Price, Product Quality, and Exporter Dynamics: Evidence from China

Joel Rodrigue*
Department of Economics
Vanderbilt University

Yong Tan†
School of International Economics & Trade
Nanjing University of Finance and Economics

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Abstract

This paper investigates how prices and product quality evolve as Chinese firms grow into export markets. We develop a model of heterogeneous firms where firms 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. The results from our preferred model indicate that the incentive to build future demand reduces export prices upon initial entry by 0.7 percent and increases export sales by 4 percent for the average exporter. Over the following five years, export prices, product quality, and sales are estimated to grow by 2.2, 12, and 79 percent, respectively, due to endogenous demand accumulation.

Keywords: productivity, demand, product quality, export price
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*Department of Economics, Vanderbilt University, VU Station B #351819, 2301 Vanderbilt Place, Nashville, TN 37235-1819; Tel.: +1 615 322 2871; fax: +1 615 343 8495. Email: joel.b.rodrigue@vanderbilt.edu.

†School of International Economics & Trade, Nanjing University of Finance and Economics, Nanjing, China. Email: yongtan_econ@163.com

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. (2018) 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. Matching Chinese 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 influence 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. Further confirming our intuition, we show that Chinese exporters tend to upgrade product characteristics as they grow into export markets.

Given these stylized facts, we build a dynamic model where firms choose export prices and source quality-differentiated inputs to grow sales in each market and 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, provides 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.[1] Small electric appliances belong to a class of Chinese exports where there has been substantial growth in export value across a wide set of export destinations. A second advantage of this industry is that nearly all of the firms in the electric kettle industry import intermediate inputs and the sample records detailed input purchase information among these firms. Following Alessandria and Kaboski (2011) we identify observable differences in product characteristics and investigate how changes in product quality evolve as firms grow into export markets. 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. Being specific about the exact product we study also allows us 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 product quality, prices, and sales through time and decompose the impact of static and dynamic incentives on the evolution of firm characteristics across export markets. Using our preferred estimates we find that dynamic considerations *reduce* firm-level prices and increase firm-level sales upon initial entry into new markets by 0.5-0.7 and 4-5 percent, respectively. Over time, prices, product quality and sales endogenously rise. Five years after entry, prices and product quality are predicted to increase by 1-2 and 6-12 percent, while sales endogenously grow by 39-68 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 has 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,

[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. Rauch (1999) classifies these products as differentiated, is relatively differentiated according to the Gollop-Monahan index reported in Kugler and Verhoogen (2012), and is among the differentiated set of industries in Fan et al. (2015).

[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), Gourio and Rudanko (2014), and Perla (2017) for examples.

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 (2008), Baldwin and Harrigan (2011), and Manova and Yu (2017). 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 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. (2017).

Our model likewise shares intuition with Foster et al. (2016) 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. (2016) focus on the US domestic market, we study the exporter decisions across a diverse set of world-wide 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. (2016) 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 (2012) 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 Yu, 2017), 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, 2012; Crozet et al., 2012; Kugler and Verhoogen, 2012; Gervais, 2015; Hu et al., 2017; Roberts et al., 2018), and the impact of trade on product quality upgrading (Verhoogen, 2008; Amiti and Khandelwal, 2013; Fan et al., 2015; Flach, 2016; Eslava et al., 2018).[3]

[3]The paper is also related to papers which examine the role of product quality in international trade, including Gabszewicz

Likewise, our empirical exercise has several similarities with Roberts et al. (2018). However, there are at least four substantial differences which largely 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. (2018) document the important role that demand differences play in explaining export market selection, we are primarily interested in characterizing the intertemporal evolution of firm-level pricing, product quality, and export sales. Specifically, Roberts et al. (2018) 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. (2018) 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.

Our research also overlaps significantly with a nascent literature that studies the nature of demand dynamics. As in our work, Eaton (2014) and Piveteau (2018) consider export entry and growth in a setting where demand accumulates in foreign markets. Both empirical models are estimated on a much wider set of products and provide broad set of aggregate implications from demand growth. While Eaton et al. (2014) considers a setting where Columbian exporters grow through the search for foreign distributors and the learning of their own ability, firm pricing features constant markups. Piveteau (2018) instead focuses on mechanism where demand accumulates with the growth of past sales and French firms set prices to optimally build their demand stock over time. Alternatively, Berman et al. (2017) instead posit a Bayesian learning process where French firms gradually determine the true level of demand for their product in a given export market. Fitzgerald et al. (2017) similarly studies the impact of gradual demand accumulation among Irish manufacturing exporters through advertising investments and marketing. Unlike our work, Berman et al. (2017) and Fitzgerald et al. (2017) abstract from export entry decisions and changes in product quality to focus on the evolution of output prices and sales conditional on survival.

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), Alessandria and Kaboski (2011) and, Hallak and Schott (2011).

In contrast to each of these papers, we focus on a particular product and provide evidence that product quality evolves alongside output prices and sales among Chinese kettle exporters. Unlike these alternative frameworks, we precisely define the nature of vertical differentiation and distinguish variation in 'demand' from unobserved quality differences across varieties. Moreover, in our stylized model we theoretically characterize export entry, survial and the evolution of firm-level prices, quality and sales. By structurally estimating our model we quantify the degree to which each margin influences Chinese firm-level dynamics. In each paper, including ours, we find that export sales tend to grow quickly among surviving firms in export markets. Relative to existing papers which study firm-level price dynamics, our estimates fall roughly in the middle of the range reported elsewhere. Our findings for the Chinese kettle industry are larger than those reported by Fitzgerald et al. (2017) who find little or no impact on prices among Irish exporters, but smaller than those documented by Piveteau (2018).

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 (2016). 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. (2017) 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

Our primary objective here is to provide a simple characterization of the evolution of firm-level prices, product quality, and sales in export markets. The data we use is collected by the Chinese Customs

Office and reports firm and product-specific export and import information between 2000 and 2006. Specifically, for each year the data report the f.o.b value, quantity and price from firm-level exports across products and destination countries.[4] The data also collects the intermediate material prices for imported inputs at the firm-level. Following Kugler and Verhoogen (2009, 2012), Manova and Zhang (2012) and Bastos, Silva and Verhoogen (2018), 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.

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.[5] Fourth, nearly all of the firms in the electric kettle industry import intermediate inputs from abroad. This provides us with highly detailed data regarding the inputs used in production among these firms. Following Alessandria and Kaboski (2011), we document below that observable changes degrees of vertical differentiation present the vary in a fashion which is consistent with a 'quality' interpretation of input prices. In this manner we are able to tractably consider differences in firm, product, and market characteristics and quantify the influence that firm pricing and quality choices on export outcomes.

Nonetheless, we also reproduce our benchmark 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.[6]

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

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

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

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

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.

2.1 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:

$$\ln(x_{fjkt}) = \alpha + \beta \ln(Q_{fjk,t-1}) + \Gamma_{fkt} + \Gamma_{jkt} + \epsilon_{fjkt} \quad (1)$$

where past performance is measured as past physical sales $Q_{fjk,t-1}$ in that market (the quantity exported to that market), Γ_{fkt} is a firm-product-year fixed effect, Γ_{jkt} is a destination-product-year fixed effect, and f, j, k and t index firms, destination countries, products, and years, respectively. We include the firm-product-year fixed effects to capture unobserved differences in productivity and destination-product-year fixed effects to capture common time-varying shocks to specific export markets. All standard errors are clustered at the firm-level.

Fact 1: Past physical exports are positively correlated with current physical exports.

Column 1 of Table 1 reports the OLS results from regression of past physical sales in a given export market on current physical sales. We only control for common time-varying shocks in this exercise. Not surprsingly, we find a strong degree of persistence in physical sales. Column 2 introduces firm-product-year specific fixed effects to our regression. In this sense, we are demeaning each variable by each firm-product-year triplet to control for firm-and-product specific variation. As such, the regression in Column 2 relates destination-specific deviations in the past to current deviations in the same destination market.

We find that firms with greater past physical sales in a given market are more likely to have greater current physical sales. Table 1 documents that the coefficient on current physical sales, β, is always positive and highly significant. The coefficient ranges between 0.360 in the full sample of Chinese exporters to 0.224 in the electric kettle industry.[8]

[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. (2015) for examples.

[8] As documented in Berthou and Vicard (2015) and Bernard, Massari, Reyes, and Taglioni (2017), estimates of sales growth may be biased by partial-year sales in the first year. Among electric kettle exporters firms tend to ship once per year regardless of whether they are new or incumbent exporters to a given destination. We nonetheless test whether first-year bias affects our stylized facts by including first-year dummies in an alternative specification. This had little effect on the estimated coefficients. These exercises and the corresponding results can be found in the Supplemental Appendix.

Table 1: Correlation Between Current and Past Physical Exports

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
Past Market Sales	0.642***	0.224***	0.686***	0.360***
	[0.014]	[0.076]	[0.001]	[0.006]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Year/Firm-Product-Year 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, clustered at the firm-level, 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-year 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 time-varying unobserved firm effects, such as firm productivity, in Column 2 (electric kettles only) or firm-product-year effects in Column 4 (all exporters). Rather, our intent is to examine how past departures from average sales are correlated with current departures from average sales. That is, even after controlling for time-varying firm and product differences we find that firms which experienced relatively large past sales in a particular market may reasonably expect to have relatively larger than average current 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 current sales if consumers[9] are loyal to a particular brand or variety.[10] 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: Past physical exports are positively correlated with current export prices.

The second robust empirical pattern we find is that current prices, in a given destination market, are positively correlated with past physical 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 well established that there is often a strong positive

[9]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, 2018) suggest strong sales growth among exporters which maintain a relationship with an importer over time.

[10]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-year or product-destination-year fixed effects. Nonetheless, we revisit this issue in Section 3.7 and consider additional sources of dynamics in Section 4.1.

correlation between measures of firm size and output prices.

Examining changes within firms allows us to consider how past departures from average sales are related to current prices. Columns (2) and (4) of Table 2 report that the coefficient on past sales is 0.070 in the electric kettle industry and 0.044 in the full sample, after conditioning on firm-product-year fixed effects. This suggests that firms which saw their sales increase in the past are likely to increase their prices in the current 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 improve consumer appeal. 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.[11]

Table 2: Correlation Between Current Market Prices and Past Physical Exports

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
Past Market Sales	0.148***	0.070***	0.281***	0.044***
	[0.011]	[0.038]	[0.001]	[0.004]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Year/Firm-Product-Year 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, clustered at the firm-level, 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-year fixed effects, while the others do not. *** p<0.01, ** p<0.05, * p<0.1.

Fact 3: Past physical sales are positively correlated with current input prices.

Exploring the correlation between past physical exports and product quality is inherently difficult since product quality is unobserved. Following Kugler and Verhoogen (2009, 2012), Manova and Zhang (2012), and Bastos, Silva and Verhoogen (2018), 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 physical 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

[11] Although the above specification directly relates past sales and future prices, but does not rule out that price dynamics may be driven by a changing composition of firms. To address this issue, we consider a more extensive formulation for the evolution of prices across market tenure similar to Fitzgerald et al. (2017). There we find significant evidence of price growth among surviving Chinese exporters. An extended discussion can be found in the Appendix.

Table 3: Correlation Between Current Import Prices and (Aggregate) Past Physical Sales

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
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 physical sales across all export markets on the average firm-level import price in the current year. Robust standard-errors, clustered at the firm-level, 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.

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, destination-product-year dummies are replaced with year fixed effects:

$$\overline{\ln(import\ price_{ft})} = \alpha + \beta \ln(Q_{f,t-1}) + \Gamma_f + \Gamma_t + \epsilon_{ft} \quad (2)$$

where Γ_f and Γ_t are firm and year fixed effects, respectively, and ϵ_{ft} is again an iid error term.[12]

In Table 3 we document that after controlling for firm fixed effects the coefficient on past sales takes a value of 0.035 which is indicative of positive correlation between current input prices and past physical sales for exporters for electric kettles. Although we have only included firms which import intermediate inputs in this regression, the large majority of firms in our sample do so.[13] 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. We again find strong positive correlation between past deviations from average sales and future input prices.[14]

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. Should alternative mechanisms generate similar correlation between input prices and past sales, a 'quality' interpretation of our findings may be misleading. To further examine this issue we consider observable dimensions of vertical differentiation among kettle importers. In particular, we reconsider equations (1) and (2), but instead of using export/import prices as the dependent variable we use observable measures of input or output quality.[15]

[12] The number of observations in this regression is also reduced since we only have one observation per firm-year, rather than by firm-destination-year.

[13] 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.

[14] 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.

[15] The reader will notice a consistent change in sign from Column 1 (3) to Column 2 (4) of Table 3. A natural explanation

Following Alessandria and Kaboski (2011) we identify observable differences in kettle characteristics or the imports of kettle producers which are plausibly correlated with product quality. For example, we might reasonably expect that higher quality kettles are able to heat rapidly, hold greater quantities, and are fabricated of more durable components (e.g. steel vs. plastic kettles). Fortunately, the Chinese customs data distinguishes kettles in two such dimensions. First, the data records kettles which are produced to heat water 'instantaneously' separately from those which heat water at a normal rate. Second, the customs data records kettles which have 'pumps' separately from those that do not. Typically, the addition of a pump to a kettle is only necessary if the kettle holds a relatively large quantity of water.

Unfortunately, the data does not record steel kettles separately from plastic kettles. We can, however, examine the materials imported by individual firms and distinguish firms which import materials needed for steel casings from those which import materials necessary for hard plastic casings. Using the above information we construct three distinct dummy variables: D_{fjt}^{inst} takes a value of 1 if firm f exports a kettle that heats water rapidly to destination j in year t and 0 otherwise; D_{fjt}^{pump} takes a value of 1 if firm f exports a kettle with a pump to destination j in year t and 0 otherwise; D_{ft}^{steel} takes a value of 1 if firm f imports steel casings in year t and 0 otherwise. We then reconsider our benchmark regressions but replace x_{fjt} with D_{fjt}^{inst} and D_{fjt}^{pump} in equation (1) or D_{ft}^{steel} in equation (2). The results from these regressions are reported in Table 4.

Columns 1 and 2 indicate that firms which experience larger positive deviations from average physical sales in the past are more likely to export plausibly higher quality kettles in the current period. Moreover, the identifying variation here relies strictly on changes in measurable kettle quality within a given firm-destination pair over time since we are conditioning on destination-year, firm-year and firm-destination fixed effects. Similarly, Column 3 reports the results from repeating this exercise for imported steel casings and likewise finds the that firms which experience larger positive deviations from average physical sales in the past are more likely to import steel casings rather than other materials (e.g. plastic or aluminum). As above, here we can only include firm and year fixed effects due to the dimension of our quality measure. Nonetheless, as a further check of our quality interpretation, we create an additional binary variable, $D_{ft}^{plastic}$, which takes a value of 1 if the firm imports plastic casings and 0 otherwise.[16] If our quality interpretation is correct, we would expect that the results from using this variable in equation (2) would be the *opposite* of that from using D_{ft}^{steel}. In column 4, we observe that this is precisely the case; firms which experience larger positive deviations from average physical sales in the past are less likely to import plastic casings.[17]

for this finding is that larger and more productive firms invest greater resources in finding the cheapest possible source for each input as in Antràs et al. (2017). However, once we condition of time-invariant firm characteristics, we observe that changes physical sales are positively correlated with changes in input prices.

[16]Unconditionally, D_{fjt}^{inst}, D_{fjt}^{pump}, and D_{ft}^{steel} are all positively correlated with the quantity exported, export prices and import prices, while $D_{ft}^{plastic}$ is negatively correlated with the same three outcome variables. Although these are measurable dimensions of quality in our data, we do not intend to suggest that they fully capture quality differentiation across firms and products. Among electric manufacturers 11.49 percent export instant kettles and 10.38 percent export kettles with pumps. Likewise, among importing producers 10.61 percent import plastic casings, 45.54 percent import steel casings, and the remaining import other types of casings (e.g. aluminum). Nearly 70 percent of firms import some type of casings.

