus, product quality. A first order difficulty with our exercise is that while sales evolve product-market-by-product-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 3, 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 basic correlation between sales and input prices, should it exist. As such, we repeat our experiment using the average 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 fixed effects:

$$\overline{\ln(import\ price_{it})} = \alpha + \beta \ln(Q_{i,t-1}) + \Gamma_i + \Gamma_t + \epsilon_{it}$$

where $\Gamma_i$ and $\Gamma_t$ are firm and year fixed effects, respectively, and $\epsilon_{it}$ is again an $iid$ error term.

Table 3 documents that after controlling for firm fixed effects there remains positive correlation between current input prices and past sales for exporters for electric kettles. The coefficient on past sales is 0.035 in the electric kettle industry even though we cannot distinguish export destinations. 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.[10] Considering all Chinese exporters adds an additional layer of complexity. In particular, many firms export multiple products and there is no natural manner to aggregate the physical units of export sales across different products. As such, columns (3) and (4) restrict the sample to only consider single-product exporters. In this case, we again find strong positive correlation between past deviations from average sales and future input prices.[11]

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

| | Electric Kettles | | All Exporters | |
|---|---|---|---|---|
| Past Export Sales | -0.021* | 0.035** | -0.132*** | 0.078** |
| | [0.012] | [0.018] | [0.016] | [0.036] |
| Year Fixed Effects | Yes | Yes | Yes | Yes |
| Firm 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 are in brackets. Columns 1 and 2 report estimates from the electric kettle industry, while columns 3 and 4 report results across all industries. Columns 2 and 4 include firm fixed effects, while columns 1 and 3 do not. *** p<0.01, ** p<0.05, * p<0.1.

Overall, we cannot rule out the possibility that improvements in past performance lead 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 requires substantially more structure than provided by our simple regression. We propose a model of demand accumulation where firms optimally set prices and product quality through time to grow demand and maximize the long-run value of the firm.

[10] In the electric kettle industry over 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. Moreover, our findings for single product or single destination kettle exporters is similar to those presented in Table 3. See the Appendix for a full set of robustness checks.

[11] As a robustness check, we also reconsider the regression specification in columns (3) and (4) of Table 3, but instead of using past physical sales as an explanatory variable we use past export revenue over all products. This allows us to include all firms in our regression. We again find clear evidence that higher than average lagged revenue is associated with higher future input prices. Specifically, the coefficients on lagged revenue for the specifications in columns (3) and (4) are 0.030 and 0.023, respectively. Each coefficient is statistically significant at the 1 percent level.

# 3 A Model of Export Price and Quality Dynamics

We consider an environment composed of $J$ countries where $j = 1, ..., J$. Each country is populated by $N_j$ consumers with identical preferences which are summarized by the utility function

$$U_{jt}(k, \omega) = u_{jt}(k) + \theta[M_{ij,t-1}(\omega), \bar{I}_j]q_{ijt}(\omega) + \zeta_{jt}(\omega)$$

where $k$ is the consumption of a non-differentiated numeraire good, $q_{ijt}(\omega)$ is the quality of the differentiated final product $\omega$, $\zeta_{jt}$ is a random consumer-specific product taste shock, and $i$ indexes the source country of variety $\omega$. As is well known assuming that $\zeta_{jt}$ is independent and identically distributed across consumers and time by a Type 1 extreme-value distribution will allow us to solve for closed form demand functions. As is typical, $U_{jt}(k, \omega)$ is the consumer's utility when they consume one unit of product $\omega$ and $k$ units of the numeraire good. Each consumer is endowed with $L$ units of labor which they supply inelastically to produce either a quality differentiated intermediate input $\iota_j$ or a non-differentiated, numeraire good $k$.

The function $\theta[M_{ij,t-1}(\omega), \bar{I}_j]$ captures consumers' taste for a given variety of the differentiated final good, which we assume is a function of $M_{ij,t-1}(\omega)$, past market share of variety $\omega$ by the end of period $t-1$, and $\bar{I}_j$, is the steady state income level in country $j$ which we assume is constant over time. By construction the taste function is complementary to product quality and, by assumption $\theta$ is assumed to be increasing in $M_{ij,t-1}(\omega)$ and $\bar{I}_j$,

$$\frac{d\theta}{dM_{ij,t-1}} > 0 \text{ and } \frac{d\theta}{d\bar{I}_j} > 0. \tag{2}$$

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 have sold more in a market have greater brand recognition.[12] 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. We expect that this effect, should it exist, will demonstrate diminishing returns:

$$\frac{d\theta^2}{d^2M_{ij,t-1}} < 0 \tag{3}$$

The reader might be concerned that preferences are directly a function of past market share. This mod-

[12] In practice, many manufactured goods do not necessarily have brand names that would be directly recognized by final consumers, but they would be well known to importers. For example, evidence in Eaton et al. 2014 suggests that importers which add a new foreign supplier will purchase more from a given supplier over time, should that relationship survive. The mechanism in our model can be interpreted as a reduced-form representation of the more complex importer-exporter matching process which we do not observe in our data.

elling approach directly follows the literature which models demand as a function of external signals as in Ravn et al. (2006), Ravina (2007) and Gilchrist et al. (2015). In each of these papers, past, external consumption influences current consumer preferences in a similar fashion to that specified in our utility function.[13] Moreover, as shown below, this is equivalent in our model to the assumption that current demand reflects the evolution past pricing and product quality over the life-cycle of the firm in each market. In fact, consistent with the empirical patterns in Section 2, differences in past market share summarize differences in demand across firm brands within a cohort of firms and over time.[14] This approach has two key advantages. First, it makes the dynamic process at the heart of our model transperent. Second, it links our work to a broad literature which links brand-specific growing sales to future firm behavior.[15]

The standard assumption that the random consumer-product-match term, $\zeta_{jt}$, is independent and identically distributed across consumers and time by a Type 1 extreme-value distribution, it is straightforward to write the residual demand for product $\omega$ at time $t$ in market $j$ as

$$\begin{aligned} Q_{ijt}(\omega) &= \frac{N_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]}{\int_\Omega \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]} \\ &= r_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right] \end{aligned} \tag{4}$$

where $u_j$ is a parameter of the distribution of $\varepsilon_{jt}$ that captures the degree of differentiation between goods and $r_j = N_j / \int_{\Omega_j} \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]$ is a steady-state demand shifter. Moroever, equation (4) makes it apparent that market share is effectively a function of past sales up to a market size constant, $Q_{ijt} = N_j M_{ijt}$.

### 3.1 Non-differentiated production

Entry into the non-differentiated sector is free and these goods are produced solely by labor, $k_{jt} = A_j L^k_{jt}$ where $L^k_{jt}$ is the aggregate amount of labor devoted to producing good $k$ in market $j$ and $A_j$ is the productivity of country $j$ in producing $k$ type goods. Perfectly competitive firms hire labor from consumers up to the point that the value of the marginal product of labor is equal to its wage, $w_{jt}$: $p^k_{jt} MP_L = w_{jt} \Rightarrow p^k_{jt} A_j = w_{jt}$. Normalizing the price of non-differentiated goods to 1, we find that a unit of labor can always earn a wage $w_{jt} = A_j$ in the non-differentiated sector, as long as $k$ is produced.[16]

[13] Ravina (2007) provides empirical evidence of past external demand influencing current consumers choices, while Ravn et al. (2006) and Gilchrist et al. (2015) are primarily interested in explaining the movements of mark-ups or inflation with aggregate shocks. We demonstrate that preferences of this type can also help explain the evolution of firm pricing, product quality and sales in international export markets.

[14] Further, while the above specification emphasizes differences in past *market share*, while the stylized facts in Section 2 emphasized differences in *past sales*. We demonstrate below these will have the same dynamic properties, but choose to focus on market share since it is conveniently bounded between 0 and 1 in any product-market.

[15] See Foster et al. (2015), Piveteau (2015) or Ruhl and Willis (2015) for examples.

[16] We assume the total supply of labor is sufficiently large to guarantee this to be the case.

### 3.2 Intermediate production

Each country also produces a range of country-specific, quality-differentiated, intermediate inputs. Let $v_{jt}$ represent the quality of country $j$'s intermediate input $\iota_{vjt}$ in year $t$. The production function for the physical number of intermediate units produced of a given quality can be summarized by the production function $\iota_{vjt} = L_{vjt}/v_{jt}$ where $L_{vjt}$ is the total amount of labor allocated to produce inputs of quality $v_{jt}$ in country $j$ and year $t$. Since consumers in any country are indifferent between supplying labor towards the production of homogeneous good $k_{jt}$ and input $\iota_{vjt}$, one unit of an intermediate of quality $v_{jt}$ costs $w_{jt}v_{jt}$ to produce. Most importantly, the cost of the intermediate is always proportional to its quality in any country. We assume shipping a unit intermediate good between countries $i$ and $j$ requires paying a iceberg-shipping cost, $\tau_{ij}$, where $\tau_{ij} \geq 1$ if $i \neq j$ and $\tau_{ij} = 1$ if $i = j$.

### 3.3 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 $S$ upon entry in order to draw a firm-specific productivity level $\lambda$ 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 role of demand accumulation on the evolution of firm-level entry, prices, and product quality over time.

An individual firm produces a single variety $\omega \in \Omega$ where $\Omega$ is the set of all varieties. A firm can enter a given market $j$ by paying an iceberg shipping cost, $\tau_{ij}$, a fixed overhead cost, $f_{jt} = \bar{f}_j + \epsilon_{jt}$, and hiring inputs to be used in the production process. The fixed overhead cost has two components: a deterministic, time-invariant component $\bar{f}_j > 0$ and a stochastic component, $\epsilon_{jt}$. For simplicity, we assume that in each period the stochastic component $\epsilon_{jt}$ is an $iid$ draw from the distribution $G^{\epsilon}_{j} \sim N(0, \sigma^{j}_{\epsilon})$.[17] Total firm production, $h$, is a constant returns to scale function of composite input, $\iota_t$:

$$h_t(\omega) = \lambda(\omega)\iota_t(\omega) \tag{5}$$

where $\lambda$ captures the firm productivity, $\iota_t$ is a CES aggregate of domestic and foreign inputs:

$$\iota_t(\omega) = \left[\sum_{j \in J} \iota_{vjt}(\omega)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{6}$$

and $\sigma$ captures the elasticity of substitution across inputs from different countries. Importantly, this structure implies that the firm will purchase both domestic and foreign differentiated inputs. This feature is broadly consistent with our data; over 90 percent of producers in the electric kettle industry import

[17] Fixed costs are denominated in units of labor and for notational simplicity we absorb the wage term into $f_{jt}$.

intermediate inputs used for production.

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

$$v_t(\omega) = \min\{v_1(\omega), ..., v_J(\omega)\}. \tag{7}$$

We then allow final product quality $q_t(\omega)$ to depend on the differentiated input quality index $v_t$:

$$q_t(\omega) = \lambda v_t(\omega)^{\alpha} \tag{8}$$

where we assume that product quality is an increasing, concave function of input quality, $\alpha \leq 1$. There are a number of features of equations (7) and (8) which merit comment. First, equations (7) and (8) jointly imply that a firm's output quality will be determined by the lowest quality input. As such, no firm will optimally choose to vary their input quality across intermediate inputs.[18] That is, whatever product quality the firm optimally chooses, it must be that it is cost minimizing for the input quality to be equalized across components $v_{1t}(\omega) = v_{2t}(\omega) = ... = v_{Jt}(\omega)$. Second, if $\alpha < 1$ then to increase product quality by fixed amounts the firm must increase input quality at a faster rate.[19] Third, we allow product quality to explicitly depend on firm productivity $\lambda$, to allow for potential complementarity between these two dimensions of unobserved heterogeneity.[20]

### 3.4 Profit Maximization

We next turn to determining the firm's optimal price and quality choices over time.[21] Because the firm's production function exhibits constant returns to scale and demand is independent across markets, we can characterize firm-level decisions within each export market separately. The cost of producing and shipping one unit of output at quality level $q_{ijt}$ for consumption in country $j$ is[22]

$$C_{ij}(q_{ijt}, \lambda) = \tau_{ij} \left( \sum_{j' \in J} \tau_{ij'} w_{j'}(q_\iota) \iota_{j'}(q_\iota) \right) = \left( \frac{q_{ijt}}{\lambda^{1+\alpha}} \right)^{\frac{1}{\alpha}} \tau_{ij} \eta_i \tag{9}$$

where $i$ indexes the country of production, $j'$ indexes the source country of each input, $j$ is the destination where the final product reaches consumers, and $\eta_i = \left( \sum_{j' \in J} (w_{j'} \tau_{ij'})^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$. As common to models of product quality differentiation, the cost function is a strictly increasing function of quality and a strictly decreasing function of productivity, conditional on quality.

[18] It also is consistent with using imported input prices as a measure of input quality as in Manova and Zhang (2012a).

[19] We maintain the assumption that $\alpha < 1$ throughout the rest of our model description and verify its validity in Section 5.

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

[21] A similar model without intertemporal spillovers is described in Verhoogen (2008).

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

Firms choose price and quality to maximize the discounted stream of future profits. In each period, the incumbent firm first observes its shock to fixed overhead costs, $\epsilon_{jt}$, and decides whether or not to produce for market $j$:

$$V_j(M_{ij,t-1}, f_{jt}) = \max[0, W(M_{ij,t-1}, f_{jt})] \tag{10}$$

where $W(M_{ij,t-1}, f_{jt})$ is the continuation value of the firm with past market share $M_{ij,t-1}$ and the overhead cost draw $f_{jt}$[23]

$$\begin{aligned} W(M_{ij,t-1}, f_{ct}) &= \max_{p_{ijt}, q_{ijt}} \pi_j(p_{ijt}, q_{ijt}, f_{jt}) + \rho \int V_j(M_{ijt}, f_{j,t+1}(\epsilon_{j,t+1}))G^{\epsilon}(\epsilon_{j,t+1})d\epsilon_{t+1} \\ &= \max_{q_{ijt},\, p_{ijt}} r_j \exp\left[\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt}\right)\right]\left[p_{ijt} - C_{ij}(q_{ijt}, \lambda)\right] - f_{jt} \\ &\quad + \rho E V_j(M_{ijt}, f_{j,t+1}) \end{aligned} \tag{11}$$

and $\rho$ is the discount factor. To solve for the firm's optimal price and quality choices 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 (10) and (11) to characterize the firm's optimal 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** *Firm value is increasing in past market share,* $V'_{j1}(M_{ijt}, f_{jt}) \equiv \frac{\partial V_j(M_{ijt}, f_{jt})}{\partial M_{ijt}} \geq 0$.

Lemma 1 implies that the marginal benefit of consumer loyalty on firm value is positive. This is intuitive: as the firm grows into a given market it can exploit the increased demand for its product and increase profits over time. While the fact that the value function is increasing past market share is a key feature of our intertemporal problem, solving our model will further require that the value function is concave. A sufficient condition for this to be true is summarized in Lemma 2.

