Your (Country's) Reputation Precedes You: Information Asymmetry, Externalities and the Quality of Exports*

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November 28, 2018

Abstract

The problems of moral hazard and adverse selection can seriously impede the development of export markets for firms from less developed countries. Importing firms have little recourse in developing country courts should their suppliers provide sub-quality goods, and they face great difficulty in distinguishing good firms from bad ones. My paper is the first to develop and estimate a dynamic structural model that incorporates both features of asymmetric information, namely moral hazard and adverse selection. In the model, the information asymmetry is high for new entrants but then gradually fades as idiosyncratic fixed cost shocks drive inefficient firms from the market. Thus, a firm's tenure in export markets is a signal of its efficiency, and consequently the price that it can obtain rises with tenure. Market-wide shocks to fixed costs, as occur when product safety regulations are imposed, flatten the price-tenure gradient as they disproportionately induce inefficient firms to exit. Using a triple-difference strategy, I show that these predictions hold in firm-level Chinese export data. This variation in the data also allows me to estimate my model and use it for counterfactual analysis. I show that the problem of information asymmetry is severe for Chinese entrants into export markets and that the problem is made worse by government export subsidies. Reducing these subsidies would raise aggregate export profits for Chinese firms.

*I am indebted to Stephen Yeaple and Kala Krishna for their invaluable guidance and support throughout this project, as well as Jonathan Eaton, Jingting Fan, Michael Gechter, Elisa Giannone, Paul Grieco, Daniel Grodzicki, Charles Murry, Peter Newberry, Karl Schurter, James Tybout, Ruilin Zhou for their insightful conversations and comments. I would like to thank many seminar participants at IO Brown Bag and Trade/Development Reading Group at Penn State for comments and suggestions. Finally, I thank the Rosenberg Fellowship and Bates and White fellowship for financial support. All remaining errors are my own.

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1 Introduction

The problems of moral hazard and adverse selection can seriously impede the development of export markets for firms from developing countries. Importing firms have little recourse in developing country courts should their suppliers provide sub-quality goods, and they face great difficulty in distinguishing good firms from bad firms. The consequences to importing firms that source goods from developing countries, such as China, can be high. For instance, according to the US Consumer Product Safety Commission (2014), Chinese firms supplied 23% of consumer products to the US market but account for over 50% of product recalls.

The fact that such bad outcomes are common can be attributed to the inability of efficient Chinese firms that value long-term relationships with foreign buyers to distinguish themselves from inefficient firms that will breach contracts for immediate gain. Prior to China's opening to international trade few Chinese firms had had an opportunity to establish an international reputation and the few options available for signaling individual firm quality, such as buying foreign brand names, were financially out of reach of most Chinese firms.

This paper is the first to develop and to estimate a dynamic structural model of exporter entry into foreign markets that incorporates both moral hazard and adverse selection. My paper is important because the structural model that I develop allows me to measure the magnitude of the information asymmetry in the export market and because the counterfactuals that model allows me to perform are of first order policy significance. Specifically, I find that Chinese export subsidies that are intended to increase export firm revenue and profits have exactly the opposite effect because they exacerbate the underlying problems created by asymmetric information.

In my model, foreign buyers cannot observe the capabilities of new individual Chinese firms that they meet and so are forced to rely on their knowledge of how the capabilities of new Chinese exporters are distributed. Chinese supplier entry into the export market is endogenous. New potential entrants differ in their productivity and in their realization of a market access cost shock. Following Ruhl and Willis (2017) the market access shock is stochastic. This has the implication that some inefficient exporters will receive low market access cost shock and will be induced to enter the market. Every period, exporters draw new market access cost shocks so that over time less efficient firms are induced to exit. Foreign buyers understand the entry and exit process and so they can infer the distribution of efficiencies in every cohort. Hence, a firm's tenure in the export market becomes a signal of its efficiency.

Foreign buyers' profits are increasing in the quality of goods that they can procure and decreasing in the price that they pay for them. When a foreign buyer meets a Chinese supplier, it faces the problem of moral hazard. Because foreign buyers must pay for the goods before observing the goods' quality, and because Chinese firms can cheat with impunity, the higher the quality and the lower the price that they specify in a contract, the more likely it is that the supplier will cheat by delivering worthless goods. Buyers make their quality and price offers to Chinese suppliers knowing that for each quality and price offer there is some cutoff firm efficiency above which the Chinese supplier will deliver the contracted quality because the supplier will value repeated dealings with that buyer and below which firms will breach the contract. When combined with information about a firm's tenure in the export market, this reveals the distribution of firm efficiencies and so informs the buyer's offer to the supplier.

The presence of low quality, inefficient Chinese firms in any given cohort of exporters exerts a negative externality on high-quality, efficient firms. Chinese firms with a potentially bright future are forced to accept low price contracts that are far below their potential. Only over time as inefficient firms are gradually knocked out of the market does it become possible for high-quality firms to distinguish themselves through their longevity.

Finally, in the structural model I also allow foreign buyers to observe a noisy signal of each exporter's efficiency in addition to observing its tenure in the export market. The variance of this signal from around the actual firm efficiency scales the size of the information problem, e.g. when it is zero the problem of adverse selection problem disappears and when it goes to infinity buyers can only make inferences on a supplier's efficiency by its length of time in the market.

The model has two key implications that make it possible to identify the size of the problem of asymmetric information in the market. First, as the distribution of Chinese firm efficiencies that are active in each cohort improves over time, the price that Chinese firms get for their exports rises, and the slope of this relationship is informative about the size of the information problem. Second, an exogenous increase in the market access cost that hits all firms serving a market induces inefficient firms to exit, and this makes the surviving pool of active firms more homogeneous and efficient. Because there is less scope for the distribution of efficiencies to shift over time, the price-tenure slope becomes flatter.

From Chinese customs data, I observe the distribution of prices across firms, products, export markets, and time for the period 2002-2011. Crucially, during the sample period there is a policy shock that affects a subset of products sold in only the European market. This shock, the Restriction of Hazardous Substances Directive 2002/95/Ec (henceforth RoHS), which took effect on July 1st, 2006 in the EU, restricts heavy metals and other harmful substances in electrical and electronic products. This regulation raises the market access cost of Chinese exporters to enter the EU market in the electronics industry.[1]

[1] To comply with the RoHS, exporters in China have to redesign their production lines, restructure their supply lines and substitute with eco-friendly (but more expensive) materials. Also, they must obtain certificates for each

The asymmetric impact of the shock across countries and products allows me to use a triple difference strategy to identify the role played by asymmetric information. I show that prices charged by individual firms rises with tenure in the export market and that the tenure slope of export prices to the EU for goods in the treated industries flattens relative to the same goods sold in the US and Canada and relative to the untreated goods sold in the EU only after the implementation of the RoHS in 2006. According to the triple difference estimates, the price-tenure slope flattens from 0.05 to 0.032 after the implementation of the RoHS in the EU. My empirical strategy controls for industry and market specific shocks and so convincingly demonstrates that the novel predictions of my model are consistent with the behavior of real-world firms.

I estimate the model using a simulated GMM procedure in which the triple difference coefficient estimates are included in the set of moments. The change in the tenure slope helps to identify the size of the externalities, i.e. the variance of the noisy signal of exporters' efficiencies. Given the other model parameters, the price-tenure slope is steeper when the variance of the signal is larger because foreign buyers rely more heavily on the information in tenure to infer exporters' efficiency when offering contracts.

The structural estimates indicate substantial negative externalities on quality provision due to excessive inefficient exporter entry into export markets. To demonstrate the implications of the estimated signal accuracy, I decrease the signal variance by 50% and simulate the counterfactual distributions of price, quality, and quantity provided to export markets. I find that the average price increases by 40% and the average quality by 12%. I also find that although the number of entrants into export markets falls by 2.9% total export revenue increases by 6.3% and total export profits increases by 2.2%.

An important implication of the estimated model is that export promotion policies are counterproductive. In a counterfactual scenario that mimics a reduction in Chinese government export subsidies, I raise the market entry cost of exporters to see how export performance is affected. There are two forces at work in the counterfactual. On the one hand, export sales and profits decrease as fewer exporters enter the market. On the other hand, many exporters can sell at a higher price when the externalities are alleviated by the improvement in the efficiency distribution of entrants. I find that the force that dominates depends on the size of the increase in market access costs. For an increase in market entry costs that reduces the number of entrants by 14 percent, the average export price would rise by 10 percent, aggregate export revenues would rise by 3.1 percent, and aggregate export profits would increase by 3.7 percent. These numbers indicate

batch of orders to prove their compliance. According to ARCADIS and RPA (2008), the initial compliance costs of coming into conformance with the RoHS are much higher than that the firm would incur in subsequent years, once it was already in compliance. See Section 2.1 for more details.

that Chinese export subsidies have severe negative implications.