[17]We recognize that quality upgrading to a particular location may take numerous different forms. For instance, a firm may

Table 4: Correlation Between Kettle Quality and Past Physical Sales

	Export Characteristics		Import Characteristics	
	(1)	(2)	(3)	(4)
Dependent Variable	D_{fjt}^{inst}	D_{fjt}^{pump}	D_{ft}^{steel}	$D_{ft}^{plastic}$
Past Market Sales	0.013**	0.005**	0.017**	-0.004**
	[0.006]	[0.002]	[0.008]	[0.002]
Destination-Year Fixed Effects	Yes	Yes	No	No
Year Fixed Effects	No	No	Yes	Yes
Firm-Year Fixed Effects	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes
Firm-Destination Fixed Effects	Yes	Yes	No	No
Obs.	2249		1375	

Notes: The above table reports the estimated coefficients from an OLS regression of past physical sales in a given export market on obserable dimensions of electric kettle quality. The binary variable D_{fjt}^{inst} takes a value of 1 if firm f exports a kettle that heats water rapidly to destination j in year t and 0 otherwise; D_{fjt}^{pump} takes a value of 1 if firm f exports a kettle with a pump to destination j in year t and 0 otherwise; D_{ft}^{steel} takes a value of 1 if firm f imports steel casings in year t and 0 otherwise; $D_{ft}^{plastic}$ takes a value of 1 if firm f imports plastic casings in year t and 0 otherwise. Robust standard-errors, clustered at the firm-level, are in brackets. Columns 1 and 2 include destination-year and firm-year fixed effects, while columns 3 and 4 include firm and year fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

Despite the above evidence regarding the evolution of export prices, import prices and physical sales, 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.

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 ω, ζ_{jt} is a random consumer-specific product taste shock, and i indexes the source country of variety ω. As is typical, $U_{jt}(k, \omega)$ is the consumer's utility when they consume one unit of product ω 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 ι_j or a non-differentiated, numeraire good k.

improve the quality of a given product, introduce a new higher quality product alongside a older lower quality variety, or entirely replace an older, low quality product with a new, higher quality product. Unfortunately, there is not sufficient information to distinguish these cases in our customs data. In this sense, the process outlined in our model is a reduced-form for a number of different mechanisms which we cannot separately identify.

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 ω 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, θ is increasing in $M_{ij,t-1}(\omega)$ and $\bar{I}_j$,

$$\frac{d\theta}{dM_{ij,t-1}} > 0 \text{ and } \frac{d\theta}{d\bar{I}_j} > 0. \tag{3}$$

The second part of equation (3) 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.[18] The first part of (3) 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.[19] 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:

$$\frac{d\theta^2}{d^2M_{ij,t-1}} < 0 \tag{4}$$

The reader might be concerned that preferences are directly a function of past market share. Our 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. (2017). In each of these papers, past, external consumption influences current consumer preferences in a similar fashion to that specified in our utility function.[20] 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.[21] 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 sales growth to future firm behavior.[22]

Under the standard assumption that the random consumer-product-match term, ζ_{jt}, is independent

[18]Alternatively, one can consider a non-homothetic demand structure. We employ this particular demand framework as it leads to a transperant relationship between past sales are current demand.

[19]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.

[20]Ravina (2007) provides empirical evidence of past external demand influencing current consumers choices, while Ravn et al. (2006) and Gilchrist et al. (2017) 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.

[21]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.

[22]See Foster et al. (2016), Berman et al. (2017), Fitzgerald (2017), Ruhl and Willis (2017) or Piveteau (2018) for examples.

and identically distributed across consumers and time by a Type 1 extreme-value distribution, it is straightforward to write the residual demand for product ω at time t in market j as

$$\begin{aligned} Q_{ijt}(\omega) &= \frac{N_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]}{\int_{\Omega} \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]} \\ &= r_j \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right] \end{aligned} \quad (5)$$

where the parameter u_j governs the ζ_{jt} distribution. This parameters captures the degree of horizontal differentiation between goods and, in our context, partially determine markups. Likewise, r_j is a steady-state demand shifter, $r_j = N_j / \int_{\Omega_j} \exp\left[\frac{1}{u_j}(\theta(M_{ij,t-1}(\omega), \bar{I}_j)q_{ijt}(\omega) - p_{ijt}(\omega))\right]$. It is clear from equation (5) that market share is 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.[23]

3.2 Intermediate production

Each country may also potentially produce a range of quality-differentiated, intermediate inputs. Let ι_{vjt} and v^k_{jt} represent the quantity and quality of country j's intermediate input $s \in \{1, ..., \mathcal{S}\}$ in year t. The production function for the physical number of units produced of a given quality can be summarized by the production function $\iota^s_{vjt} = (a^s_{jt} L^s_{vjt})/v^s_{jt}$ where a^s_{jt} is the productivity of country j workers in producting input s and L^s_{vjt} is the total amount of labor allocated to produce input s of quality v^s_{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 ι^s_{vjt}, one unit of intermediate s at quality v^s_{jt} costs $(w_{jt} v^s_{jt})/a^s_{jt}$ to produce. Most importantly, the cost of the intermediate is always proportional to its quality in any country. We assume shipping a unit of intermediate good between countries i and j requires paying a iceberg-shipping cost, τ_{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

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

λ from the distribution $G^{\lambda}(\lambda)$ and that this productivity level is constant over time. An individual firm produces a single variety $\omega \in \Omega$ where Ω is the set of all varieties. A firm can enter a given market j by paying an iceberg shipping cost, τ_{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, ϵ_{jt}. For simplicity, we assume that in each period the stochastic component ϵ_{jt} is an iid draw from the distribution $G_j^{\epsilon} \sim N(0, \sigma_{\epsilon}^{j})$.[24] Total firm production, h, is a constant returns to scale function of composite input, ι_t:

$$h_t(\omega) = \lambda(\omega)\iota_t(\omega) \tag{6}$$

where λ captures the firm productivity, ι_t is a CES aggregate of intermediate inputs:

$$\iota_t(\omega) = \left[\sum_{s \in S} \iota_{vjt}^{s}(\omega)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{7}$$

and σ captures the elasticity of substitution across intermediate inputs. This structure implies that the firm will purchase each intermediate from the lowest priced producer. In our context, over 90 percent of producers in the electric kettle industry import 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, $v_t^1, ..., v_t^S$. To map input qualities to output quality we first define an index of input quality v_t as

$$v_t(\omega) = \min\{v_t^1(\omega), ..., v_t^S(\omega)\}. \tag{8}$$

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

$$q_t(\omega) = \lambda v_t(\omega)^{\alpha} \tag{9}$$

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 (8) and (9) which merit comment. First, equations (8) and (9) 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.[25] 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 $v_t^1(\omega) = v_t^2(\omega) = ... = v_t^S(\omega)$. Second, if $\alpha < 1$ then to increase product quality by fixed amounts the firm must increase input quality at a faster rate.[26] Third, we allow product quality to explicitly depend on firm productivity λ, to allow for potential complementarity between these

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

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

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

two dimensions of unobserved heterogeneity.[27]

3.4 Profit Maximization

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[28]

$$C_{ij}(q_{ijt}, \lambda) = \tau_{ij} \left(\sum_{j' \in J} \tau_{ij'} w_{j'}(q_\iota) \iota_{j'}(q_\iota) \right) = \left(\frac{q_{ijt}}{\lambda^{1+\alpha}} \right)^{\frac{1}{\alpha}} \tau_{ij} \eta_i \tag{10}$$

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, $\eta_i = \left(\sum_{s' \in S} (w^s_{j'} \tau_{ij'})^{1-\sigma} \right)^{\frac{1}{1-\sigma}}$, and $w^s_{j'}$ is the wage in country j' from which input s is sourced. 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.

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, ϵ_{jt}, and decides whether or not to produce for market j:

$$V_j(M_{ij,t-1}, f_{jt}) = \max[0, W(M_{ij,t-1}, f_{jt})] \tag{11}$$

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}

$$\begin{aligned} W(M_{ij,t-1}, f_{ct}) &= \max_{p_{ijt}, q_{ijt}} \pi_j(p_{ijt}, q_{ijt}, f_{jt}) + \rho \int V_j(M_{ijt}, f_{j,t+1}(\epsilon_{j,t+1})) G^\epsilon(\epsilon_{j,t+1}) d\epsilon_{t+1} \\ &= \max_{q_{ijt},\, p_{ijt}} r_j \exp\left[\frac{1}{u_j} \left(\theta(M_{ij,t-1}, \bar{I}_j) q_{ijt} - p_{ijt} \right) \right] \left[p_{ijt} - C_{ij}(q_{ijt}, \lambda) \right] - f_{jt} \\ &\quad + \rho E V_j(M_{ijt}, f_{j,t+1}) \end{aligned} \tag{12}$$

and ρ is the discount factor. 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 (11) and (12) 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 condi-

[27] Our theoretical results will rely on the assumption that output quality increases monotonically in input quality. See the Supplemental Appendix for further discussion and an alterantive structure which allows for quality substitution across components, but will generate the same theoretical implications.

[28] We suppress the variety index ω hereafter for notational convenience since the following derivations will hold equally well for all firms with the same productivity level. Further, with a slight abuse of notation, we suppress productivity as a state variable since it does not change over time.

tions 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 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* $V''_{j11}(M_{ijt}, f_{jt}) \equiv \frac{\partial^2 V_j(M_{ijt}, f_{jt})}{\partial M^2_{ijt}} \leq 0$ *is*

$$\underbrace{\left(1 + \lambda^{\frac{1+\alpha}{1-\alpha}} \alpha^{\frac{2\alpha-1}{1-\alpha}} \theta^{\frac{1}{1-\alpha}}\right) \left(\frac{\partial \theta}{\partial M_{ijt}}\right)^2}_{\text{Term A}} + \underbrace{\left(\frac{(1-\alpha)\theta}{\alpha}\right) \left(\frac{\partial^2 \theta}{\partial M^2_{ijt}}\right)}_{\text{Term B}} \leq 0 \tag{13}$$

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

Term A in the above inequality is clearly positive, while Term B is negative. For condition (13) to hold Term B must dominate Term A. Fundamentally, condition (13) states that the intertemporal spillover of past sales on future profits cannot be too big.[29]

Given the results from Clausen and Strub (2013) along with Lemmas 1 and 2, we have established that the dynamic problem (11)-(12) 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 (13) holds, then* $\frac{\partial M_{ijt}}{\partial M_{ij,t-1}} > 0$. *Firm-level market-share, and thus firm-level physical 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 physical 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

[29]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 $-\theta_1 \frac{\partial^2 \theta}{\partial M^2_{jt}} = \left(\frac{\partial \theta}{\partial M_{ijt}}\right)^2$ in this case. Under this assumption, condition (13) will be satisfied as long as θ_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.

features of firm-growth in export markets. Specifically, the model implies relatively rapid growth in the quantity exported 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*

$$q_{ijt} = \lambda^{\frac{1+\alpha}{1-\alpha}} \left[\frac{\alpha\theta(M_{ij,t-1}, \bar{I}_j)}{\eta_i \tau_{ij}} \right]^{\frac{\alpha}{1-\alpha}} \tag{14}$$

and the optimal price at t is

$$p_{ijt} = \left(\frac{q_{ijt}}{\lambda^{1+\alpha}} \right)^{\frac{1}{\alpha}} \eta_i \tau_{ij} + u_j - \rho E V'_{j1}(M_{ijt}, f_{j,t+1}) \tag{15}$$

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 θ, 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 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, $-\rho E V'_{j1}(M_{ijt}, f_{jt})$, 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. Due to consumer loyalty, forward looking firms have an incentive to sell more in early periods to enhance profitability in 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, μ_{ijt}, as

$$\mu_{ijt} = \frac{p_{ijt}}{C_{ijt}} - 1 = \frac{u_j - \rho E V'_{j1}(M_{ijt}, f_{j,t+1})}{\lambda^{\frac{1+\alpha}{1-\alpha}} [\alpha\theta(M_{ij,t-1}, \bar{I}_j)]^{\frac{1}{1-\alpha}}}. \tag{16}$$

Differentiating (16) with respect to productivity we find

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

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:

$$\frac{d\mu_{ijt}}{dt} = \mu_{ijt}\left(\frac{-1}{(1-\alpha)\theta(M_{ij,t-1},\bar{I}_j)}\frac{dM_{ij,t-1}}{dt} - \frac{\rho EV''_{j11}(M_{ijt},f_{j,t+1})}{u_j - \rho EV'_{j1}(M_{ijt},f_{j,t+1})}\frac{dM_{ijt}}{dt}\right) \quad (18)$$

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 (18) is positive we again observe that dynamic incentives can offset 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. 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,

$$\text{if } \tau_{ij} < \tau_{ij'} \text{ then } q_{ijt}/q_{ij't} = (\tau_{ij'}/\tau_{ij})^{\alpha} > 1. \quad (19)$$

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*

$$M_{ijt} > M_{ijt'} \text{ and } \frac{dM_{ijt}}{d\tau_{ij}} < 0 \tag{20}$$

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

$$\frac{dq_{ijt}}{d\tau_{ij}} = -\frac{\alpha q_{ijt}}{1-\alpha}\left(\frac{1}{\tau_{ij}} - \frac{1}{\theta(M_{ij,t-1}, \bar{I}_j)}\frac{\partial\theta(M_{ij,t-1}, \bar{I}_j)}{\partial M_{ij,t-1}}\frac{\partial M_{ij,t-1}}{\partial \tau_{ij}}\right) < 0 \tag{21}$$

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 τ_{ij}:

$$\frac{dp_{ijt}}{d\tau_{ij}} = \frac{q_{ijt}}{1-\alpha}\left[\frac{-1}{\tau_{ij}} + \frac{1}{\theta(\cdot)}\frac{\partial\theta(\cdot)}{\partial M_{ij,t-1}}\frac{\partial M_{ij,t-1}}{\partial \tau_{ij}}\right] - \rho E V''_{j11}(M_{ijt}, f_{j,t+1})\frac{\partial M_{ijt}}{\partial \tau_{ij}} < 0 \tag{22}$$

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.[30]

Transforming equations (21) and (22) into elasticities, we observe that an alternative interpretation of Proposition 3 implies that changes in trade costs will differentially affect firms with different export histories. In particular, the percentage impact of a tariff change will, conditional on productivity, be particularly large on young firms with small existing stocks of demand. Our empirical exercise later verifies the extent to which we observe this pattern in Chinese export data.

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

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 ϵ_{ijt} as the productivity level where the firm with shock ϵ 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 proposition.

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

This result is a direct consequence of the evolution of market share and firm-value over time. The longer firms exist in a given market, the more entrenched they become: higher physical sales generate greater loyalty, raising future profits, and discouraging exit. We therefore expect that exit rates across similarly 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 physical sales and higher profits. This reduces their sensitivity to fixed cost shocks and encourages repeated entry in a given market.

3.7 Discussion

The model implications for prices, product quality and sales are broadly consistent with our empirical findings in China. 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. At the same time, the quantity exported in many product-markets increases rapidly, often doubling in the first few years of exporting. An autoregressive process for productivity, as productivity is often modeled, would be unlikely to drive this robust empirical pattern. Nonetheless, in our empirical application we consider variants 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. 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., 2018; Eaton et al. 2014; Monarch, 2018), 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.

An alternative mechanism, would be to allow sales to grow through continual productivity improvements (e.g. Arkolakis, 2016) or learning-by-doing (Bastos, Dias and Timoshenko, 2018). We do not suggest that these mechanisms may not be important, particularly in the Chinese context. However, we would note that firm-level productivity growth cannot explain most of our stylized facts (Section 2) since these regressions include firm-product-year fixed effects. That is, our stylized facts have already removed a time-varying, firm-specific component; any remaining variation must be exclusively due to temporal changes which are firm and destination specific.

Further, if learning-by-doing were to drive growth in quantities we would expect that this would also be reflected in price movements. For instance, as marginal costs decline in a setting with learning-by-doing, we might expect prices to move in a parallel fashion and the quantity sold to consequently rise. However, as Fitzgerald et al. (2017) note, post-entry increases in export revenue are disproportionately accounted for by changes in quantities. Our model offers a mechanism that allows for both a large post-entry increase in physical sales and moderate increases in prices due to the compensating effect of quality upgrades.

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. As documented in the Supplemental Appendix, this assumption is unnecessary for any of our theoretical results, but allows us to use a common measure of input quality, average import prices, as a theoretically consistent measure of product quality. In general, our results continue to hold as long as higher quality inputs are more costly to procure, whether at home or abroad.

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.

4 Empirical Model

This section describes our empirical model and identification strategy 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:

$$\theta(M_{ij,t-1}, \bar{I}_j) \quad = \quad \theta_0 + \theta_1 \ \ln\left(1 + \frac{Q_{ij,t-1}}{N_j}\right) + \theta_2 \ln \bar{I}_j \tag{23}$$

where $M_{ij,t-1} \equiv \frac{Q_{ij,t-1}}{N_j}$ and the parameter N_j maps physical exports into market share across destination markets of different sizes. In this sense, in the empirical model N_j has the role of normalizing past physical sales across very different regions of the world. The parameters θ_0, θ_1 and θ_2 play a particularly important role in our analysis since they govern the impact of past sales on future firm performance and the extent to which this varies across rich and poor countries.