**Lemma 2** *A sufficient, but not necessary, condition for* $V''_{j11}(M_{ijt}, f_{jt}) \equiv \frac{\partial^2 V_j(M_{ijt}, f_{jt})}{\partial M_{ijt}^2} \leq 0$ *is*

$$\underbrace{\left(1 + \lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{2\alpha-1}{1-\alpha}} \theta^{\frac{1}{1-\alpha}}\right)\left(\frac{\partial \theta}{\partial M_{ijt}}\right)^2}_{\textit{Term A}} + \underbrace{\left(\frac{(1-\alpha)\theta}{\alpha}\right)\left(\frac{\partial^2 \theta}{\partial M_{ijt}^2}\right)}_{\textit{Term B}} \leq 0 \tag{12}$$

*where the arguments of* $\theta = \theta(M_{ijt}, \bar{I}_j)$ *are suppressed for notational convenience.*

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

Term A in the above inequality is clearly positive, while Term B is negative. For condition (12) to hold Term B must dominate Term A. Fundamentally, condition (12) states that the intertemporal spillover of past sales on future profits cannot be too big.[24] More generally, as long as equation (12) holds, the marginal benefit of higher current sales on the future value of the firm declines.

Given the results from Clausen and Strub (2013) along with Lemmas 1 and 2, we have established that the dynamic problem (10)-(11) satisfies the necessary conditions for the solution of optimal prices, product quality and sales for any firm in any market at any point in time. These are formulated in the propositions 1 and 2.

**Proposition 1** *When condition (12) holds, then* $\frac{\partial M_{ijt}}{\partial M_{ij,t-1}} > 0$. *Firm-level market-share, and thus firm-level sales in a given destination market, will grow over time.*

A key finding in this model is that the internal incentives to build market share over time endogenously create time-varying sales even though firm-productivity and market characteristics are constant over time. We argue that this is a particularly plausible mechanism which matches well-established features of firm-growth in export markets. Specifically, the model implies relatively rapid sales growth among new entrants which slows down among firms which successfully continue to export to the same destination over time. It also implies pricing and product quality dynamics which are consistent with the patterns documented in Section 2.

**Proposition 2** *The optimal quality at time t is*

$$q_{ijt} = \lambda^{\frac{1+\alpha}{1-\alpha}} \left[ \frac{\alpha\theta(M_{ij,t-1}, \bar{I}_j)}{\eta_i \tau_{ij}} \right]^{\frac{\alpha}{1-\alpha}} \tag{13}$$

*and the optimal price at t is*

$$p_{ijt} = \left( \frac{q_{ijt}}{\lambda^{1+\alpha}} \right)^{\frac{1}{\alpha}} \eta_i \tau_{ij} + u_j - \rho E V'_{j1}(M_{ijt}, f_{j,t+1}) \tag{14}$$

Proposition 2 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 $\theta$, the consumers' taste for quality, and, as such, both average income, $\bar{I}_j$, and past market share $M_{ij,t-1}$. This suggests that among new entrants we should expect that both price and quality will grow over time since $M_{ij,t-1} = 0$ for all new entrants. We note, however, that even though our model suggests that quality will change over time, it is entirely

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

$$\theta(M_{ij,t-1}, \bar{I}_j) = \theta_0 + \theta_1 \ln(1 + M_{ij,t-1}) + \theta_2 \ln \bar{I}_j$$

then we can reduce our condition further since $-\theta_1 \frac{\partial^2 \theta}{\partial M_{jt}^2} = \left( \frac{\partial \theta}{\partial M_{ijt}} \right)^2$ in this case. Under this assumption, condition (12) will be satisfied as long as $\theta_1$ is sufficiently small and the values of $\frac{\partial^2 \theta}{\partial M_{jt}^2}$ and $\left( \frac{\partial \theta}{\partial M_{ijt}} \right)^2$ are bounded. That is, as long as the future gain from past sales isn't too big, the value function will be concave.

determined by firm productivity, the firm's past market share, and time-invariant destination-market characteristics.

The pricing equation can be decomposed into two parts. The first part, $\left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij} + u_j$, captures the firm's optimal price, ignoring the impact of its current price on future market share and profits. Although this term captures the firm's static pricing incentives we do not intend to imply that it is constant over time. Rather, as the firm builds market share it will produce higher quality, more costly products which, in turn, will be reflected in higher prices.

The second part of the firm pricing decision, $-\rho EV'_{j1}(M_{ijt}, f_{jt})$, represents the impact of dynamic considerations on the firm's pricing decision. Conditional on quality, the firm's current valuation of future profits always has the effect of lowering the current price. The intuition for this result is straightforward: due to consumer loyalty, forward looking firms have an incentive to sell more in early periods to enhance profitability in the subsequent periods. Because of the concavity of the value function, the dynamic incentive to depress current prices declines as the firm builds market share over time.

To get a sense of how the dynamic considerations affect firm decisions, we characterize the evolution of markups across firms and time. We write the firm's markup, $\mu_{ijt}$, as

$$\mu_{ijt} = \frac{p_{ijt}}{C_{ijt}} - 1 = \frac{u_j - \rho EV'_{j1}(M_{ijt}, f_{j,t+1})}{\lambda^{\frac{1+\alpha}{1-\alpha}} [\alpha\theta(M_{ij,t-1}, \bar{I}_j)]^{\frac{1}{1-\alpha}}}. \tag{15}$$

Differentiating (15) with respect to productivity we find

$$\frac{d\mu_{ijt}}{d\lambda} = -\mu_{ijt}\left(\left(\frac{1+\alpha}{1-\alpha}\right)\frac{1}{\lambda} + \frac{\theta(M_{ij,t-1}, \bar{I}_j)}{1-\alpha}\frac{dM_{ij,t-1}}{d\lambda} + \frac{\rho EV''_{j11}(M_{ijt}, f_{j,t+1})}{u_j - \rho EV'_{j1}(M_{ijt}, f_{j,t+1})}\frac{dM_{ijt}}{d\lambda}\right) \tag{16}$$

The first term in brackets represents the current period markup incentives. It captures the fact that in this class of models more productive firms have an incentive to charge lower markups and increase sales, *ceteris paribus*. Both of the second and third terms rely on the fact that market share is increasing in productivity, $\frac{\partial M_{ijt}}{\partial \lambda}$. The second term indicates that differences in past market share give highly productive firms further incentive to reduce markups. Past market share is an additional state variable which is reflective of both firm productivity and the history of the firm in the destination market. Firms with larger past sales exploit this advantage in the same manner as firms with higher productivity and reduce markups to increase current sales. Finally, the last term mitigates this effect. Specifically, as market share grows, the marginal benefit of greater current sales in future periods declines and encourages firms to charge higher profits in the current period.

Propositions 1 and 2 also allow us to characterize the evolution of markups over time:

$$\frac{d\mu_{ijt}}{dt} = \mu_{ijt}\left(\frac{-1}{(1-\alpha)\theta(M_{ij,t-1}, \bar{I}_j)}\frac{dM_{ij,t-1}}{dt} - \frac{\rho EV''_{j11}(M_{ijt}, f_{j,t+1})}{u_j - \rho EV'_{j1}(M_{ijt}, f_{j,t+1})}\frac{dM_{ijt}}{dt}\right) \tag{17}$$

The first term in brackets represents the change in the firm's current period markup to due to larger past

market share, $M_{ij,t-1}$. As market share grows, firms have an increased incentive to exploit the quality-reputation tradeoff and reach more consumers. Since the second term in (17) is positive we again observe that dynamic incentives can offset the short-term markup incentives. As intertemporal spillovers decline over time, firms have an incentive to charge a higher markup. Moreover, if unit profit, $u_j - \rho EV'_{j1}(\cdot)$, is relatively small (large) then we would expect that the dynamic (static) pricing incentives will dominate and markups will increase (fall) over time.

### 3.5 Quality, Pricing and Export Trade Costs

We now consider how quality and pricing decisions vary across countries at the time of entry and, likewise, what impact these initial differences have on the evolution of prices and product quality in export markets. Export markets vary on five dimensions: consumer income, $\bar{I}_j$, market size, $N_j$, demand, $r_j$, the degree of competition, $u_j$, and transport costs $\tau_{ij}$. For brevity we focus our discussion on the impact of trade costs on firm pricing and product quality decisions.

Consider a firm located in country $i$ which exports two distinct markets $j$ and $j'$ which differ only in the distance from the exporting country. If past market share in each country is identical, $M_{ij,t-1} = M_{ij',t-1}$, then the firm will produce higher quality products for the closer market. Specifically,

$$\text{if } \tau_{ij} < \tau_{ij'} \text{ then } q_{ijt}/q_{ij't} = (\tau_{ij'}/\tau_{ij})^{\alpha} > 1. \tag{18}$$

In general, we would not expect that for any firm which enters two markets that $M_{ij,t-1} = M_{ij',t-1}$, 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 countries which are identical in every respect except transport costs for the first time in the same year, then the firm's market share will be larger in the country which is less costly to enter in any subsequent period. Specifically, if $N_j = N'_j$, $u_j = u'_j$, $r_j = r'_j$, $\bar{I}_j = \bar{I}_{j'}$ and $\tau_{ij} < \tau_{ij'}$ then*

$$M_{ijt} > M_{ijt'} \text{ and } \frac{dM_{ijt}}{d\tau_{ij}} < 0 \tag{19}$$

Proposition 3 indicates that an exporting firm will, all else equal, have greater sales in 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

$$\frac{dq_{ijt}}{d\tau_{ij}} = -\frac{\alpha q_{ijt}}{1-\alpha}\left(\frac{1}{\tau_{ij}} - \frac{1}{\theta(M_{ij,t-1}, \bar{I}_j)}\frac{\partial\theta(M_{ij,t-1}, \bar{I}_j)}{\partial M_{ij,t-1}}\frac{\partial M_{ij,t-1}}{\partial \tau_{ij}}\right) < 0 \tag{20}$$

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. The above 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 *decreasing* in $\tau_{ij}$:

$$\frac{dp_{ijt}}{d\tau_{ij}} = \frac{q_{ijt}}{1-\alpha}\left[\frac{-1}{\tau_{ij}} + \frac{1}{\theta(\cdot)}\frac{\partial\theta(\cdot)}{\partial M_{ij,t-1}}\frac{\partial M_{ij,t-1}}{\partial\tau_{ij}}\right] - \rho EV''_{j11}(M_{ijt}, f_{j,t+1})\frac{\partial M_{ijt}}{\partial\tau_{ij}} < 0 \tag{21}$$

where $\theta(\cdot) = \theta(M_{ij,t-1}, \bar{I}_j)$. Counterintuitively, initial prices are *declining* with the cost of exporting. When past market share is identical across similar markets, the firm optimally chooses to produce higher quality products in the markets in which it has a greater comparative advantage.[25]

### 3.6 The Distribution of Exporters

Index the age of a cohort of exporters in country $j$ 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

$$\chi^a_{ijt}(\lambda) = \int_{\epsilon_{ijt}} \tilde{\chi}^a_{ijt}(\lambda|\epsilon_{ijt})G^\epsilon(\epsilon_{ijt}) \quad \text{where} \quad \tilde{\chi}^a_{ct}(\lambda|\epsilon_{ct}) = \begin{cases} \frac{\chi^{a-1}_{ij,t-1}(\lambda)}{1-\chi^{a-1}_{ij,t-1}(\lambda^*(\epsilon_{ijt}))} & \text{if } \lambda \geq \lambda^*_{ij}(\epsilon_{ijt}) \\ 0 & \text{otherwise} \end{cases}$$

and $\lambda^*_{ij}(\epsilon_{ijt})$ is implicitly defined for each value $\epsilon_{ijt}$ as the productivity level where the firm with shock $\epsilon$ is indifferent between producing and exiting the country altogether:

$$W_{ijt}(\lambda^*(\epsilon_{ijt}), M_{ij,t-1}(\lambda^*), f_{ijt}(\epsilon_{ijt})) = 0.$$

Given this structure, we characterize the composition of a new cohort of exporters over time. These are summarized in the following propositions.

**Proposition 4** *Consider a set of firms with productivity level $\lambda$ which enter market $j$ in year $t$. The probability of exit from market $j$ is falling over time.*

This result is natural to expect given the dynamic evolution of market share and firm-value over time. The longer firms exist in a given market, the more entrenched they become: higher sales generate greater loyalty, raising future profits, and discouraging exit. We therefore expect that exit rates across similarly

[25]Note: Conditional on product quality, prices are increasing in trade costs, as we would typically expect.

productive firms will be highest in the year of entry and then decline thereafter. Moreover, it also implies that the expected duration of a firm in any country is increasing in productivity.

**Corollary 1** *The expected duration (survival) of a firm in a destination 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.

### 3.7 Discussion

Our model has important dynamic implications for prices, product quality and sales which are broadly consistent with empirical findings in China and elsewhere. This, however, comes at a cost and we would be remiss not to highlight assumptions which allow us to tractably characterize the dynamic features of our model. First and foremost, our theoretical model restricts firm-specific productivity to be constant over time. An alternative mechanism, would be to allow sales to grow through productivity improvements (e.g. Arkolakis, 2015). We do not suggest that these mechanisms may not be important, particularly in the Chinese context. However, we would note that trend productivity growth is inconsistent with our stylized facts in Section 2 since these have already been controlled for with firm-product-destination fixed effects. Further, we note that firm sales in many product-markets increase rapidly, often doubling in the first few years of exporting. An autoregressive process for productivity, as productivity is often modeled, would be insufficient to explain this robust empirical pattern. [26] Further, the dynamic spillover mechanism emphasized in our paper is consistent with those emphasized in recent work examining buyer and seller networks in international trade (Bernard et al., 2014; Eaton et al. 2014; Monarch, 2015), each of which makes the same productivity assumption that we do. Our paper contributes to this literature by mapping sales growth to endogenous dynamic pricing and product upgrading across diverse markets.

Our model also makes strong assumptions regarding the production of quality. In particular, all firms in our model will optimally choose to equalize the input quality of all components. This assumption is unnecessary for any of our theoretical results, but greatly assists the mapping of our model to the Chinese customs data. Likewise, although it is convenient that almost all firms in the electric kettles industry import intermediate inputs, in most industries this would not be the case. That said, our results continue to hold as long as higher quality inputs are more costly to procure, whether at home or abroad.[27] As noted above, this measure of product quality is used widely in empirical studies of product upgrading in a wide set of countries.[28]

[26] Nonetheless, in the Supplemental Appendix we consider a variant of our model with a stochastic productivity process to empirically confirm that this alone will not explain the price and sales dynamics emphasized in our theoretical model. Moreover, since we do not have product-level for domestic sales, we are empirically limited in evaluating the extent learning-by-doing across all markets may play a role.

[27] We have solved similar models relaxing these assumptions, but we do present them here since we cannot tractably map these models into our data.

[28] See Manova and Zhang (2012a) for an example using Chinese data.