The idea that the existence of inefficient, low quality firms exerts a negative externality on efficient firms has a long history in the literature on international trade and can be found in the work of Grossman and Horn (1988). More recently, Chisik (2003), and Cagé and Rouzet (2015) explore how firms' choice of export quality is affected by the country-of-origin label. My paper contributes to this literature by building a structural framework that contains the important elements of the literature but that can be brought to the data and used to conduct counterfactual exercises.[2]

My paper is most closely related to a small but growing literature on information asymmetry as a barrier to international trade.[3] Within this literature, the closest antecedents are Bai et al. (2018) and Startz (2018). Bai et al. (2018) also find that the poor performance of some firms creates negative externalities for others. Specifically, they find that the exports of all dairy firms fell after the Chinese dairy scandal of 2008 regardless of whether a firm was implicated in selling contaminated milk. Startz (2018) finds evidence of moral hazard in export markets. She finds that face-to-face transactions help cope with the search and contracting problems in trade. My paper provides a wholistic approach that simultaneously addresses the problems of both moral hazard and adverse selection in a structural framework.

My paper also contributes to a literature on exporter dynamics that focuses on the forces that shape the entry and exit decisions of firms and the growth of exports over time.[4] There are many similarities in the model apparatus, but the fact that this literature has not considered asymmetric information means that the policy implications of this literature are starkly different than those of my estimated model. In the absence of the negative externalities that are present in my paper, export subsidies would always raise exports.[5]

The rest of the paper proceeds as follows: Section 2 describes the empirical strategy and findings. Section 3 presents an exporter dynamic model that accounts for both moral hazard and

[2] There exists an empirical IO literature on information asymmetry on quality between buyer and seller (Jin and Leslie (2009) on hygiene of restaurants; Björkman-Nyqvist et al. (2014) on antimalarial medicine; and Galenianos and Gavazza (2017) and Galenianos et al. (2012) on illicit drugs), but this literature does not allow for negative externalities across firms that are so critical to export performance and that are the focus of my paper.

[3] For example, Jensen (2007); Aker (2010); Allen (2014); Steinwender (2014); Banerjee and Duflo (2000), Macchiavello (2010); Macchiavello and Morjaria (2015); Bardhan et al. (2013); and Chen et al. (2016)

[4] Das et al. (2007) and Impullitti et al. (2013) on hysteresis of export decisions; Fitzgerald et al. (2016), Eaton et al. (2014), Bastos et al. (2017), Berman et al. (2015), Arkolakis et al. (2018), Albornoz et al. (2012) and Rauch and Watson (2003) on exporters learning idiosyncratic demand; Piveteau (2016), Foster et al. (2016) and Drozd and Nosal (2012) on customer accumulation; Rho and Rodrigue (2016) on investment in physical capital and etc.

[5] The standard paper in the export dynamic literature does not feature market failures that justify export subsidies. There is a literature on market failures, such as credit constraints (e.g. Itskhoki and Moll, 2018), where market failures can be used to justify such subsidies. As I do not consider market failures outside buyer-supplier information asymmetries, my model is silent on those issues.

adverse selection, which allows me to quantify the extent of externalities. Then, in Section 4, I discuss the identification of the model and present the estimates. Section 5 explores several counterfactual exercises and potential policy implications. Finally, Section 6 concludes and discusses possible directions for future work.

2 Empirical Evidence

2.1 RoHS in the EU Market

In February 2003, the European Commission passed its RoHS legislation in order to restrict the use of hazardous substances in the Electrical and Electronic Equipment (EEE) industry. The RoHS covers most products pertaining to Chapter 85, as well as some in Chapters 63, 84, 91, and 95 of the Harmonized System ("HS code," hereafter).[6] Examples of products covered by the RoHS include large and small home appliances, electrical and electronic tools (e.g., drills, saws), and so forth. All applicable products in the EU market after July 1, 2006, have been subject to the RoHS and must, therefore, be compliant.[7]

The RoHS restricts the use of hazardous materials such as lead, mercury, and cadmium to low levels, and it encourages producers to use safer alternatives to these substances. To comply with the regulation, exporters incur both (a) one-time fixed costs for finding, testing, and employing safer substitutes for restricted materials, in addition to costs for upgrading, modifying, and replacing existing equipment, and (b) yearly costs attendant to incorporating these more expensive alternative materials, in addition to recurring compliance certification fees.

According to a study on European companies by ARCADIS and RPA (2008), the average one-time compliance cost is 2% of turnover; for small and medium firms, it is 5.2%. However, once firms have finished transitioning production over to RoHS compliance, subsequent yearly costs—such as certifications—are relatively low: roughly 0.04% of turnover (though these costs are also disproportionately higher for small and medium firms.).[8]

The RoHS compliance cost is potentially higher for Chinese exporters since they are usually smaller and have less access to advanced technologies. The increase in production cost is estimated

[6] Appendix B lists HS 6-digit codes that are covered by RoHS. The list is based on ARCADIS and RPA, 2008, Study on RoHS and WEEE Directives N° $30 - CE - 0095296/00 - 09$. This study was funded by the European Commission's Directorate-General (DG) for Internal Market, Industry, Entrepreneurship and SMEs, and was conducted by the consulting firms ARCADIS and RPA.

[7] Source: http://www.rohsguide.com/.

[8] Similar estimates are also found in a study done for the Consumer Electronics Association, U.S., by Technology Forecasters Inc., 2008, "Study of the Economic Impact of the EU RoHS on the Electronics Industry".

from 5% to 20% based on a report by AEDE (Asia Eco-design Electronics, 2007).[9]

RoHS compliance costs are high compared with the profit margin in the EEE industry. For contrast, a study by the ECSIP consortium for DG Enterprise and Industry[10] estimated that the average EEE profit margin[11] ranges from 5.5% to 9.1% for European companies, but from just 2.4% to 6.2% for Chinese companies.

It has been reported that the RoHS has forced small and medium manufacturers out of the EU market, since they cannot afford to meet the stringent requirements it poses (Asia Eco-design Electronics, 2007). A survey of Chinese exporters by Yu et al. (2006) found that 16% of respondents exited the EU market without taking any action to comply with the RoHS. More details about the terms of the RoHS are in Appendix A.

2.2 Empirical Strategy

Identifying information asymmetries in data is difficult. In this paper, I propose a novel identification strategy that exploits a natural experiment. The empirical analysis proceeds in two steps, as follows:

First, I show that exporters with more experience in the export market charge higher prices, import more expensive intermediate inputs, and have a higher survival rate. The positive correlation between prices and tenure is consistent with the idea that more experienced exporters upgrade the quality of their goods.[12] In Appendix D, I show that exporters, when exiting the market, have a lower export price compared with those that continue. This is consistent with the intuition that exporters who produce low-quality goods are more likely to drop out of the market.

Second, to identify the information asymmetries in the data, I exploit the implementation of the RoHS that shifts the efficiency distribution of market entrants and thus, changes the information content in tenure.

The identification strategy is based on the following intuition. Foreign buyers prefer to source high-quality goods from more efficient exporters, who produce high-quality goods at a lower cost. However, foreign buyers have difficulty in distinguishing efficient exporters from inefficient ones. As inefficient firms are gradually driven out of the market by idiosyncratic cost shocks ("market

[9]AEDE (Asia Eco-design Electronics), 2007, Country Report on the Chinese Electronics Sector, Issues and Capacity Building Needs in Relation to International and National Product-related Environmental Regulations and Other Requirements.

[10]ECSIP Consortium for client DG Enterprise and Industry, 2013, Study on the Competitiveness of the Electrical and Electronic Engineering Industry.

[11]profit margin = profit or loss before tax/operating revenue × 100.

[12]Stories in the literature, such as customer accumulation and quality upgrading, can also explain the upward tenure slope of unit price (Piveteau 2016; Bastos and Dias 2013; Rodrigue and Tan 2015)

access cost" in my model), the share of inefficient exporters falls over time for any given cohort. Therefore, tenure implicitly contains information on exporters' efficiency level. As tenure can be easily observed by foreign buyers, foreign buyers optimally source higher quality goods from more experienced exporters. The rate at which they drop out governs the rate at which exporters can upgrade their quality and so receive higher prices for their products.