Similarly, we 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 η_i will not be separately identified from the mean productivity draw we normalize its 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 (6)-(9) imply that the average price of imported inputs is equal to product quality for a single-destination exporter to market j in year t:

$$\ln \bar{w}_{ijt} = \gamma_w + \frac{1}{1-\alpha}\big(2\ln\lambda + \ln\theta(M_{ij,t-1}, \bar{I}_j) - \gamma_\tau \ln(d_{ij}) - \ln(1 + \text{tariff}_{ij})\big) + \varepsilon^w_{ijt} \tag{24}$$

where $\gamma_w = \frac{1}{1-\alpha}\ln(\alpha)$ is a constant and ε^w_{ijt} is treated as iid measurement error. Since many firms export to more than one destination in a given year, we compute the model-implied average import price among multiple-destination exporters as a quantity-weighted average of the import price used to export the product to each destination

$$\bar{w}_{it} \equiv \frac{\sum_j Q_{ijt}\bar{w}_{ijt}}{\sum_j Q_{ijt}} \tag{25}$$

Equation (25) implies that although we do not generally observe $\bar{w}_{ijt}$ for multiple destination exporters we can relate the observed variation in average import prices to quality differences using the firm-level entry and export outcomes across destinations and time.

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

$$\ln p_{ijt} = \ln\left[\left(\frac{\widehat{q}_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \tau_{ij} + u_j - \rho E V'_{j1}(M_{ijt}, f_{j,t+1})\right] + \varepsilon^p_{ijt} \tag{26}$$

where $\widehat{q}_{ijt}$ is the model-implied firm-specific product quality of exports to destination j in year t (from equations (24) and (25)) and ε^{p}_{ijt} is iid measurement error in the pricing equation. A non-trivial challenge for our empirical exercise is most clearly presented in equation (26). Given an estimate of product quality, $\widehat{q}_{ijt}$, the parameter governing the relationship between input and output quality, α, market-competitiveness, u_j, and firm-productivity, λ, 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 (26) and discussed at length in the next section.

The third estimating equation relates firm sales to predicted prices and product qualities across markets:

$$\ln Q_{ijt} = \ln r_j + \frac{1}{u_j}[\theta(M_{ij,t-1}, \bar{I}_j)\widehat{q}_{ijt} - \widehat{p}_{ijt}] + \varepsilon^{Q}_{ijt} \tag{27}$$

where $\widehat{p}_{ijt}$ is the model-implied export price to destination j in year t (from equation 26) and ε^{Q}_{ijt} is iid measurement error in demand equation (27). Given this structure, we can identify most model parameters. For instance, suppose we have an initial guess at λ and EV'_{j1} for each firm. Equations (24) and (25) relate variation in import prices to that in the physical quantity export last year and identify the parameters α, θ_0, θ_1, θ_2 and γ_τ. Note that λ, γ_τ, α, θ_0, θ_1 and θ_2 are sufficient for computing model consistent measures of τ_{ij} and each firm's $\widehat{q}_{ijt}$. Combining α, $\widehat{q}_{ijt}$ and our guess of EV'_{j1} with pricing equation (26), we recover markup parameter u_j and update the estimate of λ.[31] Using the predicted qualities, markups, and prices, $\widehat{q}_{ijt}$, $\widehat{p}_{ijt}$ and u_j, the demand equation (27) pins down parameters r_j, N_j, and provides further identification of spillover parameters θ_0, θ_1 and θ_2.

Although the parameters governing the evolution of price and quality can be identified from equations (24)-(27) 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. We augment the above equations with a theoretically-consistent binary choice model for exporting to any given market in any year

$$\Pr[D_{ijt} = 1 | M_{ij,t-1}, f_{jt}, \lambda] = \Pr[\epsilon_{ijt} < W(M_{ij,t-1}, f_{jt}, \lambda | D_{ijt} = 1)]. \tag{28}$$

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 $\bar{f}_j$.

[31] The parameters of θ 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 (24) is not a function of u_j while output prices (26) are a function of both θ 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.

4.1 Alternative Empirical Models

We relax a number of the functional form restrictions above to investigate the degree to which alternative demand processes or productivity variation affect the performance of our quantitative model.

4.1.1 Demand

Our theoretical model assumes that only last year's market performance matters for the firm's current demand conditions in any destination market. We quantitatively study whether this assumption affects our empirical conclusions by estimating models with alternative dynamic demand processes, $\theta(M_{ij,t-1}, \bar{I}_j)$.

First, we consider a dynamic process which allows market share from the previous two years to influence current demand:

$$\theta(M_{ij,t-1}, \bar{I}_j) \quad = \quad \theta_0 + \theta_1 \; \ln\left(1 + \frac{Q_{ij,t-1}}{N_j} + \gamma_m \frac{Q_{ij,t-2}}{N_j}\right) + \theta_2 \ln \bar{I}_j \tag{29}$$

where the parameter γ_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. In general, we will refer to this process as the '*augmented*' model of demand.

Second, we also estimate a variant of the model where demand accumlates over time according to the process

$$\theta(M_{ij,t-1}, \bar{I}_j) \quad = \quad \theta_0 + \theta_1 K_{ijt} + \theta_2 \ln \bar{I}_j \tag{30}$$

where K_{ijt} is the current stock of demand in market j at time t,

$$K_{ijt} = (1 - \varsigma) \ln \left(1 + M_{ij,t-1}\right) + \varsigma K_{ijt-1} = (1 - \varsigma) \ln \left(1 + \frac{Q_{ij,t-1}}{N_j}\right) + \varsigma K_{ijt-1}$$

and ς is a weight which captures the contribution of last year's sales to the current stock of demand. Although this is conceptually straightforward, it requires that we specify each firm's initial stock of demand in each market. Empirically, we treat this as an initial conditions problem and treat K_{ij0}, the initial stock of demand prior to entry, as a random variable drawn from a log-normal distribution with mean μ_K and variance σ_K.[32]

[32] Details can be found in the Supplemental Appendix.

4.1.2 Productivity

To the extent that stochastic productivity growth drives product quality upgrading and export growth, treating productivity as constant over time may lead us to overestimate the role of demand accumulation on firm behavior. To characterize the role of productivity dynamics on our main results, we also consider variants of our model with one additional equation:

$$\lambda_{it} = \rho^{\lambda}\lambda_{i,t-1} + \varepsilon_{it}^{\lambda} \tag{31}$$

where ρ^{λ} captures the degree of persistence in productivity and $\varepsilon_{it}^{\lambda}$ is an iid stochastic productivity shock. In this case, the productivity process is identified by common changes in prices and exports across destinations, while destinations-specific variation continues provide sufficient information to characterize the demand process $\theta(\cdot)$.

4.1.3 Model Classification

We consider six different variations of our empirical model. The first model corresponds most closely to our theoretical framework and maintains our benchmark assumptions that productivity is constant over time, demand accumulates according to equation (23), and firms optimally choose product quality in each market they enter in every period. Models (2) and (3) consider our augmented demand process and an the accumulating demand process, outlined in equations (29) and (30) respectively. Models (4)-(6) estimate a version of our model with each demand process (benchmark, augmented and accumulating demand, respectively) while simultaneously allowing for productivity to follow an AR(1) process as documented in equation (31).[33]

5 Estimation

As noted in Section 2, we focus on Chinese exporters of electric kettles engaged in ordinary trade. To reduce the state-space of our exercise, we consider seven 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.[34]

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.[35] The estimation algorithm proceeds in two steps

[33] Our Supplemental Appendix documents variations on our benchmark framework which are omitted from this manuscript.
[34] GDP and population data are taken from the Penn World Tables. Distance data are obtained from CEPII (www.cepii.fr).
[35] See Das, Roberts and Tybout (2007) for a related discussion.

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 (15) 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 its first derivative until they both converge.

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.[36] This approach is similar to that used in the empirical literature which models dynamic decisions (see Keane and Wolpin (1997) or Gallant et al. (2017), 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, $\frac{\partial EV_j^*(s_{jt})}{\partial M_{jt}} = \frac{\partial (B^k \cdot X_{ijt})}{\partial M_{jt}}$. 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 ϵ 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 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 Θ^o, a new draw is made from a conditional distribution

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

$q(\Theta^*|\Theta^o)$. To facilitate the computation Θ^* is drawn from a normal distribution with mean Θ^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.[37]

6 Results

6.1 Parameter Estimates

Table 5 reports the means and standard deviations (in parentheses) of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2)$, quality transformation process, α, and the trade cost parameter, γ_τ. For models with the augmented demand process (Models 2 and 5) or an accumulating demand process (Models 3 and 6) we report the deprecation parameter on lagged market share, γ_m, or the weight on past demand stock, ς. Likewise, in Models (4)-(6) we report the autoregressive coefficient on past productivity, ρ^λ.

The key model parameter, θ_1, maps past performance into future profits. We find robustly positive estimates for θ_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 θ_2 is positive. Consistent with existing research, this implies that richer countries have a stronger taste for quality. However, in our context, this also implies that the quality of exports will evolve differently across rich and poor countries. Subsequent sections quantify the impact of the estimated dynamic spillovers on the evolution of prices and quality in export markets.

The positive coefficient on α indicates that firms which choose higher quality inputs produce higher quality products. Because it is estimated to be less than 1, successive product quality upgrades require increasingly large improvements in input quality.[38] Finally, the positive coefficient on trade costs indicates it is more costly to export to more distant destinations. Simulating each model variant we find that the implied trade elasticity ranges from 3.41 (Model 6) to 5.84 (Model 5), which is similar to that reported elsewhere.[39]

Across the first three models, we observe that the primary difference is θ_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. In contrast, θ_1 is largest in the model where demand accumulates over time (2.240). We note that this effectively offsets the lower weight on the previous year's market share through the definition of K_{ijt}. Specifically,

[37]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 (24)-(27) are drawn from an inverse Wishart distribution. Details, along with sensitivity analysis for our prior distributions, can be found in the Appendix.

[38]Eliminating the complementarity between input quality and productivity increases the value of α, but reduces model fit.

[39]See Simonovska and Waugh (2014) for evidence and related discussion.

Table 5: Parameter Estimates

Model No.	(1)	(2)	(3)	(4)	(5)	(6)
θ_0	0.911	0.907	0.884	0.862	0.818	0.907
	(0.006)	(0.005)	(0.025)	(0.011)	(0.026)	(0.014)
θ_1	1.987	1.697	2.240	2.044	1.721	2.267
	(0.009)	(0.018)	(0.011)	(0.010)	(0.043)	(0.019)
θ_2	0.022	0.137	0.038	0.045	0.027	0.028
	(0.002)	(0.037)	(0.071)	(0.021)	(0.071)	(0.075)
α	0.051	0.137	0.068	0.084	0.069	0.078
	(0.001)	(0.006)	(0.020)	(0.020)	(0.010)	(0.013)
γ_τ	0.198	0.122	0.086	0.167	0.107	0.181
	(0.053)	(0.005)	(0.019)	(0.022)	(0.003)	(0.019)
γ_m		0.498			0.397	
		(0.019)			(0.135)	
ς			0.121			0.208
			(0.017)			(0.025)
ρ^λ				0.971	0.893	0.880
				(0.021)	(0.032)	(0.032)

Notes: The above table reports the means and standard deviations (in parentheses) of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2)$, quality transformation process, α, the trade cost parameters, γ_τ, the deprecation parameter on lagged market share, γ_m, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

in Column (3) we $(1 - \varsigma) \times \theta_1 = (0.879) \times 2.240 = 1.967$, which is only slightly smaller than the estimate of θ_1 in Column (1). This does not imply that Models (1) and (3) are identical. Rather, as firms age the weight on last year's existing demand stock allows for each model to diverge in performance. We investigate the economic importance of these differences below.

Adding productivity dynamics to our framework in Models (4)-(6) has little effect on the estimated spillover parameter. This is not entirely surprising, productivity is estimated to be a relatively persistent process. We note, however, that as we consider increasingly persistent demand processes, the persistence parameter in the productivity process falls slightly. This suggests a natural tradeoff between different sources of persistence in this class of models.

Table 6 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 smaller or poorer markets. Recall that u_j is not the observed markup itself, but rather the parameter which determines the magnitude of the static markup. The average implied markups across all firms and countries range from 24 percent (Model 1) to 39 percent (Model 6). Our markup estimates are comparable to the De Loecker and Warzynski (2012) study of Slovenian manufacturers (the median markups range between 11-28 percent), the average industry-level estimate from Lu and Yu (2015) for Chinese manufactuers (markups which range up to 37 percent), and those from De Loecker et al. (2016) where the median estimated markup for Indian manufacturers is reported to be 60 percent.

It is also clear from Table 6 that the estimated static markup parameter in South America and Mexico,

Table 6: Country-Specific Parameter Estimates

	Size, N_j						Demand, r_j					
Model No.	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
USA/CAN	13.599	11.087	14.002	11.708	12.605	11.540	16.823	15.224	16.996	15.693	16.900	16.138
	(0.592)	(0.592)	(0.682)	(0.460)	(0.418)	(0.682)	(0.434)	(0.225)	(0.389)	(0.453)	(0.431)	(0.286)
JAP/KOR	11.147	9.901	12.401	11.367	9.829	10.936	18.436	15.642	21.161	18.109	15.702	19.125
	(0.187)	(0.187)	(0.408)	(0.311)	(0.205)	(0.408)	(0.301)	(0.622)	(0.716)	(0.363)	(0.294)	(0.530)
EU	24.106	23.413	27.053	23.128	23.340	27.254	36.456	36.894	35.342	33.901	34.281	39.449
	(0.613)	(0.613)	(0.107)	(0.499)	(0.485)	(0.107)	(0.653)	(0.909)	(0.507)	(1.006)	(0.344)	(0.682)
AUS/NZ	4.585	4.386	4.467	4.682	5.695	4.729	7.964	8.158	7.473	7.872	9.656	8.125
	(0.103)	(0.103)	(0.068)	(0.164)	(0.097)	(0.068)	(0.192)	(0.875)	(0.235)	(0.452)	(0.112)	(0.111)
SA/MEX	7.167	6.871	6.959	7.243	7.266	10.954	6.861	6.870	7.353	6.395	7.073	10.332
	(0.020)	(0.020)	(0.322)	(0.013)	(0.083)	(0.322)	(0.273)	(0.273)	(0.138)	(0.286)	(0.074)	(0.134)
AFR	6.405	8.793	7.741	6.684	8.900	7.226	7.563	10.090	9.385	8.850	19.171	9.902
	(0.332)	(0.332)	(0.206)	(0.353)	(0.230)	(0.206)	(0.202)	(0.217)	(0.139)	(0.213)	(0.248)	(0.216)
ASIA	7.821	8.022	6.043	7.258	8.854	6.619	9.184	10.050	7.322	7.269	11.399	9.176
	(0.264)	(0.264)	(0.131)	(0.126)	(0.283)	(0.131)	(0.202)	(0.167)	(0.090)	(0.200)	(0.248)	(0.194)
	Markup, u_j						Fixed Costs, $\bar{f}_j$					
USA/CAN	0.999	1.178	0.985	0.920	1.265	1.222	8.901	10.020	8.900	7.012	10.819	10.999
	(0.031)	(0.021)	(0.044)	(0.028)	(0.016)	(0.023)	(0.086)	(0.057)	(0.061)	(0.077)	(0.057)	(0.061)
JAP/KOR	0.968	1.260	0.863	0.989	1.388	1.021	7.990	10.098	7.989	8.798	10.399	8.573
	(0.021)	(0.020)	(0.012)	(0.021)	(0.023)	(0.014)	(0.087)	(0.057)	(0.062)	(0.077)	(0.056)	(0.062)
EU	0.908	1.194	0.974	0.936	1.236	1.247	17.799	26.999	17.799	11.998	21.005	24.001
	(0.022)	(0.016)	(0.025)	(0.037)	(0.020)	(0.012)	(0.087)	(0.057)	(0.060)	(0.077)	(0.056)	(0.060)
AUS/NZ	1.101	1.299	1.093	1.101	1.359	1.298	4.809	5.701	4.810	3.899	5.542	4.699
	(0.051)	(0.030)	(0.025)	(0.014)	(0.033)	(0.011)	(0.086)	(0.057)	(0.062)	(0.077)	(0.056)	(0.060)
SA/MEX	0.306	0.421	0.316	0.319	0.621	0.800	7.088	2.996	7.092	3.920	3.002	4.650
	(0.005)	(0.006)	(0.088)	(0.007)	(0.017)	(0.011)	(0.086)	(0.058)	(0.060)	(0.087)	(0.057)	(0.061)
AFR	0.982	1.167	0.924	1.076	1.149	1.056	4.390	6.200	4.330	3.501	9.797	6.000
	(0.021)	(0.017)	(0.031)	(0.030)	(0.016)	(0.021)	(0.086)	(0.057)	(0.062)	(0.077)	(0.056)	(0.061)
ASIA	0.885	1.050	0.901	0.902	1.269	1.106	4.329	7.500	4.390	3.759	6.259	4.730
	(0.042)	(0.018)	(0.051)	(0.024)	(0.021)	(0.011)	(0.087)	(0.057)	(0.061)	(0.078)	(0.056)	(0.062)

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.