Finally, it is possible to characterize a stationary equilibrium for all firms and all countries over time. Because we choose to estimate our model on single industry, however, our counterfactual experiments and related discussion will all be partial equilibrium in nature. As such, we relegate the formal definition of equilibrium to the Supplemental Appendix for the interested reader and instead turn to the empirical implementation of our model.[29]

# 4 Empirical Model

This section describes the empirical model which we take to the customs-level trade data. We first define the demand accumulation equation, $\theta(M_{ij,t-1}, \bar{I}_j)$, since it is not given a specific functional form in the theoretical model. We assume that it is log linear in past market share and income per capita:

$$\begin{aligned} \theta(M_{ij,t-1}, \bar{I}_j) &= \theta_0 + \theta_1 \ \ln\left(1 + M_{ij,t-1}\right) + \theta_2 \ln \bar{I}_j \\ &= \theta_0 + \theta_1 \ \ln\left(1 + \frac{Q_{ij,t-1}}{N_j}\right) + \theta_2 \ln \bar{I}_j \end{aligned} \tag{22}$$

where $N_j$ is a country specific parameter capturing market size. The parameters $\theta_0$, $\theta_1$ and $\theta_2$ 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. Note that market share is not directly observable in our data, but we do observe past sales. The model parameter, $N_j$, maps sales into market share and captures the fact that a given number of sales will have a smaller impact on demand accumulation in a larger market with more competitors relative to the same number of sales in a smaller market. In this sense, in the empirical model $N_j$ has the role of normalizing past sales across very different regions of the world.

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

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

where $d_{ij}$ is measured as the distance between Beijing and the capital city in any given destination market. Last, because the cost parameter $\eta_i$ will not be separately identified from the mean productivity draw we normalize it's value to 1.

Given the above structure, we base our estimation on four model equations. First, denote the average price of the firm's imported inputs used in production of exports for destination $j$ as $\bar{w}_{ijt}$. Equations (3)-(6) imply that the average price of imported inputs is equal to product quality for a single-destination

[29] We note that equilibrium changes in this model would be of particular interest in conjunction with relaxing the assumptions on the production of quality. For example, together these would imply that trade liberalization would have the effect of changing the distribution of quality across firms and countries.

exporter to market $j$ in year $t$:

$$\ln \bar{w}_{ijt} = \gamma_w + \frac{1}{1-\alpha}(2\ln\lambda + \ln\theta(M_{ij,t-1}, \bar{I}_j) - \gamma_\tau \ln(d_{ij}) - \ln(1+\text{tariff}_{ij})) + \varepsilon^q_{ijt} \tag{23}$$

where $\gamma_w = \frac{1}{1-\alpha}\ln(\alpha)$ is a constant and $\varepsilon^q_{ict}$ is treated as $iid$ measurement error. We would ideally measure the average import price of inputs used in the production of exports for specific destinations. However, many firms export to more than one destination in a given year. Fortunately, even though the data do not not distinguish the import price for products shipped to different countries, the model implies that the average import price among multiple-destination exporters can be written as a quantity-weighted average of the import price used to export the product to each destination

$$\bar{w}_{it} \equiv \frac{\sum_j Q_{ijt}\bar{w}_{ijt}}{\sum_j Q_{ijt}} \tag{24}$$

Equation (24) implies that although we do not generally observe $\bar{w}_{ijt}$ for multiple destination exporters we can still relate the observed variation in average import prices to quality differences using the firm-level entry and sales outcomes across destinations and time.

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

$$\ln p_{ijt} = \ln\left[\left(\frac{\widehat{q}_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\tau_{ij} + u_j - \rho EV'_{j1}(M_{ijt}, f_{j,t+1})\right] + \varepsilon^p_{ijt} \tag{25}$$

where $\widehat{q}_{ijt}$ is the model-implied firm-specific product quality of exports to destination $j$ in year $t$ and $\varepsilon^p_{ijt}$ is $iid$ measurement error in the pricing equation. A non-trivial challenge for our empirical exercise is most clearly presented in equation (25). Given an estimate of product quality, $\widehat{q}_{ijt}$, the parameter governing the relationship between input and output quality, $\alpha$, market-competitiveness, $u_j$, and firm-productivity, $\lambda$, output prices depend on the first derivative of the expected value function with respect to past sales. Naturally, the expected value function itself is unobserved, let alone its first derivative. Recovering the profit function, and thus the value function, will in turn depend on the firm's price. Breaking the circular nature of this problem is necessary for estimating equation (25) and discussed at length in the next section.

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

$$\ln Q_{ijt} = \ln r_j + \frac{1}{u_j}[\theta(M_{ij,t-1}, \bar{I}_j)\widehat{q}_{ijt} - \widehat{p}_{ijt}] + \varepsilon^Q_{ijt} \tag{26}$$

A guess of $\widehat{q}_{ijt}$, $\widehat{p}_{ijt}$ and $u_j$, allows equation (26) to identify parameters $r_j$, $N_j$, $\theta_0$, $\theta_1$ and $\theta_2$. Given ($r_j$, $N_j$, $\theta_0$, $\theta_1$, $\theta_2$) equations (23), (24) and (25) in turn identify the remaining parameters $\alpha$, $u_j$ and

firm-specific productivity $\lambda$.[30]

Although the parameters governing the evolution of price and quality can be identified from equations (23)-(26) 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 and market share depend directly on whether the firm chooses to export to any market. Fortunately, our theoretical structure implies a binary choice model for exporting to any given market in any year

$$\Pr[D_{ijt} = 1 | M_{ij,t-1}, f_{jt}, \lambda] = \Pr[\epsilon_{ijt} < W(M_{ij,t-1}, f_{jt}, \lambda | D_{ijt} = 1)]. \tag{27}$$

For computational ease we assume that the fixed export costs, $f_{ijt}$, are exponentially distributed where the shape of the destination-specific distribution can be described by the shape parameter $\bar{f}_j$.

## 4.1 An Augmented Empirical Model

Our theoretical model assumes that only last year's market performance matters for the firm's current demand conditions in any destination market. Although this assumption provides analytical tractability, we study whether it affects our quantitative conclusions by estimating a model with an alternative dynamic process, $\theta(M_{ijt}, \bar{I}_j)$. Specifically, given the importance of this function in mapping past decisions into future outcomes, we also consider an alternative, more flexible dynamic process which allows market share from the previous two years to influence current demand:

$$\begin{aligned} \theta(M_{c,t-1}, \bar{I}_c) &= \theta_0 + \theta_1 \ \ln\left(1 + M_{ij,t-1} + \gamma_m M_{ij,t-2}\right) + \theta_2 \ln \bar{I}_j \\ &= \theta_0 + \theta_1 \ \ln\left(1 + \frac{Q_{ij,t-1}}{N_j} + \gamma_m \frac{Q_{ij,t-1}}{N_j}\right) + \theta_2 \ln \bar{I}_j \end{aligned} \tag{28}$$

where the parameter $\gamma_m$ captures the importance (or depreciation) of the firm's performance two years previous relative to it's performance last year. Note that if $\gamma_m \approx 0$ then we would conclude that last year's market share is close to a sufficient statistic to describe the firm's current demand. Alternatively, if $\gamma_m \approx 1$ the dynamic process suggests that one year of poor sales (or exit) may not completely eliminate the consumer loyalty accumulated in previous years. We would ideally be able to extend this process back in time well beyond two periods. However, given that our panel data only covers seven years, it is not empirically feasible for us to do so.[31]

[30] Loosely, suppose we had a guess of $\lambda$ for each firm. Then equations (23) and (24) would identify parameters $\alpha$, $\theta_0$, $\theta_1$, $\theta_2$ and $\gamma_\tau$. Given these we can compute $\tau_{ij}$ and each firm's $\widehat{q}_{ijt}$. Recalling that $EV'_{j1}$ is an object we will have already solved for in the solution of the firms dynamic problem, we can use our estimates of $\alpha$ and $\hat{q}_{ijt}$ along with equation (25) to identify both $u_j$ and update the estimate of $\lambda$. The parameters of $\theta$ and $u_j$ are typically difficult to separately identify in this class of discrete choice models. Fundamentally, they are separately identified in this model because (1) the input price equation (23) is not a function of $u_j$ while output prices (25) are a function of both $\theta$ and $u_j$, and (2) the dynamic price incentive breaks the typical scaling of prices and sales common to a static setting. See the Supplemental Appendix for further discussion.

[31] We also consider a variant of our model where productivity follows an AR(1) process, $\lambda_t = \lambda_{t-1} + \eta_t$, where $\eta_t$ is an $iid$ productivity shock. Since this has very little effect on our estimates, no effect on the model's performance, and is further removed from the process emphasized in our theoretical work, we omit further discussion here. Nonetheless, a full empirical model description and all results are available in our Supplemental Appendix.

# 5 Estimation

As noted in Section 2, the empirical exercise focusses on Chinese exporters of electric kettles engaged in ordinary trade. To reduce the state-space of our exercise, we consider 8 distinct export destinations for each Chinese exporter: (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. Our measure of distance is a population weighted measure of the distance between Beijing and each capital city in a particular region.[32]

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.[33] 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.

## 5.1 Inner Routine

The inner routine solves the Bellman equations for each firm in each destination market given a set of destination and firm-specific parameters, $s_{jt} = \{\lambda, \ln(1+M_{jt}), \ln \bar{I}_j, \bar{f}_j, N_j, r_j, u_j, \tau_j\}$ where the subscript $i$ is omitted since all exporters are from China. The key difficulty is that the optimal pricing decision (13) and, thus both current profits and the future value of the firm, depend upon the unknown derivative of the expected value function. To address this feature of our problem, we extend well-established value-function approximation methods, so that we can consistently guess the expected value function $EV_j(M_{jt}, f_{j,t+1})$ and it's derivative $EV_{j1}(M_{jt}, f_{j,t+1})'$. Given these objects we can directly iterate upon the value function and it's first derivative until they both converge.

Our approach to this problem is intuitive and computationally tractable. We first approximate the expected value function for each destination by a polynomial of $s_{jt}$ and an unknown parameter vector. Specifically, let $X_{jt}$ denote a polynomial of $s_{jt}$ then value function is approximated as

$$EV_j(s_{jt}) = b^* + B^* \cdot X_{jt}$$

where $b^*$ is a constant vector and $B^*$ is a coefficient matrix.[34] This approach is similar to that used in the empirical literature which models dynamic decisions (see Keane and Wolpin (1997) or Gallant et al (2011), for example). For our purposes, however, this approach has an additional advantage. Given the parameters $b^*$ and $B^*$ we can immediately calculate a consistent guess of the derivative of value function with respect to $M_{jt}$ by taking the derivative of the approximated value function, $\frac{\partial EV_j^*(s_{jt})}{\partial M_{jt}} = \frac{\partial (B^k \cdot X_{ijt})}{\partial M_{jt}}$.

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

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

[34] We experimented with different orders of polynomials, but it had little effect on the results.

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. For this we initialize the inner routine by setting all parameters $\{b^0, B^0\}$ to 0 and calculate consistent measures of current profits ($\pi_{jt}(s_{jt})$), the continuation value ($W_j(s_{jt})$) and the value function ($V_j(s_{jt})$). We can then regress the computed $V_j(s_{jt})$ on a constant and $X_{ijt}$ 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 $\epsilon$ is an arbitrarily tolerance level. Last, the fixed point of the value function is then computed as $EV_j^*(s_{jt}) = b^k + B^k \cdot X_{jt}$. Note that our process explicitly accounts for the endogenous entry of firms into export markets where the $V_j(s_{jt})$ is positive. A detailed description of our routine is reported in the Appendix.

### 5.2 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 $\Theta = \{\lambda_i, N_1, ..., N_7, r_1, ...r_7, u_1, ..., u_7, \bar{f}_1, ..., \bar{f}_7, \alpha, \theta_1, \theta_2, \theta_3, \gamma_\tau\}$. Given the old draw $\Theta^o$, a new draw is made from a conditional distribution $q(\Theta^*|\Theta^o)$. To facilitate the outer routine computation $\Theta^*$ is drawn from a normal distribution with mean $\Theta^o$. For each block of parameters we choose very conservative prior distributions which are documented in the Appendix. Then we follow a standard Metropolis-Hastings algorithm to update model parameters.[35]

## 6 Results

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

### 6.1 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, $\alpha$, and the trade cost parameter, $\gamma_\tau$. The first two columns correspond to the benchmark model, while the latter two report the same statistics for the augmented model along with the deprecation parameter on lagged market share, $\gamma_m$.

The key model parameter, $\theta_1$, maps past performance into future profits. We find robustly positive estimates for $\theta_1$ which implies that firms with larger past market share in a given export market are more likely to charge higher prices and produce higher quality products next year. We also find that $\theta_2$ is positive. Consistent with existing research, this implies that richer countries have a stronger taste

[35] 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 (23)-(26) are drawn from an inverse Wishart distribution. Details can be found in the Appendix.

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 is of economic significance. In the following sections we illustrate the impact of the estimated dynamic spillovers on the evolution of prices and quality in export markets.

Table 4: Parameter Estimates

| | Benchmark Model | | Augmented Model | |
|---|---|---|---|---|
| Parameter | Mean | Std. Dev | Mean | Std. Dev |
| $\theta_0$ (Taste for Quality - Intercept) | 0.911 | (0.006) | 0.907 | (0.005) |
| $\theta_1$ (Taste for Quality - Reputation Parameter) | 1.987 | (0.009) | 1.697 | (0.018) |
| $\theta_2$ (Taste for Quality - Income Parameter) | 0.022 | (0.002) | 0.137 | (0.037) |
| $\alpha$ (Quality Transformation Parameter) | 0.051 | (0.001) | 0.137 | (0.006) |
| $\gamma_\tau$ (Trade Cost Parameter) | 0.198 | (0.053) | 0.122 | (0.005) |
| $\gamma_m$ ($M_{ij,t-2}$ Depreciation Parameter) | — | — | 0.498 | (0.019) |

Notes: The above table 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, $\alpha$, the trade cost parameters, $\gamma_\tau$ and the deprecation parameter on lagged market share, $\gamma_m$.

The positive coefficient on $\alpha$ indicates that firms which choose higher quality inputs produce higher quality products. Because it is estimated to be less than 1, to repeatedly increase product quality by fixed increments, our model implies that firms will need to improve input quality by increasingly large steps.[36] Finally, the positive coefficient trade costs indicates it is more costly to export to more distant destinations.

In most cases, the estimated parameters are very close across models. As expected, the primary difference is $\theta_1$, the reputation parameter, which is substantially lower in the augmented model (1.697) relative to the benchmark case (1.987). This does not necessarily imply that past market share is less important in the augmented model since the depreciation parameter is well above zero. Rather, this difference implies that for young firms it will take longer to build brand loyalty and slow the growth of Chinese exporters into new markets. We investigate these differences in detail below.