The RoHS increases entry costs by requiring producers to substitute for intermediate input with hazardous substances using safer alternatives. Higher entry costs (such as those imposed by the RoHS) exclude inefficient exporters, who are less likely to be able to afford them, and thus the pool of entrants becomes more efficient and homogeneous. Thus, tenure contains less information about quality than it did before. As a result, the price-tenure slope flattens.

Take an extreme case as an example: if no information asymmetry exists and tenure itself contains no information, then a change in the efficiency composition would not affect the price-tenure slope.

The data pattern of primary interest for my analysis of this policy effect is the change in the price-tenure slope: before versus after the RoHS. I first use a difference-in-difference (DID) approach to identify the impact of RoHS on the price-tenure slope. This study focuses on the period 2002-2011—after China entered the WTO. This period is then split into two: 2002-2006 is defined as the *pre*-RoHS period, while 2007-2011 is the *post*-RoHS period. The treatment group is Chinese exports of electrical and electronic equipment to the EU market—such products were directly affected by the RoHS ("RoHS products" hereafter). The control group, meanwhile, is the Chinese exports of RoHS products to North America (i.e., the U.S. and Canada, referred to hereafter as "NA"), where no such regulation was passed during the data period 2002-2011. Since the EU and NA markets are comparable in many aspects, and are highly correlated in terms of aggregate shocks (Kose et al., 2012), exports to the NA market serve as a reasonable control group for exports to the EU market. The tenure slope change in the NA market helps control for common aggregate shocks, such as labor costs in China, assuming that these common aggregate shocks have the same impact on price-tenure slopes in these two markets.

One drawback of the DID strategy is that it does not control for EU- or NA-market-specific aggregate shocks that could also affect the price-tenure slope. For instance, the EU and NA markets may have experienced different market-specific demands or exchange-rate shocks, aside from the RoHS. Therefore, I further use a triple-difference strategy to identify the RoHS's impact. I add Chinese exports not covered by the RoHS as an additional control group ("non-RoHS products" hereafter), assuming that the market-specific shocks are the same for RoHS and non-RoHS products. The idea is that since there are no policy implementations directly affecting non-RoHS products, the EU vs. NA difference in tenure slope changes should be more substantial for RoHS products than for non-RoHS ones. The tenure slope change in non-RoHS products helps to account for the impact of EU- and NA-market-specific aggregate shocks on the price-tenure slope.

2.3 Data Description

I used Chinese Customs Statistics from the Chinese National Bureau of Statistics, from the years 2002-2011—when China had just joined the WTO. Chinese customs data provide information on the firm-level annual trade at 6-digit HS code, and include export shipment values, quantity, destination, ownership type, and so forth. In this paper, each 6-digit HS code is one type of product. A market in this paper is defined as an intersection of product type with destination country. I then divide the value by quantity in order to calculate the unit price of exports at the exporter-HS-6-digit-destination level. The "tenure" variable is defined as the number of years since an exporter debuted in an HS-6-digit-destination market. An exporter is considered to have exited the market if the firm never exports again during the data period under study.[13]

The products in the treatment group consist of electrical and electronic equipment under HS codes 63, 84, and 85 and which are covered by the RoHS. Appendix B lists all the HS 6-digit codes that are covered by the RoHS.[14] Other products that are not covered by the RoHS ("non-RoHS products") serve as a control group in the triple-difference regression.[15] To make the samples comparable in *pre-* and *post-*RoHS periods, the sample during the *post-*RoHS period only includes exporters that entered the market during or after 2007. In other words, when studying the tenure slope change, I have excluded exporters who experienced the regulation change after their exporting lifetime had already begun. In this way, *post-*RoHS firms' tenure profiles, which range from 1-5 years, are not interrupted by the policy change.

The empirical exercises include only those domestic private firms who suffer most from information friction, due to their small scales and lack of recognition in foreign markets.[16] I trim

[13] In this definition, I do not take gap years of export activities into account.

[14] I exclude products of HS code 95 (Toys, etc) because there was a massive recall of toys exported by China in 2008, which affected exports of the entire industry. The timing of recalls is close to the implementation of the RoHS. I also exclude HS code 91 (clocks and watches and parts thereof). The RoHS is mainly relevant to the use of lead in quartz movement. Since the RoHS does not cover all watches and clocks, for example mechanical watches in HS code 91, I drop HS code 91.

[15] To have a clean control group, I also exclude HS codes 28-43, which cover the chemicals, plastics, and rubber industries. These industries are mostly affected by the implementation of EU REACH regulation (Registration, Evaluation, Authorisation, and Restriction of Chemicals) in December, 2006. REACH increases entry costs for these industries by requiring firms to assess and manage the risks posed by chemicals and providing appropriate safety information for their users.

[16] Foreign firms and state-owned enterprises may have different pricing strategies. Foreign firms suffer less from

outliers of price in the top or bottom 0.5% of exports to each destination country.

The data period is ideal for my study because China joined the WTO in 2002 as a new player in the international market. The information asymmetry problem was more pronounced when Chinese exporters still had little recognition among foreign buyers, as was the case in that period.

2.4 Quality and Exporting Tenure

This section presents the three data patterns related to exporters' dynamics: exporters with more experience in the export market (1) charge higher prices, (2) import more expensive intermediate inputs, and (3) have a higher survival rate. The data used in the section is from exports of RoHS products to the EU and NA markets.

First, I show evidence suggesting that firms upgrade product quality alongside increasing lengths of experience in a destination market. Note that quality is not usually directly observed by researchers, but rather indirectly; in research where both quality and price can be observed in or estimated by the data (Macchiavello, 2010; Khandelwal, 2010; Gervais, 2015; Piveteau and Smagghue, 2015), quality is shown to be positively correlated with price. Hence, I follow the literature (Brooks, 2006; Johnson, 2012; Sutton and Trefler, 2011; Schott, 2004) and use the unit price of exports as a proxy for quality.

I use the data on exports of RoHS products to both the EU and NA markets to explore the price-tenure slope, after controlling for exporter-HS-6-digit-destination fixed effects. I estimate the following regression specification:

$$\ln \text{price}_{fpdt} = \sum_{T=1}^{11} \delta_T \mathbf{1}(Tenure_{fpdt}) + \mu_{fpd} + b\mathbf{X}_{pdt} + \varepsilon_{fpdt} \tag{1}$$

where, μ_{fpd} is the exporter-HS-6-digit-destination fixed effect, which helps to control for unobservable, time-invariant individual characteristics. In this specification, I exploit the within-exporter-HS-6-digit-destination variation to identify the relationship between tenure and log price. To control for aggregate shocks over time,[17] I include two control variables in $\mathbf{X}_{pdt}$ that are at the HS-6-digit-destination-year level. One is the average log price, which controls for the aggregate shocks (e.g., exchange rate, inflation) to exporters' prices. The other is the total export quantity,

information problems compared with Chinese domestic firms, since they are more likely to conduct intra-firm trade. Also, exports by FDI are more likely to bear a recognizable foreign brand. Although I do not study the effect of multinational activities on qualities in this paper, this paper does point to a possible role of multinational firms for future research. That is, FDI by multinational firms helps alleviate the general lack of information, and thus upgrades export quality in developing countries with weak contract enforcement. State-owned enterprises are subject to government intervention and receive massive subsidies. They may not follow market forces.

[17] When individual fixed effects are controlled, year dummies and tenure dummies are collinear.

which additionally controls for the total demand from the destination market. The estimates are robust to various control variables.