Table 7: Log Export Prices and Sales Across Countries

Market	(1) US/CAN	(2) JAP/KOR	(3) EU	(4) AUS/NZ	(5) SA/MEX	(6) AFR	(7) ASIA
			Log Export Prices				
Data	0.284	0.398	0.300	0.358	-0.410	0.181	0.337
Model (1)	0.296	0.417	0.200	0.405	-0.470	0.190	0.339
Model (2)	0.287	0.381	0.292	0.348	-0.395	0.170	0.317
Model (3)	0.255	0.342	0.312	0.329	-0.395	0.200	0.308
Model (4)	0.276	0.391	0.215	0.391	-0.347	0.183	0.352
Model (5)	0.256	0.404	0.239	0.324	-0.450	0.165	0.329
Model (6)	0.250	0.384	0.235	0.308	-0.422	0.195	0.306
			Log Physical Export Sales				
Data	9.513	9.185	10.228	8.414	9.550	9.343	9.224
Model (1)	9.491	9.111	10.385	8.241	10.403	8.978	8.904
Model (2)	9.399	9.150	10.163	8.332	10.284	9.019	9.095
Model (3)	9.409	9.594	10.150	8.196	9.922	9.181	8.800
Model (4)	9.427	9.050	10.316	8.281	9.784	8.460	9.449
Model (5)	9.336	9.018	10.025	8.492	10.573	9.284	8.932
Model (6)	9.510	9.438	10.280	8.464	9.349	8.891	9.094

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.

u_j, is substantially lower than the others. In fact, the average markup in South America/Mexico is roughly 8.6-12.9 percent. By comparison, we find that average markups are highest in US/Canada, Australia/New Zealand and the EU where the average markup ranges between 20.9-43.4 percent across all model variants. The estimated average markups in Japan/Korea, Africa and Asia are somewhat lower (16.8-30.2 percent across models), but are still much higher than that in South America/Mexico. 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 subsequent section.

6.2 Model Performance

We simulate each 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 the quantity exported across regions in Table 7.

We find that models (1)-(6) all generally capture the pattern of price and export quantity differences across regions relatively 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

Table 8: Log Import Prices

Data	Model No.					
	(1)	(2)	(3)	(4)	(5)	(6)
-4.840	-2.340	-2.720	-2.747	-2.981	-3.232	-3.152

Notes: The above table reports the average log import price for electric kettles producers along with the same moments from the simulated data.

regions in the model.[40]

We also predict the average log import price using the model's structure. Each variant predicts an average import price which is somewhat above the average log import price in the data, -4.84. This aspect of the results reveals some inherent tension in the model: lower values of α aid in fitting the import price level, but discourage quality upgrading. As such, it is a challenge for the model to match both input price levels and changes over time. Notably, models which combine productivity dynamics with augmented or accumulating demand growth fit this dimension of the data better than more restrictive model variants.

[40] 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 9: Market-Specific Entry and Exit Rates

Market	(1) US/CAN	(2) JAP/KOR	(3) EU	(4) AUS/NZ	(5) SA/MEX	(6) AFR	(7) ASIA
				Entry Rates (%)			
Data.	0.411	0.436	0.484	0.382	0.389	0.565	0.459
Model (1)	0.413	0.427	0.446	0.368	0.382	0.533	0.441
Model (2)	0.417	0.432	0.443	0.369	0.417	0.450	0.522
Model (3)	0.402	0.391	0.468	0.358	0.368	0.512	0.489
Model (4)	0.405	0.404	0.446	0.379	0.416	0.489	0.512
Model (5)	0.416	0.405	0.439	0.354	0.347	0.478	0.522
Model (6)	0.399	0.409	0.496	0.368	0.305	0.478	0.553
				Exit Rates (%)			
Data.	0.589	0.564	0.516	0.618	0.611	0.435	0.541
Model (1)	0.587	0.573	0.554	0.632	0.618	0.467	0.559
Model (2)	0.583	0.568	0.557	0.631	0.583	0.550	0.479
Model (3)	0.598	0.609	0.532	0.642	0.632	0.488	0.511
Model (4)	0.595	0.596	0.554	0.621	0.584	0.511	0.488
Model (5)	0.584	0.595	0.561	0.646	0.653	0.522	0.478
Model (6)	0.601	0.591	0.504	0.632	0.695	0.522	0.447

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.

Table 9 examines the model's ability to capture the turnover of export producers across diverse export markets. The model-simulated data successfully replicates the fact that the entry rate is highest in Africa, Europe and Asia, while the exit rate is largest in Australia, South America and the US.

We next evaluate whether the model captures the firm and market evolution of prices and quality as documented in Section 2. Specifically, as in equation (1), we regress a current firm-level characteristic in a given market (quantity exported, output price, average input price) on past performance in that market, firm-year fixed effects, and destination-year fixed effects. The simulated data qualitatively replicate the patterns in the actual data 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. Across models we observe that incorporating more general forms of demand evolution, such as in Models 3 and 6, significantly reduce the distance between the regressions on model-generated and actual data.

Table 10: Replicating Export Sales, Export Price and Import Price Dynamics

Data	Model No.					
	(1)	(2)	(3)	(4)	(5)	(6)
	Dependent Variable: Quantity Exported					
0.353	0.600	0.312	0.381	0.241	0.234	0.272
[0.021]	[0.077]	[0.080]	[0.050]	[0.038]	[0.064]	[0.041]
	Dependent Variable: Export Prices					
0.040	0.095	0.083	0.050	0.067	0.070	0.040
[0.015]	[0.019]	[0.030]	[0.020]	[0.024]	[0.030]	[0.020]
	Dependent Variable: Import Prices					
0.035	0.033	0.039	0.040	0.063	0.103	0.081
[0.018]	[0.015]	[0.022]	[0.015]	[0.022]	[0.041]	[0.020]

Notes: The above results are OLS estimates of β in equation (1), $\ln(x_{fjt}) = \alpha + \beta \ln(Q_{fj,t-1}) + \Gamma_{ft} + \Gamma_{jt} + \epsilon_{fjt}$, where Γ_{ft} is a firm-year fixed effect, Γ_{jt} is a destination-year fixed effect, and f, j 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, while firm-year and destination-year fixed effects are replaced by firm and year fixed effects.

6.3 Export Growth and Trade Costs

Proposition 3 indicates that past experience and distance to export markets should have a complementary impact on firm pricing and export growth. All else equal, exporters are predicted to have greater physical sales in markets which are less costly to enter. This, in turn, will reinforce differences in both the average quality and the total quantity exported across markets in later time periods.

We evaluate this complementarity by regressing the growth of a firm-characteristic, x_{fjt} (exported quantities, export prices, import prices), on firm f's age in a market, the interaction of age and distance to market, and destination-year fixed effects:

$$\Delta \ln(x_{fjt}) = \psi_0 + \psi_1 age_{fjt} + \psi_2 age_{fjt} \times \frac{1}{d_j} + \Gamma_{jt} + \xi^x_{fjt} \tag{32}$$

where age is the number of consecutive years the firm has exported to a given destination market by year t, d_j is the distance to market j, Γ_{jt} captures destination-year fixed effects, and ξ^x_{fjt} is an iid shock. Note that any direct effect of distance is subsumed in the destination-year fixed effects. As in Section 2, we cannot observe which inputs are allocated to destination-specific exports. 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 a good to a specific destination country.[41]

We expect that the coefficients on age, ψ_1 or $\tilde{\psi}_1$, to be negative; as firms grow into export markets the rate of price or physical sales growth should fall. However, Proposition 3 implies that this decline

[41]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-

Table 11: Age, Distance and Export Dynamics

	Data	Model No.					
		(1)	(2)	(3)	(4)	(5)	(6)
		Dependent Variable: Growth of Physical Exports, $\Delta \ln Q_{fjt}$					
age	-0.075	-0.046	-0.016	-0.026	-0.026	-0.023	-0.027
	[0.032]	[0.011]	[0.005]	[0.007]	[0.007]	[0.010]	[0.007]
age/d	0.205	0.249	0.117	0.164	0.174	0.182	0.171
	[0.081]	[0.122]	[0.056]	[0.075]	[0.079]	[0.107]	[0.077]
		Dependent Variable: Growth of Export Prices, $\Delta \ln p_{fjt}$					
age	-0.019	-0.012	-0.023	-0.036	-0.023	-0.017	-0.022
	[0.064]	[0.003]	[0.005]	[0.011]	[0.006]	[0.007]	[0.007]
age/d	0.176	0.068	0.372	0.236	0.127	0.137	0.152
	[0.057]	[0.034]	[0.195]	[0.120]	[0.066]	[0.075]	[0.074]
		Dependent Variable: Growth of Import Prices, $\Delta \ln w_{ft}$					
$age.$	-0.002	-0.003	-0.005	-0.005	-0.004	-0.003	-0.005
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
age/d	0.012	0.016	0.066	0.033	0.024	0.023	0.029
	[0.006]	[0.007]	[0.030]	[0.015]	[0.012]	[0.135]	[0.014]
Dest-Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The above results are OLS estimates of β in equation (1), $\Delta \ln(x_{fjt}) = \psi_0 + \psi_1 age_{fjt} + \psi_2 age_{fjt} \times \frac{1}{d_j} + \Gamma_{jt} + \xi^x_{fjt}$, where age is the number of consecutive years the firm has exported to a given destination market by year t, d_j is the distance to market j, Γ_{jt} captures destination-year fixed effects, and ξ^x_{fjt} is an iid shock. 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.

should be mitigated in less costly markets where the firm has a greater comparative advantage. As such, we expect the coefficient on the interaction of age and distance to be positive. The results for each regression, using both the actual and the simulated data, are reported in Table 11.

We observe that the impact of age and distance predicted by Proposition 3 are consistent with the estimated coefficients. This pattern is qualitatively reflected by each model variant, though there are significant differences in the degree to which each model is able to replicate the empirical patterns in the data. For instance, consider the top panel of Table 11 where the growth in physical sales is used as the dependent variable. We observe that the coefficient on the age variable is small and precisely estimated, but is also consistently somewhat larger than that observed in the actual data across all models. In comparison, models with productivity dynamics (Models (4)-(6)) appear to significantly outperform other model variants in matching the quantitative magnitude of the coefficient on the interaction between age and distance.

Finally, we also test the validity of Proposition 4 by examining the relationship between firm age, productivity and survival. Specifically, we first consider a linear probability model for firm survival where

destination exporters. As in Section 2.2, we also consider a firm-level regression for average log import price growth

$$\Delta\overline{\ln(import\ price_{ft})} = \tilde{\psi}_0 + \tilde{\psi}_1 \tilde{age}_{ft} + \tilde{\psi}_2 \tilde{age}_{ft} \times \frac{1}{d_j} + \tilde{\Gamma}_t + \tilde{\xi}^w_{ft} \tag{33}$$

where $\tilde{age}$ now measures the total number of consecutive years a firm has been exporting. Again, the model simulated data fits the actual data closely. The results can be found in the Supplemental Appendix.

Table 12: Survival, Productivity and Age

	Data	Model No.					
		(1)	(2)	(3)	(4)	(5)	(6)
		Dependent Variable, D_{fjt}					
age	-0.234	-0.196	-0.578	-0.361	-0.494	-0.493	-0.351
	[0.057]	[0.061]	[0.197]	[0.039]	[0.042]	[0.042]	[0.038]
age^2	0.034	0.030	0.069	0.041	0.079	0.078	0.040
	[0.010]	[0.011]	[0.033]	[0.007]	[0.007]	[0.007]	[0.007]
Productivity	0.049	0.123	0.053	-0.006	0.034	0.017	-0.006
	[0.008]	[0.040]	[0.012]	[0.008]	[0.027]	[0.008]	[0.008]
Dest-Year FE	Yes	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 (34). Standard errors are in brackets. Destination-year or year fixed effects are included in each regression.

we regress an indicator variable for survival in a given market on firm age, age squared, productivity and destination-year fixed effects:

$$D_{fjt} = \chi_0 + \chi_1 age_{fjt} + \chi_2 age^2_{fjt} + \chi_3 Prod_{ft} + \Gamma_{jt} + \xi^D_{fjt} \tag{34}$$

where $D_{fjt} = 1$ if firm f exports to market j in year t and zero otherwise, $Prod_{ft}$ is a measure of firm productivity in year t, and ξ^D_{fjt} is again an iid error term.

As emphasized in Ruhl and Willis (2017) many new exporters tend to exit export markets after one 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, 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.

Proposition 4 predicts that survival is jointly explained by age and firm productivity. While we do not have a direct measure of productivity, we employ the model estimated productivity for each firm as an additional regressor in our regression exercise.[42] The data again suggests that more productive firms are more likely to continue exporting to destination markets over time.

Each model variant qualitatively replicates the observed survival patterns over the distribution of firm age even though this does not feature directly in our estimation equations (24)-(28). Models which feature the accumulating demand structure (Models (3) and (6)) do not replicate the observed sign of the productivity coefficient, though standard errors are large relative to the coefficient in each case.

To provide a sense of overall model fit, we compute the ratio of marginal likelihood of each model and that from our of benchmark model, Model (1). Higher values of this quantity, known as a Bayes Factor, indicates that the model under consideration is deemed to have had a greater likelihood of generating the data.[43] We report the computed Bayes factors in Table 13. We observe that Model 6, the model

[42] The productivity measure reported in the right-panel of Table 10 for the actual data is taken from Model (6).

[43] An advantage of this approach is that there is no need to penalize models with higher numbers of parameters. Models with more parameters are more flexible, but, as a result, they assign lower likelihoods to all the data sets they can generate. In

characterized by dynamic productivity evolution and the accumulating demand structure, returns the highest Bayes factor. For brevity, our subsequent empirical analysis restricts attention to this model variant alone.

Table 13: Bayes Factors

Model No.					
(1)	(2)	(3)	(4)	(5)	(6)
1.000	1.097	1.184	1.168	1.236	1.262

Notes: The table above computes Bayes factors relative to Model (1) for each model variant. A Bayes Factor, K for any two models A_1 and A_2 is the ratio of marginal likelihood of A_1 to that of A_2: $K = \frac{\Pr(\{x_i\}|A_1)}{\Pr(\{x_i\}|A_2)} = \frac{\int_{\theta_1} \Pr(\{x_i\}|\theta_1)\Pr(\theta_1|A_1)d\theta_1}{\int_{\theta_2} \Pr(\{x_i\}|\theta_2)\Pr(\theta_2|A_2)d\theta_2}$.

6.4 Model Implications: Demand Accumulation

This section uses simulation methods to quantify the estimated model's implications in economically meaningful magnitudes. We first we simulate our preferred model (Model (6)) 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, $\theta_1 = 0$. We report the percentage difference in output prices, input prices and sales across models to quantify the impact of intertemporal spillovers for the typical Chinese exporter.

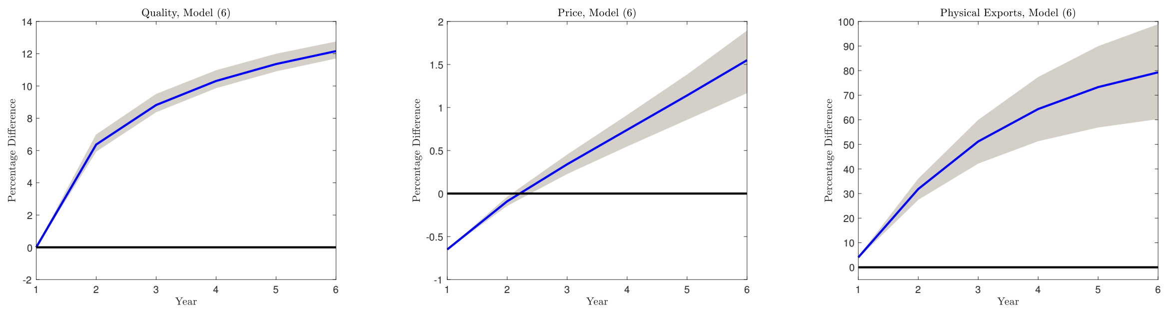
Panel (a) of Figure 1 documents the impact of demand accumulation on product quality, prices and sales over time. The blue line captures the percentage difference between the model with intertemporal spillovers and an identical 'static' firm where $\theta_1 = 0$. The grey shaded area represent 95 percent credible intervals.[44] The first year of the figure is the year of entry and, as such, past market share is zero by construction. Because θ_1 will not affect the firm's quality choice differentially across our simulations in the year of initial entry, there is no difference across the static and dynamic version of the model. After the year of entry, export growth drives up future demand which in turn increases product quality in the model with intertemporal spillovers. Specifically, between the first and second year product quality improves by 6.4 percent and then grows slowly thereafter. Five years after entry the intertemporal spillover accounts for a 12.2 percent increase in product quality.