Table 5 reports country-specific parameters. Consistent with our expectations, larger and richer markets, (e.g. US, Europe or Japan), are estimated to have more consumers, higher demand and larger markups when compared to clearly smaller or poorer markets. It is clear from Table 5 that the estimated static markup parameter in South America, $u_j$, seems to be substantially lower than the others. As we report in the following section, this is driven by the fact that our data suggest much lower export prices to South America. There is also substantial variation in fixed costs across markets, where the US, Europe and Japan are estimated to be the most costly markets to enter while South America and Africa are the least costly. This last feature, in part, reflects differences in turnover rates as documented in the subse-

[36] Eliminating the complementarity between input quality and productivity increases the value of $\alpha$, but reduces model fit. As such, we do not focus on this variant of the model

Table 5: Country-Specific Parameter Estimates

| | Size, $N_j$ | | Demand, $r_j$ | | Markup, $u_j$ | | Fixed Costs, $\bar{f}_j$ | |
|---|---|---|---|---|---|---|---|---|
| | Bench. | Aug. | Bench. | Aug. | Bench. | Aug. | Bench. | Aug. |
| USA/Canada | 13.599 | 11.087 | 16.823 | 15.224 | 0.999 | 1.178 | 8.901 | 10.020 |
| | (0.592) | (0.592) | (0.434) | (0.225) | (0.031) | (0.021) | (0.086) | (0.057) |
| Japan/Korea | 11.147 | 9.901 | 18.436 | 15.642 | 0.968 | 1.260 | 7.990 | 10.098 |
| | (0.187) | (0.187) | (0.301) | (0.622) | (0.021) | (0.020) | (0.087) | (0.057) |
| Europe | 24.106 | 23.413 | 36.456 | 36.894 | 0.908 | 1.194 | 17.799 | 26.999 |
| | (0.613) | (0.613) | (0.653) | (0.909) | (0.022) | (0.016) | (0.087) | (0.057) |
| Australia/New Zealand | 4.585 | 4.386 | 7.964 | 8.158 | 1.101 | 1.299 | 4.809 | 5.701 |
| | (0.103) | (0.103) | (0.192) | (0.875) | (0.051) | (0.030) | (0.086) | (0.057) |
| S. America/Mexico | 7.167 | 6,871 | 6.861 | 6.870 | 0.306 | 0.421 | 7.088 | 2.996 |
| | (0.020) | (0.020) | (0.273) | (0.273) | (0.005) | (0.006) | (0.086) | (0.058) |
| Africa | 6.405 | 8.793 | 7.563 | 10.090 | 0.982 | 1.167 | 4.390 | 6.200 |
| | (0.332) | (0.332) | (0.202) | (0.217) | (0.021) | (0.017) | (0.086) | (0.057) |
| Rest of Asia | 7.821 | 8.022 | 9.184 | 10.050 | 0.885 | 1.050 | 4.329 | 7.500 |
| | (0.264) | (0.264) | (0.202) | (0.167) | (0.042) | (0.018) | (0.087) | (0.057) |

The above table reports the means and standard deviations (in parentheses) of the posterior distribution for the parameters for country size, $N_j$, demand, $r_j$, markups, $u_j$, and average export entry costs, $\bar{f}_j$. The parameters $N_j$, $r_j$, and $\bar{f}_j$ are measured in thousands.

quent section. Although the standard deviations on all parameters appear to be relatively small these do not in and of themselves indicate that the estimated model is capturing key patterns from the data.

## 6.2 Model Performance

We simulate the model at the mean estimate of each parameter and collect simulated prices, qualities, sales, and turnover rates for every firm in every destination market. After repeating this exercise 100 times, we proceed to compare pricing, sales and export entry decisions from the simulated data with their empirical counterparts from the Chinese customs data. First, we examine how well our model matches average firm-level prices and sales across regions in Table 6.

Table 6: Log Export Prices and Sales Across Countries

| Market | US/CAN | JAP/KOR | EU | AUS/NZ | SA/MEX | AFR | ASIA |
|---|---|---|---|---|---|---|---|
| | | | | Export Prices | | | |
| Data | 0.284 | 0.398 | 0.300 | 0.358 | -0.410 | 0.181 | 0.337 |
| Benchmark Model | 0.296 | 0.417 | 0.200 | 0.405 | -0.470 | 0.190 | 0.339 |
| Augmented Model | 0.287 | 0.381 | 0.292 | 0.348 | -0.395 | 0.170 | 0.317 |
| | | | | Export Sales | | | |
| Data | 9.513 | 9.185 | 10.228 | 8.414 | 9.550 | 9.343 | 9.224 |
| Benchmark Model | 9.491 | 9.111 | 10.385 | 8.241 | 10.403 | 8.978 | 8.904 |
| Augmented Model | 9.399 | 9.150 | 10.163 | 8.332 | 10.284 | 9.019 | 9.095 |

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

Table 7: 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 |
| Benchmark Model | 0.413 | 0.427 | 0.446 | 0.368 | 0.382 | 0.533 | 0.441 |
| Augmented Model | 0.417 | 0.432 | 0.443 | 0.369 | 0.417 | 0.450 | 0.522 |
| | | | Exit Rates (%) | | | | |
| Data | 0.589 | 0.564 | 0.516 | 0.618 | 0.611 | 0.435 | 0.541 |
| Benchmark Model | 0.587 | 0.573 | 0.554 | 0.632 | 0.618 | 0.467 | 0.559 |
| Augmented Model | 0.583 | 0.568 | 0.557 | 0.631 | 0.583 | 0.550 | 0.479 |

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

We find that both the benchmark and augmented model generally capture the pattern of price and sales 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.[37] We also predict the average log import price using the model's structure. The benchmark and augmented models predict an average import price of -2.34 and -2.72, respectively, both of which are somewhat above the average log import price in the data, -4.84.

We further examine the model's ability to capture the turnover of export producers across diverse export markets. Table 7 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 7 suggests that the model fits dynamic entry and exit decisions relatively well, it does not reveal whether the model captures the firm and market evolution of prices and quality as documented in Section 2. 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 fixed effects, and 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. Table 8 reports regression coefficients from the simulated data along with original regression coefficients from Tables 1-3 for comparison.

[37] In particular, we note that the estimated model fits the average prices even in South America and Mexico, which are notably lower than those elsewhere. It does so at the expense of reducing the static markup parameter in Table 5, $u_j$, to be substantially lower than in other regions. We have investigated why prices may be much lower in this region. While there is little conclusive evidence from outside data sources, it is clear that China and Mexico compete intensely in this product and related industries. For example, Leromain and Orefice (2013) compute that the top three countries with a revealed comparative advantage in machinery and electrical equipment are Korea, China and Mexico. Further, as reported by Observatory for Economic Complexity these same three countries had the largest export market share among in the HS code 8516 (which includes electric kettles) among developing countries in the year 2000 (data available at https://atlas.media.mit.edu).

Table 8: Replicating Export Sales, Export Price and Import Price Dynamics

| | Dependent Variable | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Export Sales | | | Export Prices | | | Import Prices | | |
| | Data | Bench. Model | Aug. Model | Data | Bench. Model | Aug. Model | Data | Bench. Model | Aug. Model |
| Past Export Sales | 0.402 | 0.573 | 0.321 | 0.057 | 0.106 | 0.067 | 0.035 | 0.033 | 0.039 |
| | [0.017] | [0.070] | [0.067] | [0.012] | [0.017] | [0.027] | [0.018] | [0.015] | [0.022] |

Notes: The above results are OLS estimates of $\beta$ in equation (1), $\ln(x_{imt}) = \alpha + \beta \ln(Q_{im,t-1}) + \Gamma_i + \Gamma_{mt} + \epsilon_{imt}$, where $\Gamma_{ij}$ is a firm fixed effect, $\Gamma_{mt}$ is a destination-year fixed effect, and $i$, $m$ and $t$ index firms, 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. Destination-year fixed effects are replaced by year fixed effects in the import price regression.

Overall, the simulated data replicate the dynamics qualitative patterns in the actual data very closely. This is broadly suggestive that the model is capturing much of the underlying dynamics in the data generating process, particularly since this regression structure is not used to estimate the model.[38]

To investigate the dynamic properties of the model further we consider a similar exercise which examines the model's ability to replicate the empirical sales, prices and quality patterns over the firm's lifecycle. As highlighted in a number of recent contributions, young firms tend to demonstrate an 'up-or-out dynamic' to their lifecycle; that is, surviving firms tend to grow quickly upon entry, while less successful firms are highly likely to leave the market altogether (Haltiwanger et al., 2014; Foster et al., 2015; Piveteau, 2015). Over time growth tends to slow as the firm ages and the probability of survival increases. We examine whether these patterns also appear in our data and can be rationalized, in an international context, by our model.

Specifically, among new entrants we regress the growth of a firm-characteristic, $x_{imt}$ (sales, export prices, import prices), on the firm's age in a market, it's age squared, and destination-year fixed effects

$$\Delta \ln(x_{imt}) = \psi_0 + \psi_1 age_{imt} + \psi_2 age_{imt}^2 + \Gamma_{mt} + \xi_{imt}^x \tag{29}$$

where $age$ is the number of consecutive years the firm has exported to a given destination market by year $t$, $\Gamma_{mt}$ captures destination-year fixed effects, and $\xi_{imt}^x$ is an $iid$ shock. As in Section 2, we cannot observe which inputs are allocated to exports to any country. To address this issue as transparently as possible we focus on the set of producers in either the actual or simulated data which only export to a single destination. In this sense, we can be confident that the imported inputs are used for production of

[38] It would be natural to question why we present the model's performance in terms of sales rather than market share. As noted in Section 2, market share and sales are proportional to each other, $M_{ijt} = Q_{ijt}/N_j$, and, as such, we would expect that they would capture the same dynamic pattern, up to a market-specific constant. Moreover, it is straightforward (and intuitive) to compare both the quantitative magnitudes between the actual and simulated data when using sales rather than market share. In contrast, while we can measure market share in the simulated data, we cannot construct an analogous measure using the actual data.

a good to a specific destination country.[39] The results for each regression, using both the actual and the simulated data, are reported in Table 9.

Table 9: Prices, Product Quality and Age

| | Dependent Variable | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Export Sales | | | Export Prices | | | Import Prices | | |
| | Data | Bench. Model | Aug. Model | Data | Bench. Model | Aug. Model | Data | Bench. Model | Aug. Model |
| Age | 2.105 | 1.608 | 3.368 | 0.360 | 0.717 | 0.867 | 0.154 | 0.208 | 0.329 |
| | [0.176] | [0.732] | [1.863] | [0.124] | [0.188] | [0.463] | [0.044] | [0.098] | [0.137] |
| Age$^2$ | -0.193 | -0.193 | -0.399 | -0.059 | -0.099 | -0.108 | -0.029 | -0.031 | -0.056 |
| | [0.036] | [0.109] | [0.247] | [0.025] | [0.028] | [0.061] | [0.009] | [0.014] | [0.020] |
| Destination-Year FE | Yes | Yes | Yes | Yes | Yes | Yes | No | No | No |
| Year FE | No | No | No | No | No | No | Yes | Yes | Yes |

Notes: The above results are the OLS coefficient estimates on variables age and age squared as described in equations (29) and (30). Robust standard errors are in brackets. Destination-year or year fixed effects are included in each regression.

Each model generates data that matches the age dynamics of prices, product quality and sales very closely among young exporters even though age does not directly feature in our empirical structure. In this sense our formulation of demand accumulation endogenously generates non-trivial firm-destination-age dynamics for prices, product quality and sales even though the model does not feature age as a key firm-level determinant.

Finally, we also test the model's empirical predictions by examining the relationship between firm age, survival, and past market sales. Specifically, we first consider a linear probability model for firm survival where we regress an indicator variable for survival in a given market on firm age, age squared and destination-year fixed effects:

$$D_{imt} = \chi_0 + \chi_1 age_{imt} + \chi_2 age_{imt}^2 + \Gamma_{mt} + \xi_{imt}^D \tag{31}$$

where $D_{imt} = 1$ if firm $i$ exports to market $m$ in year $t$ and zero otherwise, and $\xi_{imt}^D$ is again an $iid$ error term. As emphasized in Ruhl and Willis (2015) many new exporters tend to exit export markets in the first year of exporting. Thereafter, the probability of survival tends to rise sharply. Our data strongly replicates this first feature for Chinese exporters as the coefficient on age is negative and relatively large,

[39] This approach comes at the cost of a significant sample size reduction. While there are 536 observations in the actual data for export sales and prices (using all data), there are only 179 observations for import prices once we condition on single-destination exporters. As in Section 2.2, we also consider a firm-level regression for average log import price growth

$$\Delta\overline{\ln(import\ price_{it})} = \tilde{\psi}_0 + \tilde{\psi}_1 a\tilde{g}e_{it} + \tilde{\psi}_2 a\tilde{g}e_{it}^2 + \tilde{\Gamma}_t + \tilde{\xi}_{it}^w \tag{30}$$

where $a\tilde{g}e$ now measures the total number of consecutive years a firm has been exporting. Again, the model simulated data fits the actual data closely. However, given that this exercise is somewhat more difficult to interpret we relegate the results and discussion to the Supplemental Appendix.

Table 10: Survival and Age

| | Dependent Variable, $D_{imt}$ | | | | | |
|---|---|---|---|---|---|---|
| | Data | Bench. Model | Aug. Model | Data | Bench. Model | Aug. Model |
| Age | -0.866 | -0.351 | -0.661 | -0.164 | -0.196 | -0.578 |
| | [0.010] | [0.038] | [0.104] | [0.062] | [0.061] | [0.197] |
| Age$^2$ | 0.125 | 0.040 | 0.055 | 0.026 | 0.030 | 0.069 |
| | [0.002] | [0.007] | [0.017] | [0.011] | [0.011] | [0.033] |
| Productivity | | | | 0.171 | 0.123 | 0.053 |
| | | | | [0.047] | [0.040] | [0.012] |
| Destination-Year FE | Yes | Yes | Yes | Yes | Yes | Yes |

Notes: The above results are the OLS coefficients estimates on variables age and age squared as described in equations (29) and (30). Standard errors are in brackets. Destination-year or year fixed effects are included in each regression.

the coefficient on age squared is positive, and both are statistically significant. They jointly imply an increasing survival rate the longer a firm has been exporting to a given destination market. In the left panel of Table 10, the model simulated data closely replicate the empirical pattern in the data.

However, in our model, survival is not only explained by age, but also by firm productivity. In this sense we might be concerned that if age and productivity are correlated, the coefficients may reflect omitted variable bias. While we do not have a direct measure of productivity, we can apply the modeled estimated productivity for each firm as an additional regressor in our regression exercise.[40] The second panel of Table 10 documents that the age coefficients maintain their size and significance, while higher productivity discourages exit in all three cases. Overall, the model replicates the actual survival patterns over the distribution of firm age even though this does not feature directly in our estimation equations (23)-(27).