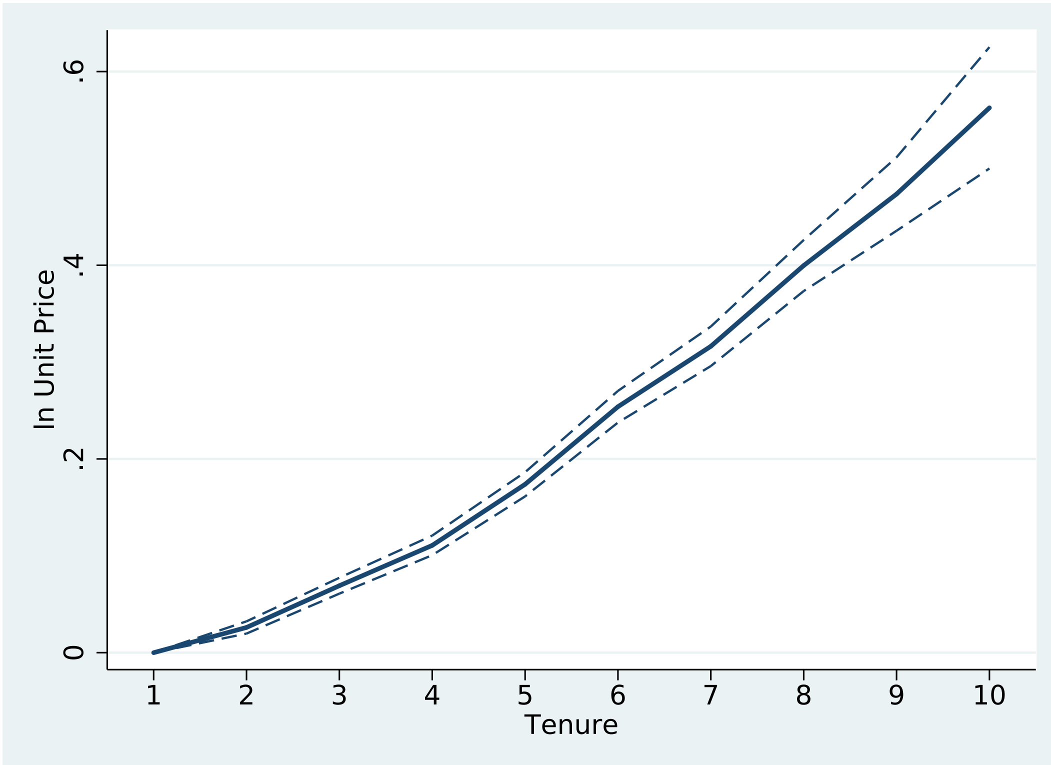


Figure 1: Price and Tenure

Figure 1 plots the estimates of δ_T in Eq (1). The dashed line plots the 95% confidence interval of the estimates. As shown in Figure 1, log price in $Tenure = 1$ is set as the base, and log price increases as exporters gain more experience in exporting product p in the destination country d.

I then run a regression of log price$_{fpd}$ on linear $Tenure_{fpdt}$, controlling for X_{pdt}. As reported in Column (1) of Table 1, the coefficient of $Tenure_{fpdt}$—referred to as "price-tenure slope" in the rest of the paper—is estimated to be 0.049 (with $SD = 0.002$). Thus, on average, price increases by 4.9% with an additional year of experience in an HS-6-digit-destination market.

An alternative specification is to include HS-6-digit-destination-year fixed effects, exploiting the variation of tenure within the HS-6-digit-destination-year cohorts. This specification controls for the aggregate shocks with year dummies but may suffer from selection problems. Intuitively, exporters who survive longer in the market are better exporters, selling higher quality goods. To deal with this endogeneity problem, I include the spell (total number of years in the market) as a control. Based on this specification, the price increases by 6.1% for an additional year of tenure and is significant at the 1% level. I also group firms based on spells. For each spell cohort, log price grows alongside tenure as well. More details regarding this specification, as well as the result tables, are in Appendix C.[18]

As for product quality, I provide additional evidence of quality upgrades by examining the relationship between the quality of intermediate inputs and tenure. Some exporters are also importers, and the price of their imports can be observed in Chinese customs data. Similar to exports, the import price is used as a proxy for quality. I only look at manufacturing exporters, rather than intermediaries, since manufacturing importers are more likely to be intermediate users. One of the complications of this specification is that exporters export multiple products, and we do not know which imports are used for producing RoHS products. I thus look at exporters with the ratio of exports of RoHS products greater than 50% in each year.[19]

I run the following regression to estimate the price-tenure slope for imported intermediate inputs.

$$\ln \text{price}_{fpdt} = \delta Tenure_{fpdt} + \mu_{fpd} + b_1 X_{fdt} + b_2 X_{pdt} + \varepsilon_{fpdt} \tag{2}$$

where, μ_{fpd} is the exporter-HS-6-digit-destination fixed effect, which helps to control for unobservable, time-invariant, individual characteristics. I use the within exporter-HS-6-digit-destination variation to identify tenure slope. To account for aggregate shocks (e.g. exchange rate and inflation) over time, I include the average price of imported product p from destination country d at year t as a control variable X_{pdt}. I additionally include log export value as a control variable X_{fdt}, to control for exporters' size. Column (2) of Table 1 presents the estimates of δ in Eq (2). The price of imported intermediate input increases by 5.2% for each additional year that an exporter stays in the destination market.

In Appendix C, I present the estimates of an alternative specification, in which I control for the HS-6-digit-destination-year fixed effect. The estimates remain similar.

Next, I study the survival rate conditional on tenure in the market. As shown in Figure 2, only around 30% of new entrants survive beyond the first year. The survival rate improves over time; for exporters who are already in the market for ten years, for example, the probability of their staying for another year is around 80%. It is a common observation in the literature that new entrants are more likely to exit the market than their more-established counterparts (Ruhl

[18] Piveteau (2016) also finds a positive relationship between tenure and unit price; he studies the pricing strategy of French wine exporters and finds that unit price increases with the years that an exporter has been in the market. Some papers have failed to find a positive correlation between tenure and unit price (Fitzgerald et al., 2016;Bastos et al., 2017). As discussed in Piveteau (2016), these papers identify the price-tenure relationship by the variation either across products or across destination countries within the same exporter. However, the order of export products or destination countries itself is an endogenous choice by exporters. Thus, coefficients of tenure are very likely to pick up this endogenous sorting across destinations and products.

[19] The upward tenure slope of intermediate input price is also robust for the sample of exporters who only export RoHS products.

Table 1: Quality Upgrade over Tenure

	(1) Exports	(2) Imports by Exporters
Tenure	0.049	0.052
	[0.002]***	[0.007]***
FE	Yes	Yes
R-sq	0.028	0.013
Obs	481137	167388

[1] I control for the exporter-HS-6-digit-destination fixed effect in both regressions.
[2] Standard deviations are clustered at exporter-HS-2-digit level.

and Willis, 2017). In Appendix D, I show that exiting exporters charge a lower price than the continuing ones. This indicates that exiting exporters sell products of lower quality.