Although quality choices are identical in the year of entry, Panel B of Figure 1 documents that the intertemporal spillovers depress export prices slightly in the initial period relative to the static model. In fact, we find that the initial output price is 0.7 percent lower than that charged by the firm in which there is no demand growth. This reflects the fact that forward-looking firms recognize the impact current choices have on future export profits. Although the percentage difference in prices difference is small, it is predicted to lead to significantly higher initial exported quantities even if it comes at the cost of lower

contrast, simpler models assign higher likelihoods to a smaller range of data sets.

[44] A credible interval is an interval in the domain of a posterior probability distribution.

Figure 1: The Evolution of Firm-Level Product Quality, Prices and Sales



Notes: The above figure documents the evolution of export product quality, export prices and export sales overtime for an average firm in an average export market. The blue line captures the firm's export decisions under the benchmark model parameters relative to the same firm when it ignores all dynamic pricing considerations starting in period 0.

initial profits. In fact, initial export quantities are 4 percent higher relative to an equivalent firm in a static setting.

As quality improves prices also rise; in our preferred model export prices increase by 2.2 percentage points over 5 years for the average firm. 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. Although price changes are modest, this should not be interpreted as having a small impact on firm exports. After five years, the combined growth product quality and prices results in export sales which are 79 percent greater than that implied by the static model.

While the above experiment quantifies the economic importance of dynamic spillovers for the average firm's product quality and pricing, it obscures the rich heterogeneity across firms. To characterize differences across firms we consider the ratio of the firm's optimal price, p_{ijt}, in equation (15) 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

$$\text{Discount} = 1 - \frac{p_{ijt}}{p^m_{ijt}} = \frac{\rho E V'_{j1}(M_{ijt}, f_{j,t+1})}{p^m_{ijt}} \tag{35}$$

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 products in the current period, as reflected by p^m_{ijt}.

Table 14: Dynamic price discounts across the distribution of Chinese exporters to the US (in Percentages)

Mkt Shr	Percentile (Pctl) of the Productivity Distribution				
Pctl.	5^{th}	25^{th}	50^{th}	75^{th}	95^{th}
3^{rd}	0	0	0	0	0.215
5^{th}	0.309	0.279	0.247	0.226	0.213
25^{th}	0.308	0.277	0.245	0.223	0.211
50^{th}	0.306	0.275	0.243	0.221	0.208
75^{th}	0.304	0.272	0.240	0.217	0.205
95^{th}	0.301	0.269	0.236	0.213	0.201

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 14 documents the dynamic price discounts, equation (35), across the distribution of productivity and past market share for Chinese exporters to the US.[45] Consider low productivity firms in the third percentile of the market share distribution. These firms are predicted to offer no dynamic price discount; in fact, the zeros pin down which firms 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 0.21-0.33 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. Consider, for example, an exporter in the 50^{th} percentile of the productivity distribution. For this firm a 0.25 percent price discount represents nearly a 3.9 percent increase in first year sales, even though there is no difference in product quality.

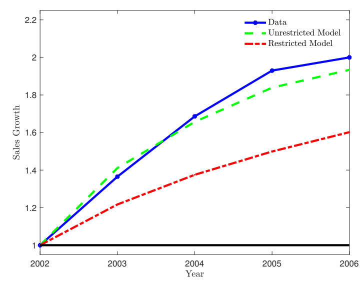
6.5 Model Implications: Quality Upgrading

To further characterize the role of quality dynamics we re-estimate our preferred model under the restriction that firm-level product quality is fixed over time. For each model we then record the simulated sales among firms which enter the US market in 2002 and continue to export to the US for five consecutive years..[46]

[45] 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.

[46] A full set of parameter estimates for the restricted model can be found in the Supplemental Appendix. We choose to focus on continuous exporters to both facilitate a comparison with the data and capture sales dynamics without the confounding average firm-growth with entry and exit dynamics.

Figure 2: The Impact of Quality Upgrading on Evolution of on Export Sales to the US



Notes: The above figure documents the evolution of average export sales to the US by firms which enter the US market in 2002 are continue sell to that over through 2005. The blue solid line represents the path of average sales in the data, the green captures the path of average sales in our preferred model, and the red documents the path of average sales in the restricted model.

Figure 2 reports the path of average sales for each model and the data, where initial sales are normalized to one in each case to facilitate the comparison. The unrestricted model with quality upgrading slightly overshoots initial sales growth, but then follows the data closely. The restricted model, in contrast, grows nearly 14 percent slower between years 1 and 2. Five years after entry, the restricted model only captures 83 percent of the sales growth implied by the unrestricted model. In this sense, quality upgrading accounts for 14-17 percent of sales growth over the initial five years of market entry. The restricted model does not match the path of sales over time because sales and price dynamics are tied in both models. For sales to grow faster in the restricted model, initial price discounts would need to be greater than that observed in the data and prices would be predicted to grow too fast. Quality upgrading provides a mechanism through which sales and prices to grow together, but at differential rates. Here, export quality growth is disciplined through changes in input prices, but the model nonetheless matches average export growth well.

7 Trade Liberalization

In this section, we consider the impact of trade liberalzation on price and quality dynamics in export markets. Specifically, we consider a partial equilibrium counterfactual simulation exercise which highlights the aggregate implications of tariff reductions in export destinations worldwide.[47] We simulate the model starting in 2006 allowing each firm to make endogenous entry, product quality and pricing decisions in each market. We then repeat this exercise after counterfactual trade liberalization and compare

[47] Fan et al. (2015) 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.

Table 15: Percentage Change in Product Quality and Prices Across Markets

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
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	1.1	1.2	1.4	1.5	1.3	1.3	1.5
5	1.5	2.0	1.9	2.0	2.1	1.7	2.1
Years After Trade Lib.			Export Prices				
1	1.4	4.2	2.4	4.0	6.1	9.2	4.7
5	1.7	5.0	2.6	5.5	9.7	11.0	6.0
Years After Trade Lib.			Export Sales				
1	5.0	4.0	3.3	2.0	5.4	4.3	4.8
5	9.3	7.3	7.6	5.9	10.0	7.8	8.7

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

the changes over time as reported in Table 15.[48]

The top panel of Table 15 documents the corresponding change in export product quality in each region. Across all markets we observe a 1-1.5 percent increase in average product quality in the first year after trade liberalization and an additional 0.4-0.8 percent increase over the subsequent 4 years as average product quality continues to increase in each market. The middle panel of Table 15 reports corresponding 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 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 unproductive, 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. As such, the counterfactual exercise finds that both prices and sales will rise in the years trade liberalization; average sales jump by 2-5 percent upon the change in trade policy and are 6-10 percent greater than they would have been otherwise 5 years after liberalization. In this sense, our findings indicate that trade liberalization induces increased competition through improved product quality and the reallocation of consumers towards high quality firms despite higher observed prices.

Across regions, larger tariff cuts are roughly correlated with larger increases in average product quality export prices, and export sales, albeit imperfectly. 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 to the fact that this the region is characterized by low markups and, as such, there was greater scope for product-quality induced price changes to have a direct impact on prices.[49]

[48]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.

[49]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

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 tend to enter export markets with low prices and produce low quality goods when 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 our preferred empirical model, we find that in the year of entry intertemporal spillovers reduce average firm-level export prices by 0.7 percent and increase average firm-level sales by 4 percent. Over time, quality, prices and sales endogenously increase. Five years after entry the average exporter optimally chooses to improve product quality by 12 percent and increase prices by 2.2 percent, while export sales grow by 79 percent among surviving entrants. In our empirical model product quality upgrading accounts for 13-17 percent of firm sales growth. 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.

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greater scope for determining percentage changes in p_{ijt}.

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A Data Appendix

Table 16 provides summary statistics for the full sample of Chinese exporters, the full subsample of electric kettle exporters, the subsample of electric kettles exporters used in Section 2, and the subsample of electric kettles used in the structural estimation exercise. The observations differ in the latter three cases because (a) the lag structure of our estimating equations and (b) the aggregation of export destinations. 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 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. Note that in columns (9)-(12) we restrict attention to firms which export continuously to the same location for at least two years.

Table 16: Summary Statistics

	Electric Kettles (Full Sample)				All Exporters			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Variable	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Export Sales (Physical Units)	34,978.4	215,205.8	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-04	14.6	4.7	236.2	7.5e-08	200,401
Import Prices	0.9	1.9	1.5e-04	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		
	Electric Kettles (Section 2)				Electric Kettles (Structural Estimation)			
	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Variable	Mean	Std. Dev.	Min.	Max.	Mean	Std. Dev.	Min.	Max.
Export Sales (Physical Units)	44,061.59	264,030.1	1	2.34e+07	42,787.29	120,228.1	1	1.73e+07
Export Revenues	272,246.2	859,037.7	6	3.10e+08	227,943.4	842,088	1	2.25e+08
Export Prices	1.7	19.1	1.0e-03	14.1	1.4	7.8	1.0e-03	13.1
Import Prices	0.9	3.7	6.3e-05	207.6	0.9	3.0	6.3e-05	207.6
No. of Export Destinations	3.2	2.0	1	7	2.4	2.0	1	7
Export Duration	3.3	0.6	2	7	1.6	1.1	1	7
Obs.		2,249				6,745		

Notes: The above table documents the mean, the standard deviation, and the 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 Price, Quantity, and Revenue Dynamics: Further Evidence

A number of recent papers investigate the evolution of firms in export markets. Abstracting from firm entry decisions, Berman et al. (2017) and Fitzgerald et al. (2017) respectively study the growth of French and Irish manufacturers in export markets. Likewise, Piveteau (2018) characterizes the growth of French wine exporters. A key finding in the Berman et al. (2017) and Fitzgerald et al. (2017) papers is that prices change very little over time, while export quantities and revenues grow rapidly among surviving exporters. A similar result was also presents itself in Piveteau (2018) where prices grow very moderately over time but revenues and quantities increase rapidly among surviving exporters.

This seems, in principle, to be somewhat inconsistent with our second stylized fact where it appears that Chinese exporters charge higher prices over time. To shed some light on the source of these differences across papers, we replicate a key empirical exercise from Fitzgerald et al. (2017) using our data.[50] Adopting the notation from Fitzgerald et al. (2017), let w_{ijk} represent log export prices (or log revenue and log quantity as alternative dependent variables). Similarly, define a_{ijk} as a vector of indicator variables for firm i's tenure in market k with product j and let s_{ijk} be a vector of indicators for the length of the relevant spell.[51] Following Fitzgerald et al. (2017) we top-code both market tenure and spell length; given that our data span 2000-2006 we top-code both variables at 6 years. Last, we also follow their structure and drop spells whose length is right-censored at a level below the top-code and include a separate indicator ($cens_{ijk}$) for spells that are both left- and right-censored. The baseline empirical specification is

$$w_{ijk} = \delta^k + c_t^{ij} + \boldsymbol{\beta}' \left(\boldsymbol{a}_t^{ijk} \otimes \boldsymbol{s}_t^{ijk} \right) + cens^{ijk} + \varepsilon^{ijk} \quad (36)$$

[50] We thank an anonymous referee for this suggestion.

[51] s_{ijk} does not vary within a spell, but is indexed by t to capture the fact that we may observe multiple export spells of different length for firm i, product j, and market k over the sample period.

which also corresponds to equation (1) in Fitzgerald et al. (2017). Vectors of fixed effects include δ^k, which represents a set of market fixed effects, and c_t^{ij}, which represents firm-product-year fixed effects.

The vector $\boldsymbol{\beta}$ captures variation in initial revenue, quantity and price with completed spell length, along with the evolution of revenue, quantity, and price with market tenure over the lifetime of spells of different length. The results from this exercise are documented in the first three columns of Table 17 below. Columns (4)-(6) report the results from the same exercise performed on the electric kettles industry alone.

Before addressing price dynamics, there are two results that merit comment. First, the estimated coefficients from the price and quantity regressions generally sum to a value that is relatively close to the estimated coefficient on the same term in the revenue regression. Though not necessary, this result is not entirely surprising given that revenue is a multiple of price and quantity. Second, the coefficients on spell length generally tend to increase over years for revenue and quantity in both exercises.

Most imporantly, however, column (3) and column (6) clearly demonstrate that the coefficients on the spell length variables consistently increase over years. This is likewise reflected in the coefficients from the revenue and quantity regressions. Although the coefficients on the spell variables increase over years, examining columns (1)-(2) we observe that the estimated coefficients on the spell length variables from the revenue regression are always larger than those from the quantity regression. The same pattern presents itself across columns (4)-(5) for the electric kettles industry alone.

These patterns suggest that price growth may potentially be an important determinant of revenue growth for Chinese exporters. A simple Wald test reveals the differences in the patterns on the spell length variables are not just of qualitative importance, but are also statistically significant. Specifically, in column (3), we find that a Wald test of the null hypothesis that the coefficient on the 5-year spell length variable (0.72) and the coefficient on the 2-year spell length variable (0.66) are the same is rejected at the 5 percent level (p-value 0.0262). For the sample of electric kettles producers the difference on the estimated coefficients on 2-year and 5-year spell length variables (1.64 and 2.25, respectively) is statistically significant at the one percent level.

One potential interpretation of the above findings is that the prices of Chinese exporters increase with the number of years a firm was present in a particular product-market. An alternative interpretation for these findings is that we have not used the correct fixed-effects structure in our regressions. An alternative fixed effects structure would include product-market-year/market-year fixed effects (in place of the market fixed effects) and firm-product-year fixed effects. We complete this exercise on our data as well and report the results in our Supplemental Appendix. Despite the additional fixed effects, similar empirical patterns present themselves even after controlling for product-market-year fixed effects. As such, we conclude that there is significant evidence of increasing prices in our sample of Chinese export data.