## 6.3 Model Implications: Export Prices, Quality and Sales

In this section, we use simulation methods to quantify the estimated model's implications in economically meaningful magnitudes. We simulate the model in two different scenarios. In the first case, we simulate the model under the benchmark parameter estimates for the average firm (average log 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, $\theta_1 = 0$. Comparing the percentage difference in output prices, input prices and sales allows us to quantify the impact of intertemporal spillovers on the typical Chinese exporter.[41]

Panel (a) of Figure 1 documents the impact of the demand accumulation on product quality over time. The first year of the figure is the year of entry and, as such, past market share is zero by construction. Because $\theta_1$ will not affect the firm's quality choice differentially across our two simulations in the year of

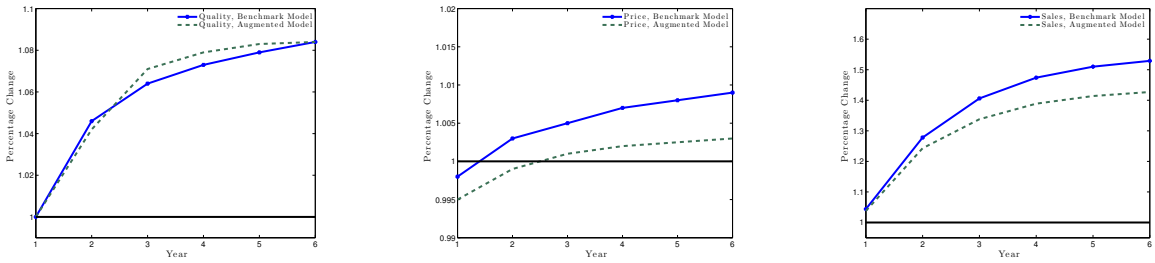
[40] The productivity measure reported in the right-panel of Table 10 for the actual data is taken from the estimated benchmark model.

[41] We normalize product quality, prices and sales for the model without intertemporal spillovers to 1 in the year of entry.

initial entry, there is no difference across models. After the year of entry, growing sales encourage future demand which in turn drives an increase in product quality in the model with intertemporal spillovers. Specifically, between the first and second year product quality improves by 4-5 percent and then grows slowly thereafter. Five years after entry the intertemporal spillover accounts for an 8 percent increase in product quality across models.

Although quality choices are identical in the year of entry, Panel (b) documents that the intertemporal spillover depresses export prices slightly in the initial period. In fact, we find that the initial output price is 0.2-0.5 percent lower than that charged by the firm in which there is demand growth. This reflects the fact that firms care about the impact that current choices have on future profits in the export market. Although the percentage difference in prices difference is small it is predicted to lead to significantly higher initial sales even if it comes at the cost of lower initial profits. In fact, initial export sales are 4 percent higher in either demand accumulation model.

Figure 1: Evolution of Export Product Quality, Prices and Sales




(a) Product Quality (b) Export Prices (c) Export Sales

Notes: The above figure documents the evolution of prices, product quality and sales overtime of an average firm in an average export market.

Without demand accumulation prices, product quality and export sales are constant over time. In contrast, the dynamic models predict endogenous growth in prices, quality and sales. As quality improves prices also rise; in the benchmark model export prices increase by 1.1 percentage points over 5 years for the average firm, while in the augmented model the price increases by 0.8 percentage points. In either case, the firm's optimal price is higher than that charged by the static firm in later years because demand accumulation encourages the growth of (product quality driven) costs and markups. The growth in prices is smaller than that of product quality because, for the average firm, the static markup parameters, $u_j$, tend to be relatively important even in a fully dynamic setting. In our simulated example, the static markup parameter is nearly twice the size of the average firm's costs, $C_{ijt}$, upon entry.

Although prices change by a relatively small percentage, this should not be interpreted as having a small impact on firm sales. Over time the combined growth of product quality and prices imply that average export sales increase by 39-48 percent relative to the average firm's first year's sales. In either case, these represent total export sales which are 43-52 percent greater than implied by the static model

after five years.[42]

While the above experiment quantifies the economic importance of the dynamic spillovers for the average firm's product quality and pricing, it obscures the rich heterogeneity across firms. As implied the model, we would expect dynamic pricing incentives to vary across the distribution of firms. To get a better sense of the quantitative magnitudes implied by the model we consider the ratio of the firm's optimal price, $p_{ijt}$, in equation (14) to the price the firm would choose if it ignored the dynamic pricing incentives. We label this latter object the firm's 'myopic' price and define it as $p^m_{ijt} \equiv \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij} + u_j$. Using the 'myopic' price we define the dynamic price discount as

$$\text{Discount} = 1 - \frac{p_{ijt}}{p^m_{ijt}} = \frac{\rho EV'_{j1}(M_{ijt}, f_{j,t+1})}{p^m_{ijt}} \tag{32}$$

Equation (32) captures the price discount induced by dynamic pricing incentives. Among firms which do not expect to export to the same destination next year $EV'_{j1} = 0$ and there is no incentive to reduce prices in the current period. Among firms that expect to continue exporting to the same destination in future periods, $EV'_{j1} > 0$ but the magnitude of the discount depends on the expected gains from current price reductions and the incentive to produce high quality, and costly, products in the current period, as reflected by $p^m_{ijt}$.

Table 11: Dynamic price discounts across the distribution of Chinese exporters to the US (in Percentages)

| | Benchmark Model | | | | | Augmented Model | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Market Share | Percentile of the Productivity Distribution | | | | | | | | | |
| Percentile | $5^{th}$ | $25^{th}$ | $50^{th}$ | $75^{th}$ | $95^{th}$ | $5^{th}$ | $25^{th}$ | $50^{th}$ | $75^{th}$ | $95^{th}$ |
| $3^{rd}$ | 0 | 0 | 0 | 0 | 0.304 | 0 | 0 | 0 | 0 | 0.216 |
| $5^{th}$ | 0.314 | 0.311 | 0.308 | 0.306 | 0.302 | 0.223 | 0.220 | 0.218 | 0.216 | 0.214 |
| $25^{th}$ | 0.280 | 0.276 | 0.274 | 0.270 | 0.267 | 0.195 | 0.192 | 0.190 | 0.187 | 0.185 |
| $50^{th}$ | 0.248 | 0.244 | 0.241 | 0.238 | 0.234 | 0.173 | 0.170 | 0.168 | 0.165 | 0.162 |
| $75^{th}$ | 0.226 | 0.221 | 0.218 | 0.215 | 0.211 | 0.158 | 0.155 | 0.153 | 0.150 | 0.147 |
| $95^{th}$ | 0.213 | 0.208 | 0.205 | 0.202 | 0.198 | 0.149 | 0.146 | 0.144 | 0.141 | 0.138 |

Notes: The above table documents the dynamic price discounts $1 - \frac{p_{ijt}}{p^m_{ijt}}$ across the joint distribution productivity and past market share for Chinese electric kettle exporters to the US.

Table 11 documents the dynamic price discounts, equation (32), across the distribution of productivity and past market share for Chinese exporters to the US.[43] Consider first low productivity firms in the third percentile of the market share distribution. In either the benchmark or augmented model, these firms are predicted to offer no dynamic price discount; in fact, the zeros effectively pin down which firms

[42] Although we are not aware of any work which highlights such steady-state patterns for export prices and product quality, this pattern for the growth of sales has been demonstrated to hold in a variety of contexts. See Eaton et al (2014), Foster et al (2015) or Rho and Rodrigue (2016).

[43] The distribution of past market share is restricted to those with positive past sales. For example, the first row captures the third percentile of the distribution of past market share among firms which had positive US exports last year.

rationally expect to exit this market in the subsequent year. As we increase productivity or market share, we initially observe larger price discounts. However, as market share continues to increase the price discount shrinks. This pattern reflects the fact that as market share grows the incentive to produce higher quality products in the current period also increases. Producing higher quality products causes costs to rise and drives myopic prices upwards faster than dynamic pricing incentives.

Across the distribution of exporters to the US, the predicted price discounts range between 0.14-0.31 percent. While these discounts are modest, our model does suggest that export markets are sufficiently competitive for these differences to have a non-trivial impact on sales. For example, for an exporter in the $50^{th}$ percentile of the productivity distribution a 0.25 percent price discount represents nearly a 3.2-3.6 percent increase in first year sales, even though there is no difference in product quality. Likewise, if it was in the $50^{th}$ percentile of the market share distribution it would account for a 3.5-4.0 percent increase in sales. In either case, these relatively small pricing differences account for economically meaningful differences in export outcomes.

# 7 Trade Liberalization

In this section, we conduct two experiments aimed at providing insight into the firm and industry responses to trade liberalization in a context where export prices and product quality endogenously evolve over time. Our first experiment again isolates an individual firm and destination to illustrate the firm's reaction to a change in trade costs in destination markets. We then consider a counterfactual simulation exercise which highlights the aggregate implications of export market tariff liberalization across destinations worldwide.[44] Note that these are strictly partial equilibrium experiments in that we do not adjust any aggregate equilibrium variables. Further, we restrict our discussion to the benchmark model since both variants of our model perform similarly.[45]

## 7.1 Individual Firm Dynamics

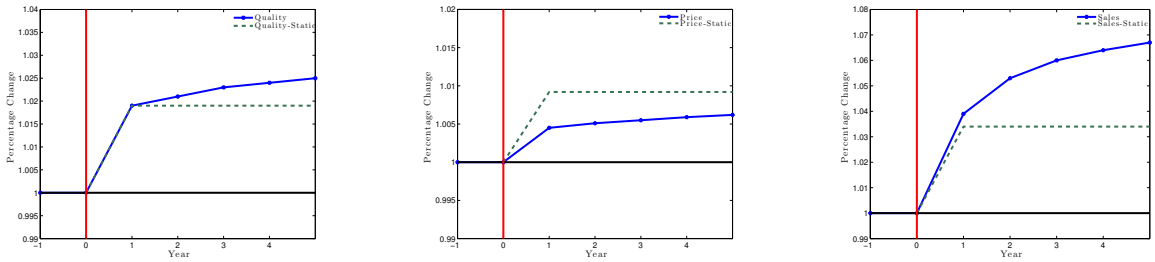
We first characterize the average firm's response to trade liberalization in the average export. To be specific, we set the average tariff in our hypothetical setting to the average tariff observed in the data prior to trade liberalization (7 percent) and allow the firm to enter and grow into the typical export market until prices, product quality and sales are constant over time. We then reduce the destination market tariff to zero and study how the firm changes it's behavior over time.

Figure 2 plots the dynamic path of export product quality, prices and sales over time, where the benchmark values are normalized to 1 in the year before trade liberalization (year -1 in Figure 2). Trade

[44] Fan et al. (2014) study the impact of Chinese tariff reductions on product quality upgrading and export prices in a related setting. While our models differ substantially, the qualitative result is the same: if the cost associated with acquiring high quality input falls, firms will endogenously respond by improving product quality and raising export prices. Our exercise is complementary in the sense that we consider the impact of tariff reductions in destination markets.

[45] The results for the augmented model are reported in the Supplemental Appendix.

Figure 2: Impact of Trade Liberalization




(a) Product Quality (b) Export Prices (c) Export Sales

Notes: The above figure documents the evolution of prices, product quality and sales overtime of an average firm in an average export market after trade liberalization in period 0. The blue starred line captures the firm pricing, product quality and sales under the benchmark model parameters. The green dashed line captures the firm's pricing, product quality and sales under the assumption that it ignores all dynamic pricing considerations starting in period 0.

liberalization is announced at the end of the subsequent year (year 0) after which we observe a sharp, immediate jump followed by a slow rise in all three variables (the blue starred lines in Figure 2). We find that trade liberalization increases the average firm's sales by 3.9 percent immediately, while product quality simultaneously rises by 1.9 percent. Prices increases by a much more moderate 0.4 percent. Although this is small, it is important to remember that we find very moderate *increases* in prices despite a 7 percent *decline* in marginal trade costs. This starkly contrasts to the large majority of trade models where tariff reductions will necessarily to lead price reductions to increase sales. After 5 years export prices are 0.6 percent higher than the pre-liberalization price despite reduced trade costs. Likewise, product quality grows by a further 0.6 percent after the first year, for a total increase of 2.6 percent. Jointly these imply that trade liberalization will increase the sales of the typical exporter by nearly 5.5 percent after 5 years. It is important to note that these changes are by no means small, particularly when we recall that we are dissecting the change in behavior of an *established firm*. That is, we consider a firm where prices, product quality and sales are stable prior to trade liberalization. In our context trade liberalization will tend to have it's largest effects on young exporters. We abstract from this to isolate the effect trade liberalization itself from the firm's internal dynamics.

Moreover, it is straightforward to show that the *relative* contribution of intertemporal spillovers to overall trade induced changes are significant. To show this we reconsider the firm's quality and pricing choices assuming (a) that the firm ignores the intertemporal spillover after the trade liberalization announcement, and (b) that it has the same state variables as our dynamic producer prior to trade liberalization. The green dashed line in Figure 2 plots the static pricing and quality contributions to the firm's reaction to trade liberalization. The difference between the green (dashed) and blue (starred) lines then capture the intertemporal spillover component.

By construction, the myopic producer makes the same quality decision in the first year after trade

Table 12: Percentage Change in Product Quality and Export Prices Across Markets

| Destination Market | US/CAN | JAP/KOR | EU | AUS/NZ | SA/MEX | AFR | ASIA |
|---|---|---|---|---|---|---|---|
| Tariff Rate (%) | 2.394 | 4.070 | 3.158 | 3.929 | 17.315 | 26.445 | 9.677 |
| Years After Trade Lib. | | | Export Product Quality | | | | |
| 1 | 0.9 | 1.1 | 1.0 | 1.5 | 1.2 | 1.0 | 1.5 |
| 5 | 1.3 | 1.2 | 1.5 | 1.9 | 1.4 | 1.4 | 1.8 |
| | | | Export Prices | | | | |
| 1 | 0.9 | 1.4 | 0.8 | 1.3 | 7.7 | 4.7 | 1.9 |
| 5 | 1.2 | 2.3 | 1.2 | 2.1 | 21.0 | 5.9 | 2.3 |

Notes: The above table reports the percentage change in average product quality or average prices for electric kettle exporters in the benchmark model induced by setting tariffs to 0 in each export market.

liberalization. However, after 5 years, the intertemporal spillover accounts for 24 percent of the total liberalization induced change in the average firm's product quality. We can likewise decompose the growth of prices and sales. We find that intertemporal concerns depress prices by 51 percent and increase sales by 13 percent upon trade liberalization. After 5 years, prices remain 33 percent lower and sales are 49 percent higher than that anticipated by a static producer.

## 7.2 Product Quality and Export Prices Across Markets

This experiment aims to characterize how the *average* product quality and export prices of Chinese electric kettles would respond to trade liberalization. We simulate the model at the estimated parameters starting in 2006 allowing each firm to make endogenous entry, product quality and pricing decisions in each market. We then repeat this exercise after trade liberalization and compare the changes over time as reported in Table 12.[46] In any destination market the predicted changes depend on the full set of country-specific parameters along with the observed variation in tariff rates.

Table 12 documents the overall change in export product quality and prices in each region. Across all markets we observe a 0.9-1.5 percent increase in average product quality in the first year after trade liberalization. Over the subsequent 4 years, average product quality improves in each market and is 1.2-1.9 percent greater than the pre-liberalization product quality. We do not reproduce results beyond the fifth year since almost all adjustment is complete by that time. The bottom panel of Table 12 reports the impact of trade liberalization on average export prices. Strikingly, trade liberalization leads to an *increase* in the average export price in every export market. The lesson from this exercise is simply that the nature of competition induced by trade liberalization in quality-differentiated markets is likely to be very different then that typically emphasized in traditional trade models. Rather than sharply dropping average prices, domestic producers in any given region will face higher quality competition at higher average prices than before.