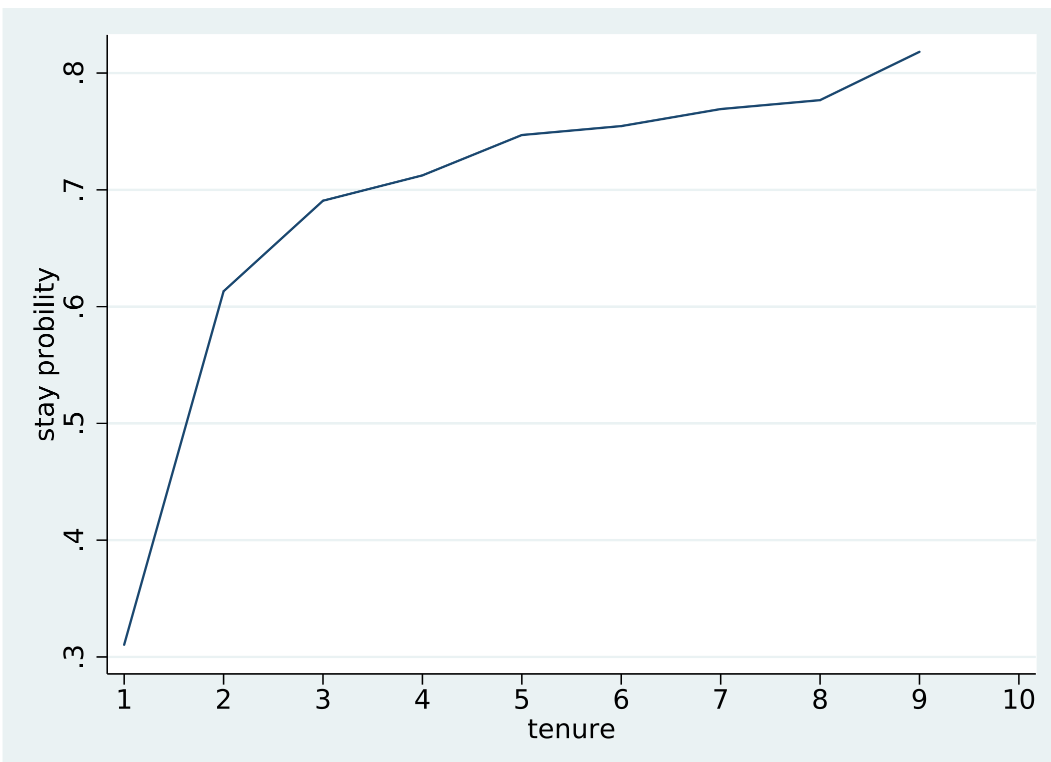


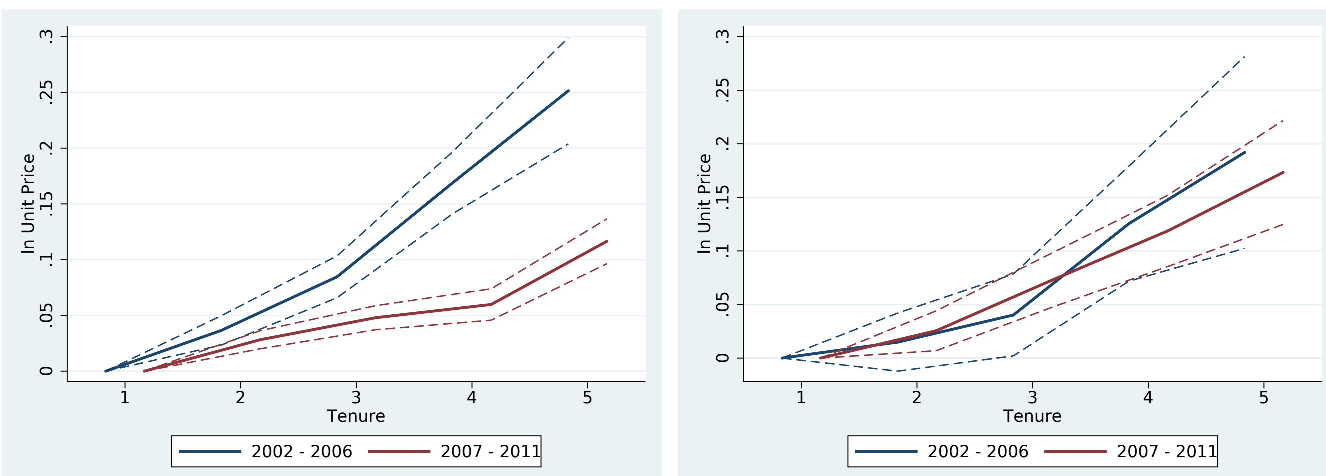
Figure 2: Survival Rate Conditional on Tenure

Though the above evidence supports the existence of information asymmetry in the Chinese export market, there are other possible explanations.[20] The following section presents the key empirical results.

2.5 Externalities and Information Asymmetry

To provide evidence for information asymmetry, I take advantage of the implementation of the RoHS as a natural experiment. More specifically, I use both difference-in-difference and triple-difference strategies to identify the impact of RoHS regulation on the price-tenure slope of exports.

Figure 3 graphically illustrates the impact of the RoHS on the tenure slope change in a difference-in-difference setup. Figure 3 plots the estimates of tenure dummies, β_T in Eq (1) for Chinese exporters in the EU and NA markets, before and after the RoHS, respectively. I include the exporter-HS-6-digit-destination fixed effect in order to control for unobservable individual heterogeneity. The upward price-tenure slope is interpreted as exporters increase prices over their lifetime in the market. The blue line plots the estimates of regressions before the RoHS, and the red line plots those after it. The dashed line represents the 95% confidence region. Panel (a) shows that the price-tenure slope in the EU market flattens after the regulation, while Panel (b) shows that the slope in the NA market—where no significant policy changes occurred during the sample period—remains similar after 2007.



(a) EU market (b) NA market

Figure 3: Price and Tenure of RoHS products

To test statistically whether the difference between the EU and NA markets is significant, I

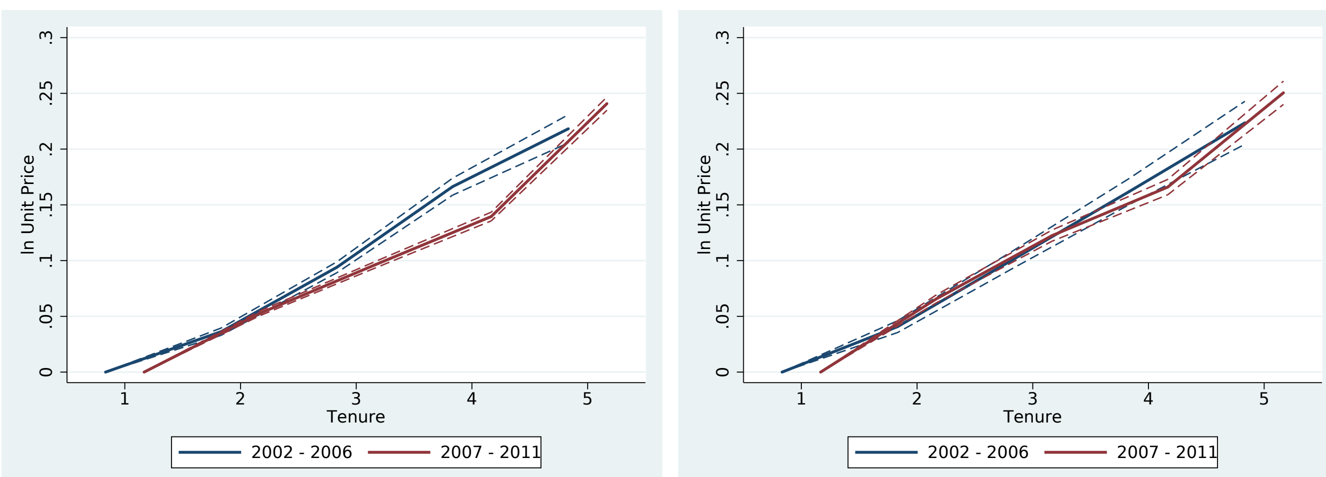
[20]For example, perhaps exporters learn about the foreign market and become able to provide high-quality goods which are more valued by their foreign customers (Piveteau 2016; Bastos and Dias 2013; Rodrigue and Tan 2015).

run the difference-in-difference regression as in Eq (3).

$$\begin{aligned} \ln \text{price}_{fpdt} &= b_1 Tenure_{fpdt} + b_2 EU_d \times Tenure_{fpdt} + b_3 After_t \times Tenure_{fpdt} \\ &+ b_4 After_t \times EU_d \times Tenure_{fpdt} + \mu_{fpd} + \varepsilon_{fpdt} \end{aligned} \tag{3}$$

As in Figure 3, I include the exporter-HS-6-digit-destination fixed effect in order to control for unobservable individual heterogeneity. $EU_d = 1$ if the destination country is in the EU. $After_t = 1$ if t is in the *post*-RoHS period. The coefficient of interest is the one of $After_t \times EU_d \times Tenure_{fpdt}$, which captures the difference in tenure slope changes between the EU and NA markets after the RoHS. I also add $Tenure_{it}$, $EU_d \times Tenure_{fpdt}$, and $After_t \times Tenure_{fpdt}$ as controls. The standard deviation is clustered at exporter-HS-2-digit level.[21]

Column (1) of Table 2 presents estimates of the DID estimation. As shown in Column (1), the estimates of b_1 and b_2 indicate that price grows by 3.7% for each additional year of tenure in the NA market, and by 5.1% in the EU market. In the NA market, there is no significant before-and-after change of tenure slope with respect to the timing of the regulation's introduction; the estimate of b_3 is slightly positive and insignificant. The estimate of b_4, the coefficient of $After_t \times EU_c \times Tenure_{fpdt}$, is significantly negative. This implies that the price-tenure slope in the EU market flattens after the implementation of the RoHS.



(a) EU market

(b) NA market

Figure 4: Price and Tenure of non-RoHS products

One problem with the DID strategy is that it does not control for aggregate shocks that are specific to each market (such as demand shocks and exchange rates), and these shocks may

[21] Note that $After_t$ and μ_{fpd} are collinear since exporters, who experienced the policy change after their exporting lifetime had already begun, are not in the sample.

influence the tenure slope as well. To deal with market-specific shocks, I use exports of non-RoHS products as an additional control group. The triple-difference regression identifies the impact of the RoHS.

Figure 4 plots the price-tenure slope of non-RoHS products in the two markets, before and after the RoHS, separately. Similarly to Figure 3, Figure 4 plots how exporters increase prices over their lifetime in the market by including the exporter-HS-6-digit-country fixed effect. The blue lines plot the estimates of regressions before the RoHS, and the red lines plot the ones after it. The dashed lines represent the 95% confidence region. Figure 4 shows that the discrepancy of changes in these two markets is much smaller. As shown in panels (a) and (b), the tenure slopes remain similar for non-RoHS products in both the EU and NA markets before and after the regulation (although that in the NA market does become steeper by a small margin).