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 χ_{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

Table 17: Dynamics of export revenue, export quantities and export prices

Sample	All Industries			Electric Kettles		
Dep. var. (ln)	Revenue (1)	Quantity (2)	Price (3)	Revenue (4)	Quantity (5)	Price (6)
Spell length	Spell Intercept					
2 years	1.90 (0.07)***	1.24 (0.08)***	0.66 (0.05)***	2.29 (0.12)***	0.51 (0.14)***	1.64 (0.16)***
3 years	2.27 (0.07)***	1.69 (0.08)***	0.70 (0.05)***	2.67 (0.13)***	0.81 (0.16)***	1.95 (0.16)***
4 years	2.41 (0.07)***	1.77 (0.08)***	0.67 (0.05)***	2.63 (0.16)***	0.82 (0.08)***	1.97 (0.17)***
5 years	2.59 (0.07)***	1.91 (0.08)***	0.72 (0.05)***	2.97 (0.20)***	0.94 (0.23)***	2.25 (0.18)***
6+ years	2.60 (0.07)***	1.91 (0.09)***	0.71 (0.05)***	2.75 (0.32)***	1.00 (0.37)***	2.06 (0.18)***
cens	2.85 (0.05)***	2.00 (0.07)***	0.98 (0.03)***	3.10 (0.17)***	1.05 (0.21)***	2.49 (0.18)***
Mkt tenure	2-year spell					
2 years	0.03 (0.01)***	-0.00 (0.01)	0.03 (0.00)***	0.86 (0.17)***	0.08 (0.32)	0.14 (0.07)**
Mkt tenure	3-year spell					
2 years	0.10 (0.02)***	0.06 (0.02)***	0.01 (0.00)**	0.16 (0.58)	0.18 (0.28)	0.02 (0.08)
3 years	0.36 (0.34)***	0.34 (0.01)***	0.04 (0.01)***	0.51 (0.30)*	0.84 (0.18)***	0.04 (0.12)
Mkt tenure	4-year spell					
2 years	0.15 (0.03)***	0.11 (0.04)***	0.01 (0.01)	1.15 (1.14)	0.02 (0.04)	0.01 (0.01)
3 years	0.54 (0.03)***	0.52 (0.03)***	0.03 (0.01)**	2.19 (1.08)**	0.85 (0.44)**	0.03 (0.01)**
4 years	0.49 (0.02)***	0.47 (0.02)***	0.04 (0.01)***	1.73 (0.05)***	0.59 (0.31)**	0.04 (0.01)***
Mkt tenure	5-year spell					
2 years	0.31 (0.07)***	0.29 (0.07)***	0.01 (0.00)***	1.89 (3.89)	2.06 (1.38)	0.07 (0.08)
3 years	0.78 (0.06)***	0.77 (0.06)***	0.04 (0.00)***	2.41 (0.32)***	2.45 (1.09)**	0.12 (0.08)
4 years	0.87 (0.05)***	0.87 (0.05)***	0.07 (0.00)***	2.24 (0.25)***	2.04 (0.76)***	0.24 (0.08)***
5 years	0.61 (0.04)***	0.61 (0.04)***	0.12 (0.00)***	1.56 (0.11)***	1.82 (0.48)***	0.30 (0.09)***
Mkt tenure	6+ years spell					
2 years	0.23 (0.14)*	0.13 (0.14)	0.01 (0.01)	0.41 (0.98)	0.47 (0.97)	0.17 (0.15)
3 years	0.85 (0.12)***	0.80 (0.14)***	0.02 (0.01)***	1.25 (0.81)	1.31 (0.81)***	0.23 (0.14)*
4 years	1.03 (0.11)***	1.00 (0.12)***	0.04 (0.01)***	1.18 (0.64)*	1.16 (0.64)*	0.28 (0.14)**
5 years	0.95 (0.09)***	0.93 (0.10)***	0.07 (0.01)***	1.46 (0.48)***	1.40 (0.48)***	0.38 (0.14)***
6+ years	0.63 (0.07)***	0.62 (0.08)***	0.13 (0.01)***	0.65 (0.32)**	0.58 (0.30)**	0.44 (0.15)***
	Fixed effects					
Firm-product-year	Yes	Yes	Yes	No	No	No
Firm-year	No	No	No	Yes	Yes	Yes
Market	Yes	Yes	Yes	Yes	Yes	Yes
N	1396461	1396461	1396461	312952	312952	312952
rsq	0.51	0.59	0.70	0.76	0.82	0.90
rsq-adj	0.49	0.49	0.60	0.58	0.69	0.82

Notes: A full set of firm-product-year and market effects are included in the firm-product-market-year regressions. Firm-year and market effects are included in the firm-market-year regressions. The omitted category is spells that last one year. Robust standard errors calculated. *** significant at 1%, ** significant at 5%, * significant at 10%. The sample includes non-importing exporters.

state $(\lambda, M_{ij,t-1}, f_{jt})$ if $f_{jt} \leq y(\lambda, M_{ij,t-1})$. Third, we rewrite the firm's Bellman equations as

$$\begin{aligned}\tilde{V}(\lambda, M_{ij,t-1}, f_{jt}) &= \max_{p_{ijt}, q_{ijt}, \chi_{ijt}} \left\{ r_j \exp\left[\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j) q_{ijt} - p_{ijt}\right)\right] \left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij}\right] \right. \\ &\left. - f_{jt} + \rho \int_{f_{jt} \in y(\lambda, M_{ij,t-1})} \tilde{V}(\lambda, M_{ijt}, f_{jt}) g_c(f_{jt}) df_{jt} \right\} \chi_{ijt} \qquad (37)\end{aligned}$$

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

$$\begin{aligned}L(\lambda, M_{ij,t-1}, f_{jt}) &= \max_{p_{ijt}, q_{ijt}} r_j \exp\left[\frac{1}{u_j}\left(\theta(M_{ij,t-1}, \bar{I}_j) q_{ijt} - p_{ijt}\right)\right] \left[p_{ijt} - \left(\frac{q_{ijt}}{\lambda^{1+\alpha}}\right)^{\frac{1}{\alpha}} \eta_i \tau_{ij}\right] - f_{jt} \\ &+ \rho \tilde{V}(\lambda, M_{ijt}, f_{jt}) \qquad (38)\end{aligned}$$

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 (38) 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,

$$\tilde{U}(\lambda, M_{ij,t-1}) = \phi(p_{ijt}, q_{ijt}). \qquad (39)$$

Under assumption 1, the support functions (38) and (39) 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 (3):

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

where $\tilde{t} > t-1$ and $M_{j,\tilde{t}-1} < M'_{j,\tilde{t}-1}$. Since θ, 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, π_{ijt}, with respect to past market share, $M_{ij,t-1}$, is clearly positive

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

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

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

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

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

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 $-\theta_1\frac{\partial^2\theta}{\partial M_{j,t-1}^2}=\left(\frac{\partial\theta}{\partial M_{ij,t-1}}\right)^2$ in this case. Under this assumption, condition (A3) will be satisfied as long as θ_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.

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 (14) and (15) 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 (13) holds. ■

Proposition 2

Proof. To establish this proposition we take the derivative of equation (11) with respect to q_{ijt}, p_{ijt} and $M_{ij,t-1}$, respectively, where our derivatives rely on the above differentiability proof.

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

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

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

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

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

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 $M_{ij,t-1} \le M_{ij',t-1}$ it must be that

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

where the only difference between $M_{ij't}$ and $\tilde{M}_{ijt}$ is that we use $M_{ij,t-1}$ in place of $M_{ij',t-1}$ inside of $\theta(\cdot)$. Now suppose that M_{ijt} is an increasing function of τ_{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 (13) is assumed to hold. The derivative of $\hat{M}_{ijt}$ with respect to $\tau_{ij'}$ is

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

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 τ_{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 ϵ^*_{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 ϵ^*_{ijt} and $\epsilon^{*\prime}_{ijt}$ denote the fixed cost shocks which induce exit from country i exporters with productivity levels λ and λ' 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 λ is more likely to survive in any period. ■

D Computational Details

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 $W_j(s_{jt}) = \pi_{jt}(s_{jt}) + \rho E V_j(s_{jt})$. 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 $V_j^*(s_{jt}) = b^k + B^k \cdot X_{jt}$.

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 Θ^o, a new draw is made from a conditional distribution $q(\Theta^*|\Theta^o)$. Denote likelihood by $L(\Theta)$, and the prior by $\varphi(\Theta)$. The parameters for each successive iteration, Θ', are generated as follows:

1. Separate the parameters into 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, λ.

   (a) Draw λ *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 Θ_2.

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

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

4. Repeat step (3) for Θ_3 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, Σ, for equations (24)-(27) 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 Θ^* is drawn from a normal distribution with mean Θ^o, so as to facilitate the outer routine computation. In this way, $q(\Theta^*|\Theta^o) = q(\Theta^o|\Theta^*)$, and the acceptance probability in any block $j = 1, 2, 3$ can be written as $a_j = \min\{1, \frac{L(\Theta^*)\varphi(\Theta^*)}{L(\Theta^o)\varphi(\Theta^o)}\}$.

Supplemental Appendix for
"Price, Product Quality and Exporter Dynamics: Evidence from China

by Joel Rodrigue and Yong Tan
Dept. of Economics, Vanderbilt University, Nashville, TN, United States
School of International Economics & Trade, Nanjing University of Finance and Economics, Nanjing, China
Contact e-mail: joel.b.rodrigue@vanderbilt.edu; yongtan_econ@163.com

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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 a simple description of the model's equilibrium. Section C presents an alternative input demand structure. Section D provides additional discussion regarding the identification of the markup parameter u_j. Section E provides estimates omitted from Section 6.5 of the main text. Sections F-I document the robustness of the stylized facts presented in Section 2 of the main text. Sections H and J-L document the robustness of the estimates of our structurally estimated model. Section M provides further discussion of the impact of trade liberalization on firm dynamics in this context. Section N briefly our approach to the initial conditions problem in Models (3) and (6) of the main text.

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 λ 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 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 (11)-(12), firm policy rules (d, p, q), firm distributions χ^a_{ijt}, and input price vectors such that at any point in time:

1. **Optimization**: All consumers optimally choose 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 (11).

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,

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

   are redistributed equally across consumers N_j.

C Input Demand: An Alternative Structure

Our production framework is admittedly simple and has implications which are not necessary for Propositions 1-4. We offer an alternative framework which delivers the same theoretical results. Assume that an electric kettle is fabricated of a fixed number of components $j \in \{1, ..., K\}$. Each component can be produced in any source country and the marginal cost of acquiring a given component is a function of prevailing wages in that country and a fixed Ricardian productivity term associated with the production of a given component of a particular quality level. In this fashion each potential source country has a schedule of input prices; one price for each quality level and kettle component. As in the main text, we assume that each firm will import components from the source country which offers the best prices for the firm's desired input quality for each component.

Let ω_j generically denote the productivity adjusted the wage, while v_j represents the quality of an intermediate purchased from country j. We assume, as before, that electric kettles are made exclusively from intermediate inputs according to a CES production function:

$$h = \left[\sum_j \iota_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}$$

where σ is the elasticity of substitution across components. In contrast to the main text we further assume that the final product quality of an electric kettle, v, is similarly a CES aggregate of the product quality across inputs:

$$v = \left[\sum_j v_j^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}$$

where ϵ measures the elasticity of substitution across input quality. Given input prices across countries, the firm chooses the most cost effective manner to produce a target level of product quality.

To solve the firm's cost minimization problem we proceed in two steps. First, given the ω_j's and v_j's the firm chooses the optional amount of each intermediate to purchase, ι_j. Second, given the conditional input demand functions, we characterize how the levels of ω_j and v_j influence the manner in which the firm achieves product quality v. Specifically:

- **Step 1**: The firm solves for the unit cost function conditional ω_j and v_j

$$\min_{\iota_j} \sum_j \omega_j v_j \iota_j \text{ s.t. } \left[\sum_j \iota_j^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} = 1$$

  Note the multiplictiy of ω_j and v_j is consistent with our benchmark assumptions where the total cost of purchasing higher quality inputs rises linearly with input quality. The first order conditions yield conditional input demand functions of the usual form

$$\iota_j = \frac{(\omega_j v_j)^{-\sigma}}{\left[\sum_j (\omega_j v_j)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}}$$

  Substituting the conditional input demand functions into the cost function delivers the following unit cost function

$$C(h = 1 | v_j, \omega_j) = \left[\sum_j (\omega_j v_j)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

- **Step 2**: The firm minimizes the unit cost function given the target product quality v

$$\min_{v_j} \left[\sum_j (\omega_j v_j)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \text{ s.t. } v = \left[\sum_j v_j^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}.$$

  Cost minimization yields the following series of first order conditions:

$$\left[\sum_j (\omega_j v_j)^{1-\sigma} \right]^{\frac{\sigma}{1-\sigma}} \omega_j^{1-\sigma} v_j^{-\sigma} + \Lambda \left[\sum_j v_j^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{1}{\epsilon-1}} v_j^{-\frac{1}{\epsilon}} = 0$$

  where Γ is the Lagrangian multiplier. The first order conditions imply that the relative input quality sourced from any two countries is a function of their relative (productivity adjusted) wages:

$$\frac{v_j}{v_{j'}} = \left(\frac{\omega_j}{\omega_{j'}} \right)^x \text{ where } x = \frac{1-\sigma}{\sigma - \frac{1}{\epsilon}} \tag{A}$$

  Substituting equation (A) into the product quality production function v we can solve for the optimal quality purchased from each source v_j:

$$v_j = \frac{\omega_j^x v}{\left[\sum_j \omega_j^{\frac{\epsilon-1}{\epsilon}x}\right]^{\frac{\epsilon}{\epsilon-1}}}$$

This alternative framework has two differences and one similarity with our benchmark structure that merit comment. First, in this alternative structure not all input qualities are the same. Second, Chinese kettle producers need not import from all countries. Nonetheless, as in our benchmark structure, each firm that chooses to produce high quality products will choose to purchase higher quality (and more costly) inputs. As long as this latter feature remains true — that it is more costly to purchase higher quality inputs — our model's theoretical implications are unchanged.

With respect to our empirical model it remains true that (a) total output quality is a weighted function of input quality and (b) log relative input quality is proportional to input prices. One could, in principle, use this alternative structure in our framework, however, it would at minimum require some knowledge of the elasticity parameters σ and ϵ.

D Identification of u_j

The markup parameter in each destination market is estimated as part of our structural estimation approach. Fundamentally, u_j is 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 (5) and (15). To minimize notation and make things as transparent as possible we set $\lambda = 1$, normalize $\eta_i = 1$, suppress the arguments of θ and the variety index, ω. Substituting optimal prices and quality into the residual demand equation (5) we can write firm sales as

$$Q_{ijt} = r_j \exp\left[\frac{1}{u_j}(\theta q_{ijt} - p_{ijt})\right] = r_j \exp\left[\left(\frac{\theta^{\frac{1}{1-\alpha}}}{u_j}\right)\frac{\alpha^{\frac{\alpha}{1-\alpha}}}{\tau^{\alpha}} - \rho E V_{j1}'\right] \tag{40}$$

and likewise optimal prices are

$$p_{ijt} = \theta^{\frac{1}{1-\alpha}}\left(\frac{\alpha}{\tau^{\alpha}}\right)^{\frac{1}{1-\alpha}} + u_j + \rho E V_{j1}'. \tag{41}$$

Scaling prices (41) by $1/u_j$ we find

$$\frac{p_{ijt}}{u_j} = \frac{\theta^{\frac{1}{1-\alpha}}}{u_j}\left(\frac{\alpha}{\tau^{\alpha}}\right)^{\frac{1}{1-\alpha}} + 1 + \frac{\rho E V_{j1}'}{u_j}. \tag{42}$$

Momentarily ignoring the dynamic pricing incentives in equation (42), 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 θ and, thus, u_j. We can write the simplified input price equation (24) as

$$\ln w_{it} = \frac{1}{1-\alpha}\ln(\alpha) + \frac{1}{1-\alpha}\ln\theta - \frac{1}{1-\alpha}\ln\tau \tag{43}$$

Because equation (43) provides separate identification of θ, equations (41) and (5) 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.

E Additional Estimates: Model (6) without Quality Upgrading

In this section we reconsider Models (6) but eliminate quality upgrading. Specifically, we fix product quality at the mean level in the data and re-estimate all of the other model parameters. This exercise is used to quantify the contribution of product quality upgrading to export growth in Section 6.5 of the main text. Tables E1 and E2 report both the estimated coefficients from the model without quality upgrading and that from the comparable model with quality upgrading.

Table E1: Parameter Estimates, Model (6)

	Quality Upgrading		No Quality Upgrading	
	Mean	Std. Dev	Mean	Std. Dev
Parameter	(1)	(2)	(3)	(4)
θ_0	0.907	(0.014)	0.369	(0.024)
θ_1	2.276	(0.019)	1.206	(0.021)
θ_2	0.028	(0.075)	0.033	(0.076)
α	0.078	(0.013)	—	—
γ_τ	0.181	(0.019)	0.086	(0.030)
ς	0.208	(0.025)	0.286	(0.044)
ρ^λ	0.880	(0.032)	0.897	(0.088)

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, α, the trade cost parameter, γ_τ, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

Table E2: Parameter Estimates, Model (6)

	Size, N_j		Demand, r_j		Markup, u_j		Fixed Costs, $\bar{f}_j$	
	Quality Up.	No Quality	Quality Up.	No Quality	Quality Up.	No Quality	Quality Up.	No Quality
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA/CA	11.540	19.571	16.138	21.675	1.222	1.073	10.999	13.718
	(0.682)	(0.410)	(0.286)	(0.340)	(0.023)	(0.039)	(0.061)	(0.088)
JAP/KOR	10.936	13.989	19.125	16.065	1.021	1.265	8.573	12.997
	(0.408)	(0.726)	(0.530)	(0.879)	(0.014)	(0.053)	(0.062)	(0.087)
EU	27.254	39.575	39.449	51.549	1.247	1.199	24.001	29.993
	(0.613)	(0.541)	(0.682)	(1.504)	(0.012)	(0.028)	(0.060)	(0.087)
AUS/NZ	4.729	5.409	8.125	9.033	1.298	1.314	4.699	5.770
	(0.068)	(0.031)	(0.111)	(0.420)	(0.011)	(0.057)	(0.060)	(0.086)
SA/MEX	10.954	12.031	10.332	10.575	0.800	0.676	4.650	3.287
	(0.322)	(0.459)	(0.134)	(0.322)	(0.011)	(0.058)	(0.061)	(0.087)
AFR	7.226	1.056	9.902	2.170	1.056	1.147	6.000	10.904
	(0.206)	(0.048)	(0.216)	(0.038)	(0.021)	(0.033)	(0.061)	(0.083)
ASIA	6.619	11.619	9.176	14.915	1.106	1.305	4.730	8.388
	(0.131)	(0.047)	(0.194)	(0.331)	(0.011)	(0.032)	(0.062)	(0.087)

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.