[46] While we do allow for the endogenous entry of any exporter to any market, it is important to note that this experiment abstracts from the possibility of non-exporters entering export markets due to data limitations.

There are additional two effects which are important for evaluating the magnitude of these results. First, the fall in trade costs is mitigated by quality upgrading since Chinese exporters are relatively more competitive in each region than when they faced pre-liberalization tariffs. Second, liberalization also induces the entry of new, relatively low productivity, high cost producers. These firms will, on average, export relatively low quality but high price varieties. These two forces oppose each other when determining average product quality, but are complementary for raising average export prices.[47]

Across regions, larger tariff cuts are roughly correlated with larger increases in average product quality and export prices, albeit weakly. A key outlier is South America and Mexico where we see strong increases in prices despite moderate improvements in average product quality. This is again due the fact that this industry is estimated to be particularly competitive (low markups) in this region and there was greater scope for product-quality induced price changes to have an impact on prices.[48]

# 8 Conclusion

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. As firms grow into export markets and build market share they tend to improve product quality and charge higher prices.

We estimate our model using detailed Chinese customs data and focus our empirical exercise on the electric kettle industry. For the average electric kettle exporter, we find that in the year of entry intertemporal spillovers reduce firm-level export prices by 0.2-0.5 percent and increase firm-level sales by 4 percent. Over time, quality, prices and sales endogenously increase. Five years after entry the average exporter, conditional on survival, optimally chooses to improve product quality by 8 percent and increase prices by 1 percent. Total sales are estimated to respond by growing 39-48 percent over the same period. Our findings further imply that trade liberalization affects the margins through which firm compete for consumers over time. Our structural model suggests that reductions in tariffs would moderately improve product quality and increase the average export price faced by consumers of electric kettles in any given export market.

[47] We find that entry reduces the predicted increase in average product quality by nearly 6 percent and causes prices to rise by an additional 1 percent, on average.

[48] Recall, for any firm $p_{ijt} = C_{ijt} + u_j - \rho EV'_{j1}$ and, thus, if $u_j$ is relatively small then quality determined costs, $C_{ijt}$ have greater scope for determining percentage changes in $p_{ijt}$.

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# A Data Appendix

Table 13 provides summary statistics for the full sample of Chinese exporters and the subsample of electric kettle exporters. In each case, we only consider exporters which are labelled as 'ordinary exporters.' That is, we exclude all foreign-owned firms, all state-owned firms, all firms engaged in processing trade and all firms which act as export intermediaries. We convert all nominal prices to real prices by constructing price deflators. For example, for each HS code we calculate the average export price for each product using a revenue-weighted geometric mean. We then convert observed prices and revenues to a common year (2000) using the average annual price as a deflator. Export sales are measured in physical units as reported on the customs forms. Export duration refers to the number of consecutive years a firm exports to the same destination country.

Table 13: Summary Statistics

| | Electric Kettles | | | | All Exporters | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Mean | Std. Dev. | Min. | Max. | Mean | Std. Dev. | Min. | Max. |
| Export Sales (Physical Units) | 34,978.4 | 215205.8 | 1 | 1.6e+07 | 71957.1 | 415712.9 | 1 | 9.5e+09 |
| Export Revenues | 206346.4 | 2,173,107.0 | 1 | 2.2e+08 | 41,143.7 | 1,295,589.0 | 1 | 2.8e+09 |
| Export Prices | 1.2 | 4.8 | 4.8e-004 | 14.6 | 4.7 | 236.2 | 7.5e-08 | 200,401 |
| Import Prices | 0.9 | 1.9 | 1.5e-004 | 128.8 | 440.0 | 2,617.4 | 8.0e-05 | 33418.5 |
| No. of Export Destinations | 26.5 | 27.2 | 1 | 115 | 48.4 | 18.8 | 1 | 177 |
| Export Duration | 1.6 | 1.1 | 1 | 7 | 2.2 | 1.7 | 1 | 7 |
| Obs. | | 30,960 | | | | 12,839,972 | | |

Notes: The above table documents the mean, standard deviation, minimum and maximum of key variables from the Chinese customs data. We eliminate all firms which are foreign-owned, state-owned, intermediaries or engaged in process manufacturing to focus on ordinary exporters. All prices and revenues are deflated as described in the appendix.

# B Robustness Checks: Fact 3

In Section 2 we document basic correlation patterns between past sales and input prices. As previously noted, it is typically impossible to isolate input price variation which is destination-specific among exporters who export to more than one destination country. A similar challenge is present for multi-product exporters. Our approach in Section 2 aggregated data to provide simple correlations. Specifically, we regressed the average log imported input price at the firm-level on a measure of total past export sales at the firm-level, instead of using a market-specific measure of sales as in the export price and export sales regressions:

$$\overline{\ln(import\ price_{it})} = \alpha + \beta \ln(Q_{i,t-1}) + \Gamma_i + \Gamma_t + \epsilon_{it}$$

where $\Gamma_i$ and $\Gamma_t$ are firm and year fixed effects, respectively, and $\epsilon_{it}$ is again an $iid$ error term.

Although this regression has the advantage that it uses as much of our sample as possible, it simultaneously has the disadvantage that it indirectly relates input prices to performance in specific-export markets. To check the robustness of our findings we repeated this exercise only on single-destination exporters, single-product exporters, and single-destination and single-product exporters. The results are reported in Table 14.

Table 14: Correlation Between Current Import Prices and Past Aggregate Export Sales

| | Electric Kettle Exporters | | | |
|---|---|---|---|---|
| | All | Single-Destination | Single-Product[a] | Single-Destination Single-Product |
| Past Export Sales | 0.035** | 0.160* | 0.137** | 0.142** |
| | [0.018] | [0.083] | [0.068] | [0.071] |
| Year Fixed Effects | Yes | Yes | Yes | Yes |
| Firm Fixed Effects | Yes | Yes | Yes | Yes |
| Obs. | 1375 | 556 | 269 | 161 |

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 for electric kettle exporters. Robust standard-errors are in brackets. Column 1 reports the results from a regression including all kettle exporters, while columns 2, 3 and 4 repeat the exercise using samples of single-destination exporters, single-product exporters, and single-destination and single-product exporters . *** p<0.01, ** p<0.05, * p<0.1. (a) The *p*-value associated with the estimated coefficient in column 2 is 0.056.

In each case, past export sales are positively associated with future input prices. Moreover, this relationship is always statistically significant; the least statistically significant coefficient has a $p$-value of 0.056, while all others are below 0.050 despite dramatic sample size reductions. If anything, the results reported in Section 2 appear to be modest relative to those in our robustness checks.

# C Proofs

## Differentiability Proof

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

$$\begin{aligned}\tilde{V}(\lambda, M_{ij,t-1}, f_{jt}) \quad = \quad & \max_{p_{ijt}, q_{ijt}, \chi_{ijt}} \left\{ r_j \exp\left[\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j) q_{ijt} - p_{ijt}\right)\right] \left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij}\right] \right. \\ & \left. - f_{ct} + \rho \int_{f_{jt} \in y(\lambda, M_{ij,t-1})} \tilde{V}(\lambda, M_{ijt}, f_{jt}) g_c(f_{jt}) df_{jt} \right\} \chi_{ijt} \qquad (33)\end{aligned}$$

Note, as is common in the literature studying the entry and exit of heterogeneous firms, 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 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.** Consider 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

$$\begin{aligned} L(\lambda, M_{ij,t-1}, f_{jt}) &= \max_{p_{ijt}, q_{ijt}} r_j \exp\left[\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j) q_{ijt} - p_{ijt}\right)\right]\left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij}\right] - f_{jt} \\ &\quad + \rho \tilde{V}(\lambda, M_{ijt}, f_{jt}) \end{aligned} \tag{34}$$

It is not obvious that our differentiable lower support function is concave in past market share 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 in Lemma 2.

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

$$\frac{\partial L}{\partial M_{ij,t-1}} > 0 \text{ and } \frac{\partial^2 L}{\partial M_{ij,t-1}^2} < 0.$$

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

$$\tilde{U}(\lambda, M_{ij,t-1}) = \phi(p_{ijt}, q_{ijt}). \tag{35}$$

Under assumption 1, the support functions (34) and (35) satisfy all of the necessary conditions of Theorem 1 from Clausen and Strub (2013). ■

## Lemma 1

**Proof.** To establish the proposition we compare $V(\lambda, M_{ij,t-1}, f_{jt})$ and $V(\lambda, M'_{ij,t-1}, f_{jt})$ when $M_{ij,t-1} < M'_{ij,t-1}$. Denote the optimal quality and price sequence as $\{q_{ijt}, p_{ijt}\}_t$ when past market share is $M_{ij,t-1}$. Observe that if past market share is $M'_{ij,t-1}$ and the firm followed the same sequence of quality and price choices $\{q_{ijt}, p_{ijt}\}_t$, then in any period $\tilde{t} \geq t$ the current profits of the firm with past market share $M'_{ij,t-1}$ would be greater than those of the firm with past sales $M_{ij,t-1}$ given (2):

$$\pi_j(\lambda, M_{ij,\tilde{t}-1}, q_{ij\tilde{t}}, p_{ij\tilde{t}}, f_{j\tilde{t}}) \leq \pi(\lambda, M'_{ij,\tilde{t}-1}, q_{ij\tilde{t}}, p_{ij\tilde{t}}, f_{j\tilde{t}})$$

where $\tilde{t} > t - 1$ and $M_{j,\tilde{t}-1} < M'_{j,\tilde{t}-1}$. Since $\theta$, and hence current demand, is strictly increasing in past market share, $M_{ij,t-1}$, a firm expects to achieve a greater discounted profit stream relative to an identical firm with smaller past market share by choosing the same quality and price sequence even if it

is not optimal. As such, $V(\lambda, M'_{ij,t-1}, f_{jt}) > V(\lambda, M_{ij,t-1}, f_{jt})$. This implies that $V(\lambda, M'_{ij,t-1}, f_{jt}) \geq V(\lambda, M_{ij,t-1}, f_{jt})$. ■

## Lemma 2

**Proof.** A sufficient, but not necessary, condition to guarantee that $V_j(\lambda, M_{ij,t-1}, f_{jt})$ is concave in $M_{ij,t-1}$ is that the current profit function is concave. The derivative of profits in a given market, $\pi_{ijt}$, with respect to past market share, $M_{ij,t-1}$, is clearly positive

$$\frac{\partial \pi_{ijt}}{\partial M_{ij,t-1}} = [u_j - \rho E V'_j(\lambda, M_{ijt}, f_{j,t+1})] Q_{ijt} \left[\lambda^{\frac{1-\alpha}{1+\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \theta(M_{ijt}, \bar{I}_j)^{\frac{\alpha}{1-\alpha}}\right] \frac{\partial \theta}{\partial M_{ij,t-1}} > 0 \tag{A1}$$

since each individual component is positive. We can then evaluate the second derivative as

$$\begin{aligned}\frac{\partial^2 \pi_{ijt}}{\partial M^2_{ij,t-1}} &= [u_j - \rho E V'_j(\lambda, M_{ijt}, f_{j,t+1})] Q_{ijt} \left[\lambda^{\frac{1-\alpha}{1+\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \theta(M_{ij,t-1}, \bar{I}_j)^{\frac{\alpha}{1-\alpha}}\right]^2 \left(\frac{\partial \theta}{\partial M_{ij,t-1}}\right)^2 \\ &+ [u_j - \rho E V'_j(\lambda, M_{ijt}, f_{j,t+1})] Q_{ijt} \left[\lambda^{\frac{1-\alpha}{1+\alpha}} \frac{\alpha^{\frac{1}{1-\alpha}}}{1-\alpha} \theta(M_{ij,t-1}, \bar{I}_j)^{\frac{2\alpha-1}{1-\alpha}}\right] \left(\frac{\partial \theta}{\partial M_{ij,t-1}}\right)^2 \\ &+ [u_j - \rho E V'_j(\lambda, M_{ijt}, f_{j,t+1})] Q_{ijt} \left[\lambda^{\frac{1-\alpha}{1+\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \theta(M_{ij,t-1}, \bar{I}_j)^{\frac{\alpha}{1-\alpha}}\right] \frac{\partial^2 \theta}{\partial M^2_{ij,t-1}}\end{aligned} \tag{A2}$$

Note that destination-specific sales, $Q_{ijt}$, and unit profit, $[u_j - \rho E V'_j(\lambda, M_{ijt}, f_{j,t+1})]$ are non-negative. While the former (sales) is obvious, in our context it is not clear that unit profit must be positive. This is due to the fact that firms must pay for inputs in the current period. As such, in an environment without lending, profits must at least cover unit costs. While adding a financial sector and allowing firms to borrow and save intertemporally would be a useful direction for future research, it is beyond the scope of our current paper. Moreover, since most of our exporters are relatively small, it is likely that the assumption that production and shipping costs must be covered in the current period is relatively mild.

Dividing (A2) by $\left[\lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{\alpha}{1-\alpha}} \theta(M_{ij,t-1}, \bar{I}_j)^{\frac{\alpha}{1-\alpha}}\right]$, multiplying by $\frac{\theta(1-\alpha)}{\alpha}$ and collecting like terms we have

$$\left(1 + \lambda^{\frac{1-\alpha}{1+\alpha}} \alpha^{\frac{2\alpha-1}{1-\alpha}} \theta(\cdot)^{\frac{1}{1-\alpha}}\right) \left(\frac{\partial \theta(\cdot)}{\partial M_{ij,t-1}}\right)^2 + \left(\frac{(1-\alpha)\theta(\cdot)}{\alpha}\right) \left(\frac{\partial^2 \theta(\cdot)}{\partial M^2_{ij,t-1}}\right) \leq 0 \tag{A3}$$

where $\theta(\cdot) = \theta(M_{ij,t-1}, \bar{I}_j)$. ■

Although condition (A3) is sufficient to guarantee the concavity of $\pi_{ijt}(\lambda, M_{ij,t-1}, f_{jt})$ and $V_j(\lambda, M_{ij,t-1}, f_{jt})$ it is regrettably cumbersome and difficult to interpret. Fundamentally, condition (A3) states 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 more transparent claims. For instance, if we assume that

$$\theta(M_{ij,t-1}, \bar{I}_j) = \theta_0 + \theta_1 \ln(M_{ij,t-1}) + \theta_2 \ln \bar{I}_j$$

then we can reduce our condition further since $-\theta_1 \frac{\partial^2 \theta}{\partial M^2_{j,t-1}} = \left(\frac{\partial \theta}{\partial M_{ij,t-1}}\right)^2$ in this case. Under this assumption, condition (A3) will be satisfied as long as $\theta_1$ is sufficiently small and the values of $\frac{\partial^2 \theta}{\partial M^2_{jt}}$ and

$\left(\frac{\partial\theta}{\partial M_{ijt}}\right)^2$ are bounded. That is, as long as the future gain from past sales isn't too big, the value function will be concave.