To quantify the difference between RoHS and non-RoHS products, I then run the following triple-difference regression with the exporter-HS-6-digit-destination fixed effect (μ_{fpd}).

$$\begin{aligned}
\ln \text{price}_{fpdt} &= b_1 RoHS_p \times After_t \times EU_d \times Tenure_{fpdt} \\
&+ b_2 After_t \times EU_d \times Tenure_{fpdt} \\
&+ b_3 After_t \times RoHS_p \times Tenure_{fpdt} + b_4 RoHS_p \times EU_d \times Tenure_{fpdt} \\
&+ b_5 RoHS_p \times Tenure_{fpdt} + b_6 After_t \times Tenure_{fpdt} + b_7 EU_d \times Tenure_{fpdt} \\
&+ b_8 Tenure_{fpdt} + \mu_{fpd} + \varepsilon_{fpdt} \qquad (4)
\end{aligned}$$

where, $RoHS_p = 1$ if product p is covered by the RoHS. The estimate of key interest is b_1, i.e. the coefficient of $RoHS_p \times After_t \times EU_d \times Tenure_{fpdt}$. b_1 captures the additional difference in the tenure slope change of RoHS products in the EU vs. the NA markets, compared to the non-RoHS products. This specification is saturated, as it controls for all possible combinations of interaction terms in Eq (4). Note that the exporter-HS-6-digit-destination fixed effect absorbs the following interaction terms, $After_t \times EU_d$, $After_t \times RoHS_p$ and $RoHS_p \times EU_d$.

Column (2) of Table 2 reports the estimates of the triple-difference regression. The estimate of β_1 shown in column (2) of Table 2 is -0.025, and is significantly different from zero at 5%.

2.6 Robustness Check

This section presents robustness checks for the empirical results in Section 2.5.

First, I provide the following supportive evidence which conforms to my interpretation of the price-tenure relationship. (1) The price of exports increased after the RoHS. (2) The standard deviation of price became smaller as the composition of entrants after the RoHS was more ho-

Table 2: The Change of Tenure Slope of log Price

	DID		DDD	
	(1)	(2)	(3)	(4)
Tenure	0.034	0.052		
	[0.009]***	[0.002]***		
RoHS × *Tenure*		-0.017		
		[0.009]**		
EU × *Tenure*	0.017	-0.002		
	[0.009]*	[0.002]		
RoHS × *EU* × *Tenure*		0.019		
		[0.009]**		
After × *Tenure*	0.0049	0.0082		
	[0.01]	[0.002]***		
After × *RoHS* × *Tenure*		-0.0034		
		[0.01]		
After × *EU* × *Tenure*	-0.031	-0.0065	-0.011	-0.0053
	[0.01]***	[0.002]***	[0.003]***	[0.002]**
RoHS × *After* × *EU* × *Tenure*		-0.025	-0.018	-0.022
		[0.01]**	[0.01]*	[0.01]**
Controls	NO	NO	YES	YES
X_{pdt}	NO	NO	NO	YES
FE	YES	YES	YES	YES
Obs	433455	6846595	6846595	6846595

[1] Exporter-HS-6-digit-destination fixed effect is controlled in all columns.

[2] Controls in column (3) and (4) include dummies for RoHS-HS-2-digit-destination-tenure and RoHS-HS-2-digit-destination-after-tenure. These dummies flexibly control tenure schedules for different groups of exports by countries, HS 2-digit industries, and before vs. after RoHS. Column (4) additionally controls for HS-6-digit-destination level aggregates by including X_{pdt}, $RoHS \times X_{pdt}$, $After \times X_{pdt}$ and $RoHS \times After \times X_{pdt}$. X_{pdt} are the log average price of product p exporting to destination country d at year t.

[3] Standard deviations are clustered at the Exporter-HS-2-digit level.

mogeneously efficient on average. (3) There were fewer entrants after the RoHS, since inefficient firms were unable to afford the extra compliance costs to enter the market. (4) There are fewer exits, due to the more efficient composition of exporters in the market who are more resilient to temporary cost shocks.

Table 3 presents this supportive evidence from the triple-difference regressions. The interaction term $RoHS \times After \times EU$ identifies the net impact of the policy change. All regressions include HS-

6-digit, RoHS-HS-2-digit-country, RoHS-HS-2-digit-year, and country-year fixed effects. Column (1) shows that the log price of RoHS products to the EU market increases by 4.6% on average. In column (2), I calculate the standard deviation of prices within each HS-6-digit-destination-year cohort, and then take the log of it. Column (2) shows a decrease of 11% in the dispersion of price. In column (3), the number of entrants is calculated for each HS-6-digit-destination market in every year. Additionally in this regression, I control for the size and the competition intensity of an HS-6-digit-destination market by including log number of incumbents. The triple-difference shows that the number of entrants is reduced by 15% for RoHS products in the EU market after the RoHS. Column (4) is a linear regression of the exit indicator on $RoHS \times After \times EU$. The dependent variable is equal to 1 if the year is the final year of an exporter in an HS-6-digit-destination market. The estimate of the triple interaction shows that the exit probability drops by 2.1 percentage points after the RoHS.

Table 3: Robustness Checks

	(1) log Unit Price	(2) log (Std of log Unit Price)	(3) log Number of Entrants	(4) Exit Probability
$RoHS \times After \times EU$	0.046	-0.11	-0.15	-0.021
	[0.02]**	[0.06]*	[0.04]***	[0.007]***
Controls	YES	YES	YES	YES
R-sq	0.554	0.694	0.828	0.085
Obs	6846595	428620	211315	5563328

[1] Controls include RoHS-HS-2-digit-country and RoHS-HS-2-digit-year, country-year and HS 6-digit fixed effects. Column (3) additionally includes log number of incumbents at HS-6-digit-destination level in every year.

[2] Standard deviations in column (1) and (4) are clustered at Exporter-HS-2-digit level, while the counterparts in column (2) and (3) are clustered at HS-6-digit-country level.

Second, I adopt a more flexible tenure schedule of price in the specification of Eq (4). Instead of imposing a linear form as in Column (2) of Table 2, I include dummies for $RoHS_p \times$ *HS-2-digit* $\times EU_d \times Tenure_{fpdt}$ and $After_t \times EU_d \times Tenure_{fpdt}$ to flexibly control tenure schedules for exports to different countries, in different HS-2-digit industries, and before and after the RoHS. Column (3) of Table 2 presents the estimate of the interaction term, which is -0.018 and significant at 10%.

Thirdly, I include the average log price and the log total quantities at HS-6-digit-destination level of each year to control for aggregate shocks such as inflation, exchange rate and demand shocks. Although the triple-difference specifications capture the effect of aggregate shocks on tenure using control groups, I add additional control variables for a robustness check. As shown in Column (4) of Table 2, the coefficient of interests, $RoHS \times After \times EU \times Tenure$, is -0.022 and significant at 5%, similar to the estimates in Column (2) and (3).

Finally, all results are robust to various definitions of tenure, as well. Tenure in the main results is defined as the number of years of an exporter in an HS-6-digit-destination market. I redefine tenure as the number of years in an HS-4-digit-destination and HS-2-digit-destination market, and all the estimates are similar.

3 Model

In this section, I build a structural model where exporters differ in terms of how efficient they are at making high-quality products. The model is the first in the literature in international trade to incorporate both adverse selection and moral hazard and explore their implications for export dynamics.

In what follows I will use t to denote the year and T to denote the tenure of a firm in an export market.

3.1 Exporters

Each year, there is a fixed measure, M_t, of potential exporters entering the market. Exporters are heterogeneous in terms of their efficiency in producing quality, which is denoted by θ. I assume that the unit cost of an exporter with efficiency θ is increasing in quality q. The marginal cost of production is given by

$$c(\theta, q) = \frac{q}{\exp(\theta)}.$$

Marginal cost is increasing in quality ($\frac{\partial c(\theta,q)}{\partial q} > 0$), but less so for higher θ producers ($\frac{\partial^2 c(\theta,q)}{\partial q \partial \theta} < 0$).