There are a number of important differences in the estimated coefficients. In particular, we observe a much smaller coeffient on θ_1, which is indicative of slower demand growth over time and smaller complementarity between past sales and firm product quality. This in turn places greater emphasis on other forms of heterogeneity such as productivity (which is more persistent) and the initial stock of demand.

There are also a number of notable differences in the country specific parameters. In particular, the size and demand coefficients are notably larger than those from the full model. This parameters are adjusting to capture differences in the size of demand constant, θ_0, is smaller in the model variant without quality upgrading. As the size and demand parameters increase for all firms, the average fixed cost draw must also increase to match the empirical rates of entry and exit in export markets.

F Robustness: Price, Quantity and Revenue Dynamics

The section reports the results from the estimation of equation (36) with the addition of product-market-year/market-year fixed effects (in place of market fixed effects). With many more fixed effects, it is not surprising that numerous standard errors are somewhat larger than those reported in Table 17, especially for our small sample of electric kettle exporters. Despite the additional fixed effects, similar empirical patterns present themselves even after controlling for product-market-year fixed effects. As such, we conclude that there is significant evidence of increasing prices in our sample of Chinese export data.

Table F1: Dynamics of export revenue, export quantities and export prices

Obs. level	Firm-Product-Year					
Sample	All Industries			Electric Kettles		
Dep. var. (ln)	Revenue (1)	Quantity (2)	Price (3)	Revenue (4)	Quantity (5)	Price (6)
Spell length	Spell Intercept					
2 years	0.38 (0.00)***	0.27 (0.00)***	0.11 (0.00)***	0.70 (0.40)*	0.50 (0.06)***	0.32 (0.09)***
3 years	0.96 (0.00)***	0.82 (0.08)***	0.14 (0.00)***	1.67 (0.41)***	0.83 (0.08)***	0.39 (0.09)***
4 years	1.32 (0.00)***	1.23 (0.08)***	0.09 (0.00)***	2.11 (0.41)***	0.83 (0.13)***	0.39 (0.09)***
5 years	1.75 (0.00)***	1.61 (0.01)***	0.15 (0.00)***	2.17 (0.20)***	1.06 (0.16)***	0.45 (0.09)***
6+ years	2.08 (0.01)***	1.89 (0.01)***	0.19 (0.01)***	1.83 (0.57)***	1.17 (0.37)***	0.41 (0.10)***
cens	2.41 (0.01)***	2.24 (0.01)***	0.27 (0.01)***	2.65 (0.44)**	1.24 (0.21)**	0.49 (0.09)**
Mkt tenure	2-year spell					
2 years	0.03 (0.01)***	-0.00 (0.01)	0.03 (0.00)***	-0.06 (0.11)	-0.19 (0.13)	0.05 (0.04)
Mkt tenure	3-year spell					
2 years	0.25 (0.02)***	0.27 (0.02)***	0.02 (0.00)**	0.31 (0.26)	0.28 (0.29)	0.06 (0.05)
3 years	-0.11 (0.17)***	-0.70 (0.01)***	0.04 (0.01)***	0.94 (0.17)***	0.91 (0.19)***	0.11 (0.05)**
Mkt tenure	4-year spell					
2 years	0.28 (0.02)***	0.30 (0.02)***	0.02 (0.01)**	0.02 (0.60)	-0.12 (0.64)	0.06 (0.07)
3 years	0.32 (0.03)***	0.35 (0.03)***	0.03 (0.01)***	1.16 (0.44)**	0.87 (0.37)**	0.07 (0.07)
4 years	-0.16 (0.03)***	-0.12 (0.04)***	0.04 (0.01)***	0.64 (0.31)**	0.59 (0.33)**	0.16 (0.07)
Mkt tenure	5-year spell					
2 years	0.32 (0.07)***	0.30 (0.07)***	0.01 (0.00)***	1.55 (0.16)***	1.52 (0.16)***	0.21 (0.09)**
3 years	0.79 (0.06)***	0.77 (0.06)***	0.03 (0.00)***	1.87 (0.25)***	1.92 (0.26)***	0.22 (0.09)**
4 years	0.88 (0.05)***	0.88 (0.05)***	0.06 (0.00)***	2.23 (0.34)***	2.31 (0.36)***	0.31 (0.09)***
5 years	0.61 (0.04)***	0.61 (0.04)***	0.12 (0.00)***	2.58 (0.44)***	2.74 (0.46)***	0.33 (0.09)***
Mkt tenure	6+ years spell					
2 years	0.26 (0.14)*	0.68 (0.06)***	0.01 (0.01)	0.78 (0.98)	0.77 (0.98)	0.18 (0.08)**
3 years	0.87 (0.13)***	0.85 (0.08)***	0.02 (0.01)***	1.55 (0.82)*	1.26 (0.62)**	0.25 (0.14)**
4 years	1.03 (0.11)***	0.76 (0.10)***	0.04 (0.01)***	1.34 (0.64)**	1.30 (0.64)**	0.31 (0.08)***
5 years	0.93 (0.10)***	0.45 (0.12)***	0.07 (0.01)***	1.58 (0.48)***	1.51 (0.48)***	0.33 (0.08)***
6+ years	0.61 (0.07)***	-0.14 (0.14)	0.12 (0.01)***	0.72 (0.32)**	0.64 (0.32)**	0.25 (0.14)*
	Fixed effects					
Firm-product-year	Yes	Yes	Yes	Yes	Yes	Yes
Market-product-year	Yes	Yes	Yes	No	No	No
Market-year	No	No	No	Yes	Yes	Yes
N	1396461	1396461	1396461	312952	312952	312952
rsq	0.60	0.72	0.93	0.75	0.83	0.96
rsq-adj	0.50	0.65	0.91	0.33	0.46	0.61

Notes: A full set of firm-product-year and market effects are included in the firm-product-market-year regressions. The omitted category is spells that last one year. Robust standard errors calculated. *** significant at 1%, ** significant at 5%, * significant at 10%. The sample includes non-importing exporters.

G Robustness: Stylized 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:

$$\overline{\ln(import\ price_{ft})} = \alpha + \beta \ln(Q_{f,t-1}) + \Gamma_f + \Gamma_t + \epsilon_{ft}$$

where Γ_f and Γ_t are firm and year fixed effects, respectively, and ϵ_{ft} 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 G1.

Table G1: Correlation Between Current Import Prices and Past Aggregate Export Sales

	Electric Kettle Exporters			
	All (1)	Single-Destination^a (2)	Single-Product (3)	Single-Destination Single-Product (4)
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.

H Robustness: First-Year Effects

A particular concern with stylized facts (1)-(3) is that first-year sales might be artificially low if the firm does not export for a full calendar year.[52] To address this concern, we have reconsidered our specification in Section 2, but dummy out the first-year variation to determine if it is driving our results. Specifically, recall that our benchmark 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 (equations (1)-(2) in the main text). To incorporate the first-year controls we re-estimate the same equations with the addition of a first-year dummy variable which accounts for a firm's first-year entry into a particular destination market:

$$\ln(x_{fjkt}) = \alpha + \beta \ln(Q_{fjk,t-1}) + \varrho_{fjk,t-1} + \Gamma_{fkt} + \Gamma_{jkt} + \epsilon_{fjkt}$$

where ϱ_{fjkt} is a variable which takes a value of 1 if firm f enters market j with product k in year t. Repeating our benchmark regressions with this new structure we find that the estimated coefficients on past sales are slightly smaller, but very close to those in the previous manuscript. We reproduce the results from these regressions in Tables H1-H3 below.

[52] Regardless of age in a given market, electric kettles exporters typically export once per year.

Table H1: Correlation Between Current and Past Physical Exports

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
Past Market Sales	0.640***	0.185***	0.580***	0.308***
	[0.009]	[0.056]	[0.002]	[0.003]
First-Year Dummy	-1.214***	-0.851***	-0.124***	-0.117***
	[0.111]	[0.110]	[0.013]	[0.013]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Year/Firm-Product-Year 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, clustered at the firm-level, 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-year fixed effects, while the others do not. *** p<0.01, ** p<0.05, * p<0.1.

Table H2: Correlation Between Current Market Prices and Past Physical Exports

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
Past Market Sales	0.147***	0.057***	0.279***	0.040***
	[0.011]	[0.012]	[0.002]	[0.002]
First-Year Dummy	-0.160	-0.107***	0.021*	-0.012*
	[0.225]	[0.020]	[0.012]	[0.008]
Destination-Product-Year Fixed Effects	Yes	Yes	Yes	Yes
Firm-Year/Firm-Product-Year 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, clustered at the firm-level, 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-year fixed effects, while the others do not. *** p<0.01, ** p<0.05, * p<0.1.

Table H3: Correlation Between Current Import Prices and (Aggregate) Past Physical Sales

	Electric Kettles		All Exporters	
	(1)	(2)	(3)	(4)
Past Export Sales	-0.023*	0.036**	-0.130***	0.068**
	[0.013]	[0.018]	[0.021]	[0.029]
First-Year Dummy	-0.109	-0.251***	-0.410	-0.483*
	[0.099]	[0.095]	[0.320]	[0.211]
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 physical sales across all export markets on the average firm-level import price in the current year. Robust standard-errors, clustered at the firm-level, 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.

In the import price regression (Table 25), the first-year dummy variable accounts for entry into *any* export market, rather than a specific export destination, since this is a firm-level regression. Comparing these results with those from the main text, we find that the coefficients on past sales are very close to those reported in Section 2.

For completeness, we also investigate how this concern might affect our findings from the structural model. In particular, we re-estimate our preferred quantitative model (Model 6), but add a first-year dummy in the parametric demand equation:

Table H4: Parameter Estimates, Model (6) with a first-year dummy

	No First Year-Dummy		First-Year Dummy	
	Mean	Std. Dev	Mean	Std. Dev
Parameter	(1)	(2)	(3)	(4)
θ_0	0.907	(0.014)	0.850	(0.026)
θ_1	2.276	(0.019)	2.224	(0.060)
θ_2	0.028	(0.075)	0.014	(0.076)
θ_3	—	—	-0.124	(0.119)
α	0.078	(0.013)	0.083	(0.003)
γ_τ	0.181	(0.019)	0.195	(0.017)
ς	0.208	(0.025)	0.324	(0.036)
ρ^λ	0.880	(0.032)	0.901	(0.032)

Notes: The above table reports the means and standard deviations of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2, \theta_3)$, quality transformation process, α, the trade cost parameter, γ_τ, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

$$\theta(M_{ij,t-1}, \bar{I}_j) \quad = \quad \theta_0 + \theta_1 K_{ijt} + \theta_2 \ln \bar{I}_j + \theta_3 D_{ijt}$$

where D_{ijt} is again a first-year entry dummy variable and K_{ijt} is again

$$K_{ijt} = (1-\varsigma)\ln(1+M_{ij,t-1}) + \varsigma K_{ijt-1} = (1-\varsigma)\ln\left(1+\frac{Q_{ij,t-1}}{N_j}\right) + \varsigma K_{ijt-1}.$$

As reported in Tables H4 and H5, this exercise results in a smaller coefficient on past sales (θ_1 in the above equation), but one that remains positive and precisely estimated.

Table H5: Parameter Estimates, Model (6) with a first-year dummy

	Size, N_j		Demand, r_j		Markup, u_j		Fixed Costs, $\bar{f}_j$	
	No 1^{st} Yr Dummy	1^{st} Yr Dummy	No 1^{st} Yr Dummy	1^{st} Yr Dummy	No 1^{st} Yr Dummy	1^{st} Yr Dummy	No 1^{st} Yr Dummy	1^{st} Yr Dummy
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA/CA	11.540	11.236	16.138	16.271	1.222	1.177	10.999	12.002
	(0.682)	(0.582)	(0.286)	(0.387)	(0.023)	(0.111)	(0.061)	(0.059)
JAP/KOR	10.936	11.734	19.125	19.281	1.021	0.969	8.573	8.575
	(0.408)	(0.336)	(0.530)	(0.458)	(0.014)	(0.135)	(0.062)	(0.058)
EU	27.254	26.470	39.449	43.041	1.247	1.050	24.001	24.082
	(0.613)	(0.108)	(0.682)	(0.888)	(0.012)	(0.189)	(0.060)	(0.059)
AUS/NZ	4.729	4.110	8.125	7.938	1.298	1.355	4.699	4.700
	(0.068)	(0.239)	(0.111)	(0.402)	(0.011)	(0.121)	(0.060)	(0.058)
SA/MEX	10.954	10.627	10.332	9.680	0.800	0.684	4.650	4.653
	(0.322)	(0.220)	(0.134)	(0.166)	(0.011)	(0.064)	(0.061)	(0.060)
AFR	7.226	6.837	9.902	8.451	1.056	0.980	6.000	5.732
	(0.206)	(0.255)	(0.216)	(0.234)	(0.021)	(0.122)	(0.061)	(0.077)
ASIA	6.619	7.177	9.176	10.005	1.106	1.082	4.730	4.983
	(0.131)	(0.191)	(0.194)	(0.201)	(0.011)	(0.120)	(0.062)	(0.058)

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.

I Robustness: Quality-Upgrading and Firm-Destination Age

In this section we reconsider the regressions documented in Table 4 of the main text. However, we replace past market sales with firm-destination 'age.' In columns (1) and (2) of the subsequent table 'age' records the number of years a firm has consecutively exported to a given destination market, while in columns (3) and (4) 'age' represents the total number of consecutive years a firm has exported. The results are reported in the table below.

Table I1: Correlation Between Kettle Quality and Firm-Destination Age

	Export Characteristics		Import Characteristics	
Dependent Variable	D^{inst}_{fjt}	D^{pump}_{fjt}	D^{steel}_{fjt}	$D^{plastic}_{fjt}$
Age	0.0299***	0.0004***	0.0005***	-0.0664
	[0.0060]	[0.0001]	[0.0001]	[0.0450]
Destination-Year Fixed Effects	Yes	Yes	No	No
Year Fixed Effects	No	No	Yes	Yes
Firm-Year Fixed Effects	Yes	Yes	No	No
Firm Fixed Effects	No	No	Yes	Yes
Firm-Destination Fixed Effects	Yes	Yes	No	No
Obs.	2249		1375	

Notes: The above table reports the estimated coefficients from an OLS regression of firm-destination 'age' in a given export market on obserable dimensions of electric kettle quality. The binary variable D^{inst}_{fjt} takes a value of 1 if firm f exports a kettle that heats water rapidly to destination j in year t and 0 otherwise; D^{pump}_{fjt} takes a value of 1 if firm f exports a kettle with a pump to destination j in year t and 0 otherwise; D^{steel}_{ft} takes a value of 1 if firm f imports steel casings in year t and 0 otherwise; $D^{plastic}_{ft}$ takes a value of 1 if firm f imports plastic casings in year t and 0 otherwise. Robust standard-errors, clustered at the firm-level, are in brackets. Columns 1 and 2 include destination-year, firm-year and firm-destination fixed effects, while columns 3 and 4 include firm and year fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

Similar to regression exercises reported in Table 4 of the main text, we find that increasing firm-destination age is positively correlated with quality improvement and negatively correlated with quality-downgrading. Moreover, in all but the last case, the estimated point estimates are statistically significant at standard levels of statistical confidence.

J Robustness: Destination Income Growth

In this section we reconsider our preferred model, Model (6), with an additional complexity. In particular, in our benchmark model destination market income was assumed to be constant over time in our empirical application. The reader may be concerned that some degree of export quantity and price growth is driven by destination markets where income, and hence demand, is growing over time. To determine what impact income growth may have had on our main results, we re-estimate our preferred model, Model (6), but assume that the demand accumulation equation takes the following form:[53]

$$\theta(M_{ij,t-1}, \bar{I}_j) \quad = \quad \theta_0 + \theta_1 K_{ijt} + \theta_2 \ln \bar{I}_j + \theta_3 \Delta \ln \bar{I}_j$$

where $\Delta \ln \bar{I}_j$ is the average annual growth rate in each destination over the sample period and K_{ijt} is again

$$K_{ijt} = (1-\varsigma)\ln(1+M_{ij,t-1}) + \varsigma K_{ijt-1} = (1-\varsigma)\ln\left(1+\frac{Q_{ij,t-1}}{N_j}\right) + \varsigma K_{ijt-1}.$$

[53] All prior distributions are identical to those in our benchmark estimation of Model (6). The prior distribution for θ_3 is $U[-20, 20]$, though we have experimented with other prior distribution assumptions and find nearly identical results.

Tables J1 and J2 report the means and standard deviations of the posterior distribution for the model parameters estimated under income growth assumption. Benchmark Model (6) 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 a few exceptions. First, as we add an additional component to demand, income growth, each firm has higher demand than before through the $\theta(\cdot)$ process. Due to greater demand in the $\theta(\cdot)$ process, we find that the estimates for size (N_j), income (r_j) and static markups (u_j) are slightly lower than those reported in the main text. Second, markups are slightly higher than the benchmark case. Nonetheless, the model with income growth generally performs very similarly to those reported in the main text.