## Proposition 1

**Proof.** Recall, that market share in country $j$ in year $t$ can be expressed as

$$M_{ijt} = \frac{Q_{ijt}}{N_j} = \frac{r_j}{N_j} \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt})\right]$$

Then using equations (13) and (14) it must be that

$$\frac{\partial M_{ijt}}{\partial M_{ij,t-1}} = \frac{M_{ijt}\frac{1}{u_j}\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}\theta(M_{ij,t-1}, \bar{I}_c)^{\frac{\alpha}{1-\alpha}}}{1 - \frac{M_{ijt}}{u_j}}\rho EV'' > 0$$

if condition (12) holds. ■

## Proposition 2

**Proof.** To establish this proposition we take the derivative of equation (10) with respect to $q_{ijt}$, $p_{ijt}$ and $M_{ij,t-1}$, respectively, where our derivatives rely on the above differentiability proof.

$$\begin{aligned}\frac{\partial V_j(\lambda, M_{ij,t-1}, f_{jt})}{\partial q_{ijt}} = &\left\{\left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_i\tau_{ij} + \rho EV'_{j1}(\lambda, M_{ijt}, f_{j,t+1})\right]\frac{\theta(M_{ij,t-1}, \bar{I}_j)}{u_j}\right.\\ &\left.-\frac{1}{\alpha}\left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}}\eta_i\tau_{ij}\lambda^{1+\alpha}\right\} \times r_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt})\right] = 0\end{aligned}$$

$$\Rightarrow p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_i\tau_{ij} + \rho EV'_{j1}(\lambda, M_{ijt}, f_{j,t+1}) - \frac{u_j\eta_i\tau_{ij}\lambda^{1+\alpha}}{\alpha\theta(M_{ij,t-1}, \bar{I}_j)}\left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}} = 0 \tag{A4}$$

$$\begin{aligned}\frac{\partial V_j(\lambda, M_{ij,t-1}, f_{jt})}{\partial p_{ijt}} = &\left\{1 - \frac{1}{u_j}\left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_i\tau_{ij} + \rho EV'_{j1}(\lambda, M_{ijt}, f_{j,t+1})\right]\right\} \times\\ &r_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt})\right] = 0\end{aligned}$$

$$\Rightarrow p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_i\tau_{ij} + \rho EV'_{j1}(\lambda, M_{ijt}, f_{j,t+1}) - u_j = 0 \tag{A5}$$

$$\frac{\partial V_j(\lambda, M_{ij,t-1}, f_{jt})}{\partial M_{ij,t-1}} = r_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt})\right]\left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}}\eta_i\tau_{ij}\right]\frac{\partial\theta}{\partial M_{ij,t-1}}\frac{q_{ijt}}{u_j}$$
$$+\left[1 + r_j \exp\left\{\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j)q_{ijt} - p_{ijt}\right)\right\}\frac{\frac{\partial\theta}{\partial M_{ij,t-1}}q_{ijt}}{u_j}\right]$$
$$\times \rho E V'_{j1}(\lambda, M_{ijt}, f_{j,t+1}) = 0 \tag{A6}$$

We can solve (A5) directly for the firm's optimal price, $p_{ijt}$. From (A4) and (A5) we find optimal product quality

$$\frac{u_j\eta_i\tau_{ij}\lambda^{1+\alpha}}{\alpha\theta(M_{ij,t-1}, \bar{I}_j)}\left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1-\alpha}{\alpha}} = u_j \Rightarrow q_{ijt} = \left[\frac{\alpha\theta(M_{ij,t-1}, \bar{I}_j)}{\eta_i\tau_{ij}}\right]^{\frac{\alpha}{1-\alpha}}\lambda^{\frac{1+\alpha}{1-\alpha}}$$

■

## Proposition 3

**Proof.** Consider the market share in destination countries $j$ and $j'$ where $\tau_{ij} < \tau_{ij'}$. Under the assumption that $M_{ij,t-1} \leq M_{ij',t-1}$ it must be that

$$M_{ij't} \leq \tilde{M}_{ijt} \equiv \frac{r'_j}{N'_j}\exp\left[\frac{1}{u_{j'}}\left((1-\alpha)\left[\lambda^{1+\alpha}\left(\frac{\alpha}{\eta_i\tau_{ij'}}\right)^{\alpha}\theta(M_{ij,t-1}, \bar{I}_{j'})\right]^{\frac{1}{1-\alpha}} - u_{j'} + \rho E V'_{j'1}(\lambda, M_{ij't}, f_{j',t+1})\right)\right]$$

where the only difference between $M_{ij't}$ and $\tilde{M}_{ijt}$ is that we use $M_{ij,t-1}$ in pace of $M_{ij',t-1}$ inside of $\theta(\cdot)$. Now suppose that $M_{ijt}$ is an increasing function of $\tau_{ij}$, which implies $M_{ij't} > M_{ijt}$. Then, it must also be that

$$\tilde{M}_{ijt} < \hat{M}_{ijt} \equiv \frac{r'_j}{N'_j}\exp\left[\frac{1}{u_{j'}}\left((1-\alpha)\left[\lambda^{1+\alpha}\left(\frac{\alpha}{\eta_i\tau_{ij'}}\right)^{\alpha}\theta(M_{ij,t-1}, \bar{I}_{j'})\right]^{\frac{1}{1-\alpha}} - u_{j'} + \rho E V'_{j'1}(\lambda, M_{jt}, f_{j',t+1})\right)\right]$$

since $M_{ijt} < M_{ij't}$ and condition (12) is assumed to hold. The derivative of $\hat{M}_{ijt}$ with respect to $\tau_{ij'}$ is

$$\begin{aligned}\frac{d\hat{M}_{ijt}}{d\tau_{ij'}} &= \frac{\hat{M}_{ijt}}{u_{j'}}\lambda^{\frac{1+\alpha}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha)\theta(M_{ij,t-1}\bar{I}_{j't})^{\frac{1}{1-\alpha}}\left(-\frac{\alpha}{1-\alpha}\eta_i^{\frac{-\alpha}{1-\alpha}}\tau_{ij}^{\frac{-1}{1-\alpha}}\right) < 0 \\ &\Rightarrow \hat{M}_{ijt}(\tau_{ij'}) < \hat{M}_{ijt}(\tau_{ij}) = M_{ijt} \\ &\Rightarrow M_{ij't}(\tau_{ij'}) \leq \tilde{M}_{ijt}(\tau_{ij'}) < \hat{M}_{ijt}(\tau_{ij'}) < M_{ijt}(\tau_{ij})\end{aligned}$$

The last inequality contradicts our initial assumption that $M_{ij't} > M_{ijt}$. Therefore, given that $M_{ij,t-1} > M_{ij',t-1}$ it must be that $M_{ijt}$ is a decreasing function of $\tau_{ij}$. As such, we expect that firms will have greater market share in closer markets, *ceteris paribus*. ■

## Proposition 4

**Proof.** The marginal exporter is indifferent between exiting the market or continuing to produce when $W(\lambda, M_{ij,t-1}, f_{jt}(\epsilon_{ijt})) = 0$. Denote the fixed cost shock which causes the firm to be indifferent between exiting and continuing as $\epsilon^*_{ijt}$. Since $W$ is strictly increasing in $M_{ij,t-1}$ and strictly decreasing in

$f_{jt}$ it must be that

$$f_{j,t+1}(\epsilon^*_{ijt}) > f_{jt}(\epsilon^*_{ijt}) \Rightarrow \epsilon^*_{ij,t+1} > \epsilon^*_{ijt} \Rightarrow G^\epsilon_j(\epsilon^*_{ij,t+1}) < G^\epsilon_j(\epsilon^*_{ijt})$$

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

### Corollary 1

**Proof.** Let $\epsilon^*_{ijt}$ and $\epsilon^{*\prime}_{ijt}$ denote the fixed cost shocks which induce exit from country $i$ exporters with productivity levels $\lambda$ and $\lambda'$ where we assume that $\epsilon^*_{ijt} > \epsilon^{*\prime}_{ijt}$ without loss of generality. Since quality, price and past market share are unaffected by fixed cost shocks in any period, past market share is only a function of productivity. This implies

$$W(\lambda, M_{ij,t-1}(\lambda), \epsilon^*_{ijt}) = W(\lambda', M_{ij,t-1}(\lambda'), \epsilon'^*_{ijt}) = 0 \Rightarrow \lambda > \lambda'$$

Since $G^\epsilon_j(\epsilon'^*_{ijt}) > G^\epsilon_j(\epsilon^*_{ijt})$ the firm with productivity draw $\lambda$ is more likely to survive in any period. ■

# D 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 outer routine describes the details of the Bayesian MCMC methods employed for estimating model parameters.

## D.1 Inner Routine

Let $s_{jt} = \{\lambda, \ln(1 + M_{j,t-1}), \ln \bar{I}_j, \bar{f}_j, r_j, N_j, \tau_j\}$ denote a set of destination and firm-specific state parameters where the subscript $i$ is suppressed for since all exporters are from China. Then, the value function is solved as follows:

1. Let $X_{jt}$ denote a polynomial in $s_{jt}$. We approximate the expected value function in each year by $EV_j(s_{jt}) = b^* + B^* \cdot X_{jt}$, where $b^*$ is a constant vector, and $B^*$ is a coefficient matrix.

2. Search for the fixed point of $V^*_j(s_{jt})$ by initializing the expected value function $EV^0_j(s_{jt}) = 0 + 0 \cdot X_{jt}$, 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 the expected value function with respect to $M_{jt}$ by taking the derivative of the approximated value function, $\frac{\partial EV^*_j(s_{jt})}{\partial M_{jt}} = \frac{\partial (B^k \cdot X_{jt})}{\partial M_{jt}}$ noting that $M_{jt} = Q_{jt}/N_j$. Given the estimated derivative we can compute the firm's optimal price, profits and update its continuation value as $W_j(s_{jt}) = \pi_{jt}(s_{jt}) + \rho EV_j(s_{jt})$. Compute the value function using $V_j(s_{jt}) = \max\{0, W_j(s_{jt})\}$, where $W_j(s_{jt})$ is the firm's value function if they continue export to market $j$.

4. Regress $V_j(s_{jt})$ on a constant and $X_{jt}$ 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 $\{b^2, B^2\}$. Repeat this step 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 $V_j^*(s_{jt}) = b^k + B^k \cdot X_{jt}$.

Step 3 is the key step in our algorithm. Effectively, we extend value function approximation methods to allow us capture the derivative of the expected 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.

## D.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 $\Theta^o$, 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, $\Theta'$, are generated as follows:

1. Separate the parameters into 3 blocks: $\Theta_1 = \{\lambda_i\}$, $\Theta_2 = \{\alpha, \gamma_\tau, \gamma_w, N_1, ..., N_7, r_1, ...r_7, u_1, ..., u_2, \bar{f}_1, ..., \bar{f}_7\}$, and $\Theta_3 = \{\theta_1, \theta_2, \theta_3\}$.

2. Estimate firm-specific productivity, $\lambda$.

   (a) Draw $\lambda$ *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 $\Theta_2$.

   (a) Draw $\Theta_2$ 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 $\Theta_3$ using $q(\Theta_3^*|\Theta_3^o)$ and $a_3 = \min\{1, \frac{L(\Theta_3^*)\varphi(\Theta_3^*)q(\Theta_3^*|\Theta_3^o)}{L(\Theta_3^o)\varphi(\Theta_3^o)q(\Theta_3^o|\Theta_3^*)}\}$, respectively.

5. Update the variance-covariance matrix of errors. We draw a new variance-covariance matrix of the errors, $\Sigma$, for equations (23)-(26) from an inverse Wishart distribution, $IW(\mathcal{V}', \nu')$, where $\mathcal{V}' = \mathcal{V} + (e_1'; e_2'; e_3') \cdot (e_1, e_2, e_3)$, is the variance covariance matrix, $\nu' = \nu + n$, 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 $\Theta^*$ is drawn from a normal distribution with mean $\Theta^o$, 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 $j = 1, 2, 3$ can be written as $a_j = \min\{1, \frac{L(\Theta^*)\varphi(\Theta^*)}{L(\Theta^o)\varphi(\Theta^o)}\}$.

## D.3 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 15.

Table 15: Prior Distributions

| Variable | Description | Assumption |
|---|---|---|
| $\ln(N_j)$ | Market Size | $\ln(N_j) \sim N(0, 10)$ |
| $\ln(r_j)$ | Market Demand | $\ln(r_j) \sim N(0, 10)$ |
| $\ln(u_j)$ | Markup/Competitiveness | $\ln(u_j) \sim N(0, 2)$ |
| $\bar{f}_j$ | Fixed Export Cost | $\bar{f}_j \sim EXP(10)$ |
| $\ln(\gamma_\tau)$ | Transportation Cost Parameter | $\ln(\gamma_\tau) \sim N(0, 10)$ |
| $\ln(\gamma_m)$ | $M_{ij,t-2}$ Depreciation Parameter | $\gamma_m \sim U[0, 1]$ |
| $\alpha$ | Quality Transformation Parameter | $\alpha \sim U[0, 1]$ |
| $\theta_0$ | Taste for Quality Constant | $\theta_0 \sim U[-20, 20]$ |
| $\theta_1$ | Taste for Quality Loyalty Parameter | $\theta_0 \sim U[-20, 20]$ |
| $\theta_2$ | Taste for Quality Income Parameter | $\theta_0 \sim U[-20, 20]$ |
| $\ln(\lambda)$ | 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 one parameter. The fifth row corresponds to the shipping cost parameter. The sixth and seventh rows correspond to the depreciation parameter in the augmented model and the quality transformation parameter, respectively. Note that in either case these parameters are 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 8, 9 and 10, and represent the key parameters in our estimation exercise. As such, we assume a very diffuse uniform prior. The last row reports for the assumption for firm productivity. We assume an identical productivity prior for all firms in our data.

# Supplemental Appendix for
# "Price and Quality Dynamics in Export Markets"

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This appendix provides a variety of details related to model development and the empirical results. Section A documents an omitted derivation. Section B provides additional discussion regarding the identification of the markup parameter $u_j$. Section C provides a simple description of the model's equilibrium omitted from the manuscript. Section D presents additional counterfactual results which were omitted from the manuscript for brevity. Section E describes with a stochastic productivity process and presents the estimation results from this alternative empirical model.