The efficiency of an exporter at time t, θ_t, is a function of their initial efficiency draw, θ_0, and tenure in the market, T_t.

$$\theta_t = \theta_0 + \beta_\theta T_t \tag{5}$$

The initial efficiency draw θ_0 captures the heterogeneous efficiency level of exporters. β_θ captures the exogenous process of efficiency by which efficiency evolves. This process could be due to learning by exporting (Bigsten et al., 2004; Blalock and Gertler, 2004; Fernandes and Isgut, 2005;

Girma et al., 2004; Van Biesebroeck, 2005; etc). As exporters gain experience, they are more able to produce high-quality goods that are valued in the destination market. β_θ will be estimated from the data as explained in Section 4.

In each period t, exporters meet $\exp(\alpha_t)$ measure of importers if they stay in the market. Each importer demands one unit of the goods per period. α_t is interpreted as a demand shock, which is a function of α_0 and T_t,

$$\alpha_t = \alpha_0 + \beta_\alpha T_t. \tag{6}$$

β_α captures forces that raise demand over time such as customer accumulation (Piveteau, 2016; Foster et al., 2016; Drozd and Nosal, 2012).

Let $g(\alpha, \theta)$ be the density function of the joint normal distribution of the initial θ_0 and α_0. The parameters are:

$$\mu = \left\{ \begin{array}{c} \mu_\theta \\ \mu_\alpha \end{array} \right\} \qquad \Sigma = \left\{ \begin{array}{cc} \sigma_\theta^2 & \rho\sigma_\theta\sigma_\alpha \\ \rho\sigma_\theta\sigma_\alpha & \sigma_\alpha^2 \end{array} \right\} \tag{7}$$

Here, μ_θ and μ_α are the means of θ and α respectively; σ_θ^2 and σ_α^2 are the variances of θ and α respectively; ρ is the correlation between θ and α.

As described in the introduction, due to weak contract enforcement in China, moral hazard amongst exporters is a problem in international trade. Long-term relationships with repeated purchases give exporters incentives to honor contracts. The literature finds that long-term relationships between exporters and importers are prevalent in practice. Over half of trade occurs between firms that have been transacting for more than three years. (Bernard et al. 2018; Monarch and Schmidt-Eisenlohr 2016; Heise 2016). Surveys of importers in Costello (2013) and Heise (2016) indicate that a long-term relationship is the key to successful outsourcing.

Exporters receive repeated purchase contracts (p, q) from importers whom they meet. These contracts specify the price p that importers will pay and the contracted quality q. In each period, foreign buyers pay before they observe the actual quality, and they continue the contract if the exporter has provided them products with at least the contracted quality in the previous period. Otherwise, they terminate the contract immediately. For simplicity, I assume that the price within a relationship is fixed over the contract life. The assumption of no renegotiation simplifies the importers' problem in the model.[22].

[22] This is not far from reality. Heise (2016) studies the price change within an importer-exporter relationship using US customs data. He finds that the price decreases slightly with tenure within a relationship (by 0.7% per year). I assume it stays fixed.

I assume that there is no information sharing between importers. That is, breaching one contract does not have reputational effects for a given firm.[23] This allows me to think of contracts independently of one another.

Exporters never reject offers but choose whether to honor contracts or to supply a good with zero quality, because accepting a contract will ensure exporters earn at least p by defaulting.

Exporters weigh the one-time profit from breaching the contract against the present discounted value of the flow of profits in the long run when making decisions on whether to honor or to breach a contract. Thus, firms make:

$$\begin{array}{ll} p - \frac{q}{\exp(\theta)} & \textit{profit per period if they honor the contract} \\ p & \textit{one-period profit if they breach the contract} \end{array}$$

If the discounted value from future orders is higher than the one-period profit, exporters choose to honor the contract. Otherwise, they would rather default. As inefficient exporters have a lower per-period profit from honoring contracts, given p and q, they require a higher price to produce the contracted quality q.

The contract ends in three possible cases, as follows. (1) Foreign importers terminate a contract immediately after an exporter's default. (2) Contracts break up with an exogenous attrition rate δ_1. That is, in each period, exporters will lose δ_1 fraction of customers. (3) When an exporter exits the market, all his/her contracts end.

When offering contracts, foreign importers do not know the exact type θ of the exporter they meet. In other words, they do not know if the price offered is high enough for exporters they meet to produce the quality specified in the contract. Foreign importers only observe the tenure T_t and a noisy but unbiased signal of the true type θ—θ^s. Let $g_s(\theta^s|\theta)$ be the density function of θ^s conditional on the true type θ and let $G_s(\theta^s|\theta)$ be the corresponding cumulative distribution function (cdf). $g_s(\cdot|\theta)$ is assumed to be a normal distribution with mean θ and standard deviation

Allowing renegotiation introduces complications such as the ratchet effect: exporters may restrict quality because they rationally anticipate higher quality requirements or lower payments for future orders when they reveal their efficiency by honoring contracts. In reality, renegotiation costs prevent frequent updating of contracts based on past transactions. My model assumes that the renegotiation cost is too high for importers to update contracts with exporters. This simplifying assumption allows me easily to capture a relevant element of long-term relationships, namely that potential future orders give exporters the incentive to honor contracts, which alleviates the moral hazard problem. That is, potential future orders give exporters incentives to honor contracts, and thus the moral hazard problem can be alleviated. Introducing renegotiation will complicate the model considerably, but will not nullify the main mechanism.

[23] This assumption is realistic to the extent that information sharing between importers is limited. A buyer has little to gain by sharing information about bad suppliers, and even less to gain by sharing information about good suppliers, as they could be lured away from him. For this reason, experience with suppliers is rarely shared.

σ_s.

$$\theta^s \sim N(\theta, \sigma_s) \tag{8}$$

The optimal contract offered by foreign importers is a function of their information set, the signal θ^s and the tenure T of exporters at the time they meet. Let $p_T(\theta^s)$ and $q_T(\theta^s)$ be the optimal contract.

Exporters have a stock of contracts, $\mathcal{C}_T$, that are inherited from previous periods. Let C be a specific contract in $\mathcal{C}_T$. Suppose contract C has terms p and q, and let α_C denote the mass of C. In the most flexible model, exporters can decide whether to default or to honor each existing contract, in every period. However, to facilitate computation, in Section 3.2, I will make simplification assumptions on exporters' choice set.

Although price is fixed for each C, the average price of all contracts in $\mathcal{C}_T$ changes over time, when new incoming foreign buyers offer different contracts based on their information.

At the beginning of each period, exporters decide whether to pay the market access cost f to be in the market. $\log f$ is drawn each period from a normal distribution with mean $\mu_f + \eta_1 \alpha$ and standard deviation σ_f where α is the demand flow defined earlier. Let $G_f(f|\alpha)$ be the cumulative distribution function of f conditional on α.

$$f \sim \log Normal(\mu_f + \eta_1 \alpha, \sigma_f) \quad \text{with } \eta_1 > 0$$

The market access cost f is independent across time and exporters. The mean of the distribution of $\log f$ depends on the demand shock, α. With $\eta_1 > 0$, it is more costly for exporters to maintain their business relationship with a larger customer base. As long as they pay the market access cost f, they are in the market in this period. Exporters exit the market completely and permanently if they do not pay f in any period.[24] When hit with a high market access cost that outweighs the discounted value of future profit flow, exporters optimally choose to exit.

In addition to endogenous exit, there is an exogenous probability $1 - \beta_1$ of exiting in each period.

I model the RoHS as an increase in entry cost. Based on the study in ARCADIS/RPA (2008), the largest part of compliance cost is one-time, up-front costs. Once firms complete the transition from non-RoHS to RoHS compliance—by designing production lines, finding new supply chains and so forth—then future compliance costs (such as certification cost) are relatively low. Therefore,

[24] For simplicity, I do not allow re-entry in my model. Due to these fixed costs, longer tenure raises firms' expected efficiency, as efficient firms can survive adverse shocks, whereas less efficient firms cannot. It is easy for importers to know tenure.

I model the implementation of RoHS as an increase in the market access cost in the first year. More specifically, the mean of $\log f$ for first-year exporters in the market is increased by $\frac{f_{lb}}{exp(\theta)^{\eta_2}}$.

$$f \sim \log Normal(\mu_f + \eta_1 \alpha + \frac{f_{lb}}{exp(\theta)^{\eta_2}}, \sigma_f) \qquad \text{for exporters with } T = 1$$

The size of η_2 determines the extent to which entry costs are lower for firms that are more efficient in making quality. If efficient exporters have better technology and can achieve RoHS compliance at a lower cost, then $\eta_2 > 0$.