Table J1: Parameter Estimates, Model (6) with Income Growth

	Model (6)		Income Growth Model	
Parameter	Mean	Std. Dev	Mean	Std. Dev
	(1)	(2)	(3)	(4)
θ_0	0.907	(0.014)	0.784	(0.066)
θ_1	2.276	(0.019)	2.010	(0.075)
θ_2	0.028	(0.075)	0.127	(0.063)
θ_3	—	—	-0.894	(0.056)
α	0.078	(0.013)	0.054	(0.005)
γ_τ	0.181	(0.019)	0.201	(0.095)
ς	0.208	(0.025)	0.641	(0.059)
ρ^λ	0.880	(0.032)	0.877	(0.088)

Notes: The above table reports the means and standard deviations of the posterior distribution for the parameters from the spillover process, $(\theta_0, \theta_1, \theta_2, \theta_3)$, quality transformation process, α, the trade cost parameter, γ_τ, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

Table J2: Parameter Estimates, Model (6) with Income Growth

	Size, N_j		Demand, r_j		Markup, u_j		Fixed Costs, $\bar{f}_j$	
	Model (6)	Inc. Growth	Model (6)	Inc. Growth	Model (6)	Inc. Growth	Model (6)	Inc. Growth
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA/CA	11.540	11.843	16.138	17.130	1.222	1.114	10.999	11.200
	(0.682)	(0.709)	(0.286)	(0.572)	(0.023)	(0.102)	(0.061)	(0.060)
JAP/KOR	10.936	10.039	19.125	18.312	1.021	0.928	8.573	8.675
	(0.408)	(0.417)	(0.530)	(0.547)	(0.014)	(0.129)	(0.062)	(0.059)
EU	27.254	21.360	39.449	35.002	1.247	0.992	24.001	25.001
	(0.613)	(0.692)	(0.682)	(0.593)	(0.012)	(0.171)	(0.060)	(0.059)
AUS/NZ	4.729	4.110	8.125	7.462	1.298	1.337	4.699	4.802
	(0.068)	(0.172)	(0.111)	(0.272)	(0.011)	(0.149)	(0.060)	(0.059)
SA/MEX	10.954	10.026	10.332	9.706	0.800	0.668	4.650	4.750
	(0.322)	(0.316)	(0.134)	(0.133)	(0.011)	(0.076)	(0.061)	(0.058)
AFR	7.226	6.382	9.902	8.233	1.056	0.976	6.000	4.830
	(0.206)	(0.264)	(0.216)	(0.193)	(0.021)	(0.147)	(0.061)	(0.060)
ASIA	6.619	7.951	9.176	8.774	1.106	1.133	4.730	5.201
	(0.131)	(0.180)	(0.194)	(0.118)	(0.011)	(0.131)	(0.062)	(0.059)

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.

K Robustness: Import Prices Over Time

In this section we reconsider Model (6) with one significant change. Specifically, we measure the current log import price as the average log import price over the past two years. In this fashion, if firms begin upgrading products prior to exporting we are at least allowing for some weight to be placed on past import prices. Tables K1 and K2 report the means and standard deviations of the posterior distribution for the model parameters estimated under the alternative import price measurement. For sake of brevity we again only report the results for benchmark model (Model (6)) under both our initial assumption and the alternative. 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.

Table K1: Parameter Estimates

	Model (6)		Alt. Imp. Price Measure	
Parameter	Mean	Std. Dev	Mean	Std. Dev
	(1)	(2)	(3)	(4)
θ_0	0.911	(0.006)	0.826	(0.095)
θ_1	1.987	(0.009)	2.363	(0.056)
θ_2	0.022	(0.002)	0.022	(0.058)
α	0.051	(0.001)	0.063	(0.004)
γ_τ	0.198	(0.053)	0.106	(0.069)
ς	0.208	(0.025)	0.343	(0.032)
ρ^λ	0.880	(0.032)	0.869	(0.087)

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, α, the trade cost parameter, γ_τ, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

Table K2: Parameter Estimates

	Size, N_j		Demand, r_j		Markup, u_j		Fixed Costs, $\bar{f}_j$	
	Model (6)	Alt. Imp.	Model (6)	Alt. Imp.	Model (6)	Alt. Imp.	Model (6)	Alt. Imp.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
USA/CA	11.540	11.863	16.138	17.338	1.222	1.118	10.999	11.099
	(0.682)	(0.611)	(0.286)	(0.471)	(0.023)	(0.104)	(0.061)	(0.061)
JAP/KOR	10.936	10.605	19.125	18.378	1.021	0.941	8.573	8.574
	(0.408)	(0.312)	(0.530)	(0.327)	(0.014)	(0.139)	(0.062)	(0.059)
EU	27.254	26.362	39.449	41.583	1.247	1.102	24.001	24.000
	(0.613)	(0.826)	(0.682)	(0.123)	(0.012)	(0.202)	(0.060)	(0.059)
AUS/NZ	4.729	4.383	8.125	7.718	1.298	1.342	4.699	4.670
	(0.068)	(0.176)	(0.111)	(0.215)	(0.011)	(0.146)	(0.060)	(0.060)
SA/MEX	10.954	10.727	10.332	10.172	0.800	0.939	4.650	4.551
	(0.322)	(0.451)	(0.134)	(0.210)	(0.011)	(0.074)	(0.061)	(0.058)
AFR	7.226	6.312	9.902	8.127	1.056	0.987	6.000	5.737
	(0.206)	(0.244)	(0.216)	(0.199)	(0.021)	(0.154)	(0.061)	(0.060)
ASIA	6.619	6.251	9.176	9.440	1.106	1.115	4.730	4.741
	(0.131)	(0.224)	(0.194)	(0.182)	(0.011)	(0.153)	(0.062)	(0.060)

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.

L Robustness: Prior Distributions

We choose very diffuse prior distributions for all parameters estimated by Bayesian Markov Chain Monte Carlo. Our benchmark assumptions are collected in column 1 of Table L1.

Table L1: Prior Distributions

		Assumption		
		Benchmark	Alternative 1	Alternative 2
Variable	Description	(1)	(2)	(3)
$\ln(N_j)$	Market Size	$\ln(N_j) \sim N(0, 10)$	$\ln(N_j) \sim N(0, 20)$	$\ln(N_j) \sim U[-200, 200]$
$\ln(r_j)$	Market Demand	$\ln(r_j) \sim N(0, 10)$	$\ln(r_j) \sim N(0, 20)$	$\ln(r_j) \sim U[-200, 200]$
$\ln(u_j)$	Markup/Competitiveness	$\ln(u_j) \sim N(0, 2)$	$\ln(u_j) \sim N(0, 4)$	$\ln(u_j) \sim U[-20, 20]$
$\bar{f}_j$	Fixed Export Cost	$\bar{f}_j \sim EXP(10)$	$\bar{f}_j \sim EXP(20)$	$\bar{f}_j \sim U[-200, 200]$
$\ln(\gamma_\tau)$	Transportation Cost Parameter	$\ln(\gamma_\tau) \sim N(0, 10)$	$\ln(\gamma_\tau) \sim N(0, 20)$	$\ln(\gamma_\tau) \sim U[-200, 200]$
α	Quality Transformation Parameter	$\alpha \sim U[0, 1]$	$\alpha \sim U[0, 2]$	$\alpha \sim U[0, 1]$
ρ^λ	Productivity Persistence	$\rho^\lambda \sim U[0, 1]$	$\rho^\lambda \sim U[0, 2]$	$\rho^\lambda \sim U[0, 1]$
ς	Demand stock weight	$\varsigma \sim U[0, 1]$	$\varsigma \sim U[0, 2]$	$\varsigma \sim U[0, 1]$
θ_0	Taste for Quality Constant	$\theta_0 \sim U[-20, 20]$	$\theta_0 \sim U[-40, 40]$	$\theta_0 \sim U[-20, 20]$
θ_1	Taste for Quality Loyalty Parameter	$\theta_1 \sim U[-20, 20]$	$\theta_1 \sim U[-40, 40]$	$\theta_1 \sim U[-20, 20]$
θ_2	Taste for Quality Income Parameter	$\theta_2 \sim U[-20, 20]$	$\theta_2 \sim U[-40, 40]$	$\theta_2 \sim U[-20, 20]$
$\ln(\lambda)$	Firm Productivity	$\ln(\lambda) \sim N(0, 4)$	$\ln(\lambda) \sim N(0, 8)$	$\ln(\lambda) \sim U(-50, 50)$

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 next three rows correspond to the quality transformation parameter, the productivity persistence parameter parameter, and the demand stock weight parameter, respectively. Note that in any case these parameters are assumed to lie between 0 and 1, which is consistent with our theory. Productivity persistence and the demand stock weight are similarly expected to lie between 0 and 1 given the nature of these parameters. The parameters which govern demand accumulation are reported in rows nine, ten and eleven, 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.

To check the robustness of our findings with respect to our assumptions on the prior distributions, we consider the effect to alternative sets of assumptions. The alternative assumptions are presented in second and third columns of Table L1. Our first robustness check considers the impact of choosing even more diffuse priors. Our second robustness check uses a flat prior wherever possible. Tables L2 and L3 report the estimated coefficients for Model (6) under our benchmark estimate and the two alternatives. In each case, we observe parameters which are very close to those in the benchmark setting. As such, we refer the reader to the main text for a discussion of individual parameters.

Table L2: Parameter Estimates Across Different Prior Distribution Assumptions

	Model (6)		
	Bench.	Alt. 1	Alt. 2
Assumption	(1)	(2)	(3)
θ_0	0.907	0.940	0.939
	(0.014)	(0.017)	(0.008)
θ_1	2.267	2.469	2.495
	(0.019)	(0.015)	(0.054)
θ_2	0.028	0.010	0.021
	(0.075)	(0.103)	(0.101)
α	0.078	0.093	0.092
	(0.013)	(0.024)	(0.022)
γ_τ	0.181	0.185	0.186
	(0.019)	(0.029)	(0.030)
ς	0.208	0.243	0.245
	(0.025)	(0.004)	(0.005)
ρ^λ	0.880	0.896	0.897
	(0.032)	(0.174)	(0.173)

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, α, the trade cost parameter, γ_τ, the weight on the stock of demand, ς, and persistence of productivity, ρ^λ.

Table L3: Country-Specific Parameter Estimates Across Different Prior Distribution Assumptions (Model 6)

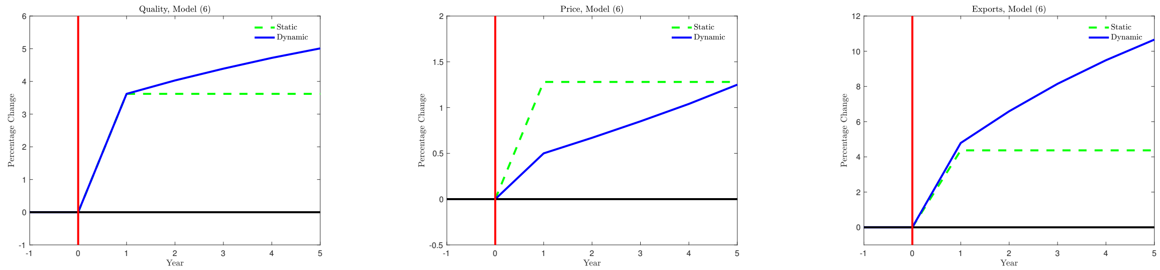
	Size, N_j			Demand, r_j			Markup, u_j			Fixed Costs, $\bar{f}_j$		
Assumption	Bench.	Alt. 1	Alt. 2	Bench.	Alt. 1	Alt. 2	Bench.	Alt. 1	Alt. 2	Bench.	Alt. 1	Alt. 2
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
USA/CAN	11.540	10.654	10.401	16.138	15.389	15.311	1.222	1.309	1.306	10.999	10.998	10.998
	(0.682)	(0.656)	(0.471)	(0.286)	(0.343)	(0.330)	(0.023)	(0.035)	(0.035)	(0.061)	(0.087)	(0.087)
JAP/KOR	10.936	10.091	10.730	19.125	18.749	18.809	1.021	1.016	1.012	8.573	8.752	8.742
	(0.408)	(0.733)	(0.712)	(0.530)	(0.786)	(0.805)	(0.014)	(0.027)	(0.028)	(0.062)	(0.086)	(0.086)
EU	27.254	25.196	26.116	39.449	37.403	37.496	1.247	1.358	1.276	24.001	24.312	24.254
	(0.107)	(0.640)	(0.650)	(0.682)	(0.704)	(0.492)	(0.012)	(0.052)	(0.035)	(0.060)	(0.086)	(0.087)
AUS/NZ	4.729	4.771	4.875	8.125	8.745	8.936	1.298	1.393	1.382	4.699	4.670	4.669
	(0.068)	(0.387)	(0.360)	(0.111)	(0.514)	(0.381)	(0.011)	(0.077)	(0.052)	(0.060)	(0.086)	(0.086)
SA/MEX	10.954	10.741	10.688	10.332	9.843	9.827	0.800	0.917	1.059	4.650	4.695	4.649
	(0.322)	(0.412)	(0.436)	(0.134)	(0.158)	(0.166)	(0.011)	(0.074)	(0.038)	(0.061)	(0.086)	(0.086)
AFR	7.226	7.250	7.319	9.902	8.196	8.791	1.056	1.186	1.045	6.000	6.030	6.003
	(0.206)	(0.411)	(0.412)	(0.216)	(0.329)	(0.298)	(0.021)	(0.108)	(0.074)	(0.061)	(0.085)	(0.085)
ASIA	6.619	6.742	6.697	9.176	10.223	10.314	1.106	1.227	1.208	4.730	4.719	4.729
	(0.131)	(0.264)	(0.131)	(0.194)	(0.391)	(0.383)	(0.011)	(0.048)	(0.032)	(0.062)	(0.087)	(0.087)

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.

M Trade Liberalization: Individual Firm Dynamics

This section characterizes the average firm's response to trade liberalization in the average export market. Focussing on preferred empirical model, Model (6), 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 its behavior over time.

Figure M1: Impact of Trade Liberalization on Firm Dynamics



(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 line captures the firm product quality, pricing and sales under the estimated parameters for Model (6). 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.

Figure M1 plots the dynamic path of export product quality, prices and sales over time. In panel (a) we present findings for product quality, while panels (b) and (c) similarly document counterfactual findings for export prices and export sales. In each panel the solid blue documents in the impact of trade liberalization on the fully dynamic firm. The green dotted line, in contrast, represents the changes implied in a fully static model where there are no intertemporal demand spillovers.

Trade liberalization is announced at the end of year 0 after which we observe a sharp, immediate jump followed by a slow rise in all three variables. We find that trade liberalization increases the average firm's sales by 4.8 percent immediately, while product quality simultaneously rises by 3.6 percent. Prices increases by a much more moderate 0.5 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 1.3 percent higher than the pre-liberalization price across models. Likewise, product quality grows by a further 1.4 percent after the first year, for a total 5 percent increase. Jointly these imply that trade liberalization will increase the sales of the typical exporter by nearly 11 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 its largest effects on young exporters. We focus on established exporters to isolate the effect trade liberalization itself from the firm's internal dynamics.

Examining the static firm's decisions allows us to decompose the changes in product quality, prices and sales into various components. In particular, the distance between the green dotted line in each figure and the solid blue represents the total contribution of the model's internal dynamics to overall change in each export outcome. By construction, the myopic producer makes the same quality decision in the first year after trade liberalization. However, after 5 years, the intertemporal spillover accounts for 28 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 61 percent and increase sales by nearly 10 percent upon trade liberalization. After 5 years, prices remain 2 percent lower and sales are 59 percent higher than that anticipated by a fully static producer.

N Initial Conditions

As noted in the main text, demand process (30) creates a potentially severe initial conditions problem. We address this by modelling the initial and continuing demand stock in the following manner. First, we assume that the initial demand stock in period 1 is given by $K_{ij1} = (1 - \varsigma)\ln(1 + M_{ij0}) + \varsigma K_{ij0}$, where K_{ij0} is the firm's initial stock of demand in destination j. Thereafter, $K_{ijt} = (1 - \varsigma)\ln(1 + M_{ijt-1}) + \varsigma K_{ijt-1}$. In each iteration and for each firm, K_{ij0} is drawn from a log-normal distribution, $N(0, 10)$ as a random-starting parameter for each firm. We then update our estimate of K_{ij0} in each run of the Bayesian MCMC algorithm where the log-normal serves as our prior distribution.