## A Omitted Derivation: Markups and Productivity

This section reports the derivation of the relationship between markups and productivity. Note that $\frac{dM_{ijt}}{d\lambda} > 0$ since $M_{ijt} = r_j e^{A_{ijt}(\lambda)}$ where

$$A_{ijt}(\lambda) = \frac{1}{u_j}\left[\lambda^{\frac{1+\alpha}{1-\alpha}}\theta(M_{ij,t-1}, \bar{I}_j)^{\frac{1}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) - u_j + \rho EV'_{j1}(M_{ijt}, f_{j,t+1})\right].$$

Differentiating $M_{ijt}$ with respect to $\lambda$ we find

$$\frac{dM_{ijt}}{d\lambda} = r_j e^{A_{ijt}(\lambda)}\frac{1}{u_j}\left[\frac{1+\alpha}{1-\alpha}\lambda^{\frac{2}{1-\alpha}}\theta(M_{ij,t-1}, \bar{I}_j)^{\frac{1}{1-\alpha}}\alpha^{\frac{\alpha}{1-\alpha}}(1-\alpha) - u_j + \rho EV''_{j11}(M_{jt})\frac{dM_{jt}}{d\lambda}\right]$$

Rearranging this equation we find

$$\frac{dM_{ijt}}{d\lambda} = \frac{\frac{1}{u_j}\frac{1+\alpha}{1-\alpha}\lambda^{\frac{2}{1-\alpha}}\theta(M_{j,t-1}, \bar{I}_j)^{\frac{1}{1-\alpha}}(1-\alpha)r_j e^{A_{ijt}(\lambda)}}{1 - \frac{\rho}{u_j}EV''_{j11}(M_{ijt})re^{A_{ijt}(\lambda)}} > 0$$

## B The Identification of $u_j$

The markup parameter in each destination market is estimated as part of our structural estimation approach. Fundamentally, $u_j$ is at its root a dispersion parameter in the Type I extreme value distribution associated with the consumer demand shocks. In many discrete choice models it is not straightforward to estimate this dispersion parameter because it cannot be separately identified from other model parameters. This section demonstrates that $u_j$ is in fact identified in our setting because (1) our model explicitly connects input prices (which are not a function of $u_j$) and output prices (which are a function of $u_j$), and (2) the intertemporal changes in prices which are scaled by $u_j$.

We begin by discussing the typical source of the identification problem. Specifically, consider the residual demand and pricing equations (4) and (14). To minimize notation and make things as transparent as possible we set $\lambda = 1$, normalize $\eta_i = 1$, suppress the arguments of $\theta$ and the variety index, $\omega$.

Substituting optimal prices and quality into the residual demand equation (4) we can write firm sales as

$$Q_{ijt} = r_j \exp\left[\frac{1}{u_j}(\theta q_{ijt} - p_{ijt})\right] = r_j \exp\left[\left(\frac{\theta^{\frac{1}{1-\alpha}}}{u_j}\right)\frac{\alpha^{\frac{\alpha}{1-\alpha}}}{\tau^{\alpha}} - \rho EV'_{j1}\right] \tag{36}$$

and likewise optimal prices are

$$p_{ijt} = \theta^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{\tau^{\alpha}}\right)^{\frac{1}{1-\alpha}} + u_j + \rho EV'_{j1}. \tag{37}$$

Scaling prices (37) by $1/u_j$ we find

$$\frac{p_{ijt}}{u_j} = \frac{\theta^{\frac{1}{1-\alpha}}}{u_j}\left(\frac{\alpha}{\tau^{\alpha}}\right)^{\frac{1}{1-\alpha}} + 1 + \frac{\rho EV'_{j1}}{u_j}. \tag{38}$$

Momentarily ignoring the dynamic pricing incentives in equation (38), it is clear that $1/u_j$ and $\theta^{1/(1-\alpha)}$, both of which are unknown, enter $p_{ijt}$ and $Q_{ijt}$ multiplying each other. In a static setting $EV'_{j1} = 0$ and, thus, if we were relying only on these two equations to identify the parameters of our model we would not be able to separately identify $\theta^{\frac{1}{1-\alpha}}$ and $u_j$. Allowing for prices to reflect the non-linearity of the value function, provides a source of identification of $u_j$.

Nonetheless, we may be concerned that this may represent relatively weak identification in the sense that it depends heavily upon the demand accumulation mechanism posited in our dynamic model. Fortunately, directly estimating the input price equation provides a second source of identification for $\theta$ and, thus, $u_j$. We can write the simplified input price equation (23) as

$$\ln w_{it} = \frac{1}{1-\alpha}\ln(\alpha) + \frac{1}{1-\alpha}\ln\theta - \frac{1}{1-\alpha}\ln\tau \tag{39}$$

Because equation (39) provides separate identification of $\theta$, equations (37) and (4) can then be left to identify $u_j$ in each market. This is important for our exercise; as emphasized there are substantial differences in output prices across destination markets.

# C Stationary Equilibrium

We restrict attention to stationary equilibria. Let $\mathcal{S}_{ijt} = (\lambda, M_{ijt})$ denote the individual firm's state and allow to $d_{ijt} \in \{0, 1\}$ to capture the firm's decision to enter market $j$ in year $t$. A stationary equilibrium is a collection of value functions (10)-(11), firm policy rules $(d, p, q)$, firm distributions $\chi^a_{ijt}$, and input price vectors such that at any point in time:

1. **Optimization**: All consumers optimally choose to consumption of the quality differentiated good and numeraire good to maximize the utility function $U_{jt}(k, \omega)$. All firms optimally make all entry, quality and pricing decisions to maximize the value of the firm (10).

2. **Goods and Factor-Market Clearing**: In each factor and goods market, goods prices (final and intermediate) and factor payments (wages) adjust until supply equals demand for each factor and good. Thus, with symmetric countries trade balance is implied.

3. **Free-Entry**: The expected value of entry for a new firm is zero

$$V_j^E = \int_{j\in J}\int_{\epsilon_{jt}\in\mathcal{E}}\int_{\lambda_j^*}^{\infty} V_j(0,\lambda,f_{jt}(\epsilon_{jt}))G^{\lambda}(\lambda)G^{\epsilon}(\epsilon_{jt})d\lambda d\epsilon_{jt}dj - S_j = 0$$

4. **Stationarity**: For each year and cohort, a cohort of age $a$ in year $t$ replicates the previous cohort of age $a$ in year $t-1$:

$$\chi_{ij,t-1}^a(\lambda) = \chi_{ijt}^a(\lambda)$$

This is true for all cohorts $a$ and years $t$.

5. **Profits**: Let $M_i$ represent the mass of country $i$ firms. In any country $i$ and year $t$, aggregate profits,

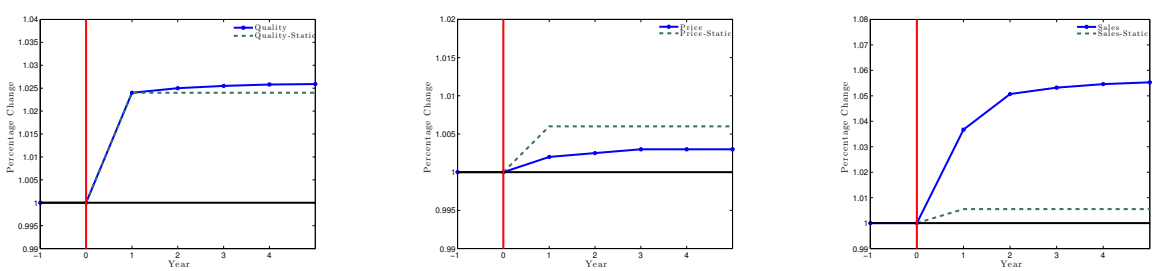
$$\Pi_{it} = M_i\int_{j\in J}\int_{a\in\mathcal{A}}\int_{\epsilon_{jt}\in\mathcal{E}}\int_{\lambda_j^*}^{\infty}\pi_{jt}(\lambda,a)\chi_{jt}^a(\lambda)G^{\epsilon}(\epsilon_{jt})d\lambda d\epsilon_{jt}dadj,$$

are redistributed equally across consumers $N_j$.

# D Additional Counterfactual Results

This section presents counterfactual results for the augmented model. The exercises are described in Section 7 of the manuscript. Figure D1 reports the results from the individual firm exercise while Table D1 reports the simulation results across firms, countries, and years. Because the augmented model results are very similar to those from the benchmark model we refer the reader to the manuscript for a general description of these findings.

Figure D1: Impact of Trade Liberalization in the Augmented Model




(a) Product Quality (b) Export Prices (c) Export Sales

Notes: The above figure documents the evolution of prices, product quality and sales overtime of an average firm in an average export market after trade liberalization in period 0. The estimates are taken from the augmented model. The blue starred line captures the firm pricing, product quality and sales under the benchmark model parameters. The green dashed line captures the firm's pricing, product quality and sales under the assumption that it ignores all dynamic pricing considerations starting in period 0.

Table D1: Percentage Change in Product Quality and Export Prices Across Markets (Augmented Model)

| Destination Market | US/CAN | JAP/KOR | EU | AUS/NZ | SA/MEX | AFR | ASIA |
|---|---|---|---|---|---|---|---|
| Tariff Rate (%) | 2.394 | 4.070 | 3.158 | 3.929 | 17.315 | 26.445 | 9.677 |
| Years After Trade Lib. | | | Export Product Quality | | | | |
| 1 | 0.4 | 0.6 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 |
| 5 | 0.5 | 0.8 | 0.6 | 0.6 | 0.7 | 0.5 | 0.6 |
| | | | Export Prices | | | | |
| 1 | 0.3 | 0.6 | 0.3 | 0.6 | 3.0 | 1.0 | 3.2 |
| 5 | 0.4 | 0.7 | 0.3 | 0.9 | 4.1 | 1.2 | 3.4 |

Notes: The above table reports the percentage change in average product quality or average prices for electric kettle exporters in the augmented model induced by setting tariffs to 0 in each export market.

# E Stochastic Productivity

In this section we reconsider our benchmark framework with an additional complexity. In particular, in our benchmark framework firm productivity was restricted to be constant over time. Although consistent with our theoretical framework, it is common to allow productivity to evolve according to an autoregressive process in numerous empirical applications. Most importantly, in our context, to the extent that stochastic productivity growth drives product quality upgrading and sales growth, our empirical strategy may overestimate the role of demand accumulation on firm behavior. To determine what role stochastic productivity may have on our main results, we re-estimate the dynamic outlined in Section 4 with one additional equation:

$$\lambda_{it} = \rho^{\lambda}\lambda_{i,t-1} + \varepsilon_{it}^{\lambda} \tag{40}$$

where $\rho^{\lambda}$ captures the AR(1) coefficient on past productivity and $\varepsilon_{it}^{\lambda}$ is an $iid$ stochastic productivity shock.[49] As in the benchmark model, the joint distribution of errors for equations (23)-(26) along with that from equation (40) are drawn from an inverse Wishart distribution. Otherwise, we have purposefully kept the remaining structure and estimation procedure identical to that described in the manuscript.

Tables E1 and E2 report the means and standard deviations of the posterior distribution for the model parameters estimated under the AR(1) productivity assumption. The benchmark model estimates are also reproduced for comparison. In general, the model parameters are estimated to be very similar in both cases and, as such, we refer the reader to the manuscript for a discussion of individual parameters with one exception. Specifically, the most notable difference is that the parameter on the demand accumulation process, $\theta_1$, is slightly smaller in the model with stochastic productivity relative to the benchmark.

Consistent with our expectations, allowing for an alternative source of firm dynamics reduces the estimated role of demand accumulation. However, the reduction, relative to the benchmark model, is quite moderate. A natural explanation for this is that while firm productivity evolves symmetrically in every market the firm enters, the evolution of demand accumulation is market-specific. To this extent, our empirics suggest that demand accumulation is broadly preferred to a solely productivity-driven explanation for firm evolution across markets and time. Finally, since the model-performance of the stochastic-productivity model is very similar to those reported in the manuscript we omit further discussion hereafter.

[49] All prior distributions are identical to those in the benchmark model. The prior distribution for $\rho^{\lambda}$ is $U[-1, 1]$.

Table E1: Parameter Estimates

| | Benchmark Model | | Stochastic Productivity Model | |
|---|---|---|---|---|
| Parameter | Mean | Std. Dev | Mean | Std. Dev |
| $\theta_0$ (Taste for Quality - Intercept) | 0.911 | (0.006) | 0.862 | (0.011) |
| $\theta_1$ (Taste for Quality - Reputation Parameter) | 1.987 | (0.009) | 2.044 | (0.010) |
| $\theta_2$ (Taste for Quality - Income Parameter) | 0.022 | (0.002) | 0.045 | (0.021) |
| $\alpha$ (Quality Transformation Parameter) | 0.051 | (0.001) | 0.084 | (0.020) |
| $\gamma_\tau$ (Trade Cost Parameter) | 0.198 | (0.053) | 0.167 | (0.022) |
| $\rho^\lambda$ (Productivity AR(1) Parameter) | — | — | 0.971 | (0.021) |

Notes: The above table 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, $\alpha$, the trade cost parameters, $\gamma_\tau$ and the autocorrelation coefficient on productivity, $\rho^\lambda$.

Table E2: Parameter Estimates

| | Size, $N_j$ | | Demand, $r_j$ | | Markup, $u_j$ | | Fixed Costs, $\bar{f}_j$ | |
|---|---|---|---|---|---|---|---|---|
| | Bench. | Sto. Prod. | Bench. | Sto. Prod. | Bench. | Sto. Prod. | Bench. | Sto. Prod. |
| USA/Canada | 13.599 | 11.708 | 16.823 | 15.693 | 0.999 | 0.920 | 8.901 | 7.012 |
| | (0.592) | (0.460) | (0.434) | (0.453) | (0.031) | (0.028) | (0.086) | (0.077) |
| Japan/Korea | 11.147 | 11.367 | 18.436 | 18.109 | 0.968 | 0.989 | 7.990 | 8.798 |
| | (0.187) | (0.311) | (0.301) | (0.363) | (0.021) | (0.021) | (0.087) | (0.077) |
| Europe | 24.106 | 23.128 | 36.456 | 33.901 | 0.908 | 0.936 | 17.799 | 11.998 |
| | (0.613) | (0.499) | (0.653) | (1.006) | (0.022) | (0.037) | (0.087) | (0.077) |
| Australia/New Zealand | 4.585 | 4.682 | 7.964 | 7.872 | 1.101 | 1.101 | 4.809 | 3.899 |
| | (0.103) | (0.164) | (0.192) | (0.452) | (0.051) | (0.014) | (0.086) | (0.077) |
| S. America/Mexico | 7.167 | 7.243 | 6.861 | 6.395 | 0.306 | 0.319 | 7.088 | 3.920 |
| | (0.020) | (0.013) | (0.273) | (0.286) | (0.005) | (0.007) | (0.086) | (0.087) |
| Africa | 6.405 | 6.684 | 7.563 | 8.850 | 0.982 | 1.076 | 4.390 | 3.501 |
| | (0.332) | (0.353) | (0.202) | (0.213) | (0.021) | (0.030) | (0.086) | (0.077) |
| Rest of Asia | 7.821 | 7.258 | 9.184 | 7.269 | 0.885 | 0.902 | 4.329 | 3.759 |
| | (0.264) | (0.126) | (0.202) | (0.200) | (0.042) | (0.024) | (0.087) | (0.078) |

The above table reports the means and standard deviations (in parentheses) of the posterior distribution for the parameters for country size, $N_j$, demand, $r_j$, markups, $u_j$, and average export entry costs, $\bar{f}_j$. The parameters $N_j$, $r_j$, and $\bar{f}_j$ are measured in thousands.