Figure 5 summarizes the timeline of exporter actions in each period t. At the beginning of t, an exporter with tenure T knows his efficiency θ and demand shock α. He/she has the stock of contracts, $\mathcal{C}_T$. First, the exporter draws his random market access cost f and decides whether to stay in the market by paying f, or not. θ^s is realized after f is paid. If he/she stays in the market, he meets $\exp(\alpha)$ measure of buyers. Second, foreign importers observe the signal θ^s and tenure T, and offer a repeated purchase contract $\{p_T(\theta^s), q_T(\theta^s)\}$ to the exporter they meet. Third, the exporter decides whether to breach or honor his contract. After shipping, buyers observe quality. If the exporter honors the contract, the contract will add to the stock of contracts in the next period $\mathcal{C}_{T+1}$. If not, the relationship is terminated. Contracts break up with the exogenous attrition rate $1-\delta_1$. Finally, exporters exit the market with an exogenous probability $1-\beta_1$. Firms that stay in the market with $(\theta, \alpha, T, \mathcal{C}_T)$ at the beginning continue to the next period with new θ', α', $T+1$ and an updated stock of contracts $\mathcal{C}_{T+1}$.

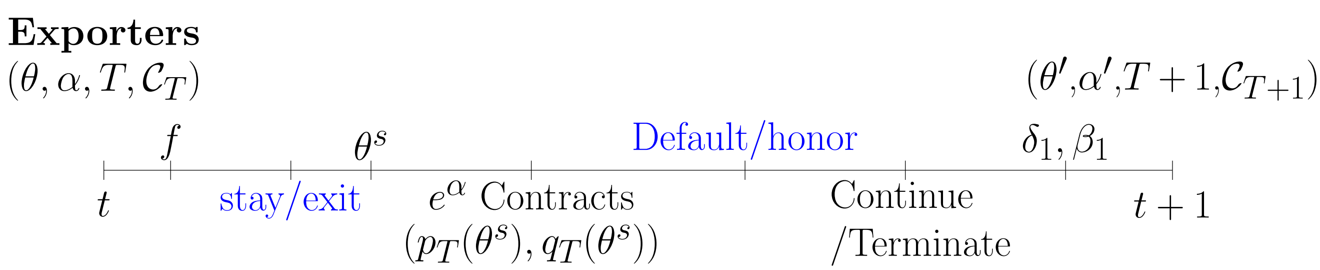


Figure 5: Time line of Exporters' and Foreign Importers' Actions

3.2 Assumptions to Simplify the Model

To solve the exporters' strategy, I need to calculate the value function of exporters. The state space of an exporter, which includes θ, α, T and the stock of contracts $\mathcal{C}_T$, is too large for computation. In order to facilitate the computation of the exporters' dynamic problem, I make several assumptions to reduce exporters' state space, and thus ease the computational burden.

Assumption 1. *Once a contract is signed, the costs of fulfilling it are locked down. Moreover, exporters choose to breach or honor the contract only in the first year of the contract.*

As in Assumption 1, if θ_τ is the efficiency level of an exporter when he/she signs the contract $C = (p, q)$ in period τ, then the production cost for this particular contract remains as $c(\theta_\tau, q)$, even though the efficiency of producing for new contracts increases/decreases with tenure T_t.

With Assumption 1 and fixed contract term (p, q), the profit flow is constant over the contract life. More specifically, for a contract (p, q) signed at T_τ, if the exporter chooses to honor the contract, then the profit flow π_C is $p - c(\theta_{T_\tau}, q)$.

The second part of Assumption 1 assumes that exporters must continue to provide goods with the contracted qualities if they choose to do that in the first year, As costs are locked down, the firm will not incur losses from doing so.

Assumptions 1 help to reduce exporters' state space. Instead of tracking the entire stock of contracts they have, the total profit flow from $\mathcal{C}$, $\pi = \sum_{C \in \mathcal{C}} \pi_C$, is all that is relevant. Exporters only care about the total profits they will lose when they decide whether to exit the market or not. This assumption does not harm the main mechanism of the paper as it still captures exporters' moral hazard problem. When exporters choose to honor or breach contracts in the first period, they weigh short-run profits against the value of long-run profit flow.

π has a nice recursive form. Let π be the aggregate profit flow from the stock of contracts in the current period, and let π' be that in the next period. The following equation shows how π gets updated, depending on whether or not the exporter chooses to renege on his current contract.

$$\begin{aligned} \pi'_h &= \underbrace{[p_T(\theta^s) - c(\theta, q_T(\theta^s))] \times \exp(\alpha)}_{\text{Surviving New Contracts}} + \underbrace{\delta_1 \pi}_{\text{Old Contracts}} && \text{if exporters honor the contract} \\ \pi'_d &= \delta_1 \pi && \text{if exporters breach the contract} \end{aligned}$$

When exporters honor the contract (p, q), the updated aggregate profit flow π'_h has two parts. The first part is the profit flow from the existing stock of contracts, π. Since $1 - \delta_1$ fraction of contracts are terminated exogenously, $\delta_1 \pi$ is the profit flow in the following period from unterminated contracts. The second part is the profit flow from new contracts, $[p_T(\theta^s) - c(\theta, q_T(\theta^s))] \times \exp(\alpha)$.

The next assumption also eases the computational burden for the exporters' value function.

Assumption 2. *For $T > \overline{T}$, exporters are mature such that*

1. $\theta_T = \theta_{\overline{T}}$ *and* $\alpha_T = \alpha_{\overline{T}}$.
2. *There is no market access cost, $f = 0$. Exporters exit the market only due to the exogenous death rate β_1.*

3. θ is fully revealed to importers.

The first part of Assumption 2 implies that θ and α are bounded, which ensures that the exporters' problem does not explode over time. The second part simplifies the exit decision after $\overline{T}$. Exporters always stay in the market until they are hit by the exogenous death shock. The third part means that there is no information asymmetry for well-established exporters in the market.

This assumption is not only meaningful in reality, but also has little impact on exporter dynamics at young age when $\overline{T}$ is set large. Assumption 2 captures the idea that exporters are mature after being in the market for several years such that exporters' efficiency type and demand are stable. When they are mature, exporters know the market well and thus, their market access costs reduce to zero. As they are in the market for a long time, buyers have learned their type better and thus, θ is fully revealed to buyers. In addition, when $\overline{T}$ is large, the discounted value for periods after $\overline{T}$ is small and thus, the payoff after $\overline{T}$ has limited impact on exporters' strategies at the beginning.

Assumption 2 implies that the discount factor of contracts for $T \geq \overline{T}$ is $\beta_1\delta_1$. Since foreign buyers observe θ after $\overline{T}$, the contract is a function of θ only. Let $\{p(\theta), q(\theta)\}$ be buyers' optimal contract, and $\pi(\theta)$ be the per-period profit from selling one unit good.

$$\pi(\theta) = p(\theta) - \frac{q(\theta)}{exp(\theta)}$$

Assumption 2 makes computation easier for two reasons. First, the importers' optimal contract after $\overline{T}$, $\{p(\theta), q(\theta)\}$, can be solved explicitly as shown in Section 3.5. Second, the value function of exporters can be solved without iteration. The value function at $\overline{T}+1$ can be calculated explicitly, as shown in Section 3.3. Thus, by backward induction, the value function for $T \leq \overline{T}$ is solved.

3.3 Value Functions of Exporters

Given contracts $\{p_T(\theta^s), q_T(\theta^s)\}$ for $T \leq \overline{T}$ and $p(\theta), q(\theta)$ for $T \geq \overline{T}+1$, I solve for the value and policy functions for exporters.

With Assumption 1 - 2, the state space of the exporters' value function is reduced to (θ, α, π, T). Let $V_T(\theta, \alpha, \pi)$ be the value function for exporters with (θ, α, π) at tenure T. The value function at $\overline{T}+1$, $V_{\overline{T}+1}(\theta, \alpha, \pi)$, can be solved explicitly due to Assumption 2. By backward induction, I will then solve the value function for all T.

3.3.1 Value function $V_{\overline{T}+1}$

The value function at $\overline{T}+1$ has two parts. One is the discounted profits of contracts inherited from the previous periods, $\frac{\pi}{1-\beta_1\delta_1}$, where $\beta_1\delta_1$ is the probability of contracts continuing into the next period. The other part is the discounted profits from future contracts. In each period after $\overline{T}$, exporter with (θ,α) receives $exp(\alpha)$ measure of contracts. The discounted value of each such contract is $\frac{\pi(\theta)}{1-\beta_1\delta_1}$. Summing this value over all contracts received every period after $\overline{T}$, along with the discount factor β_1, gives the discounted value from all future contracts, $\frac{\exp(\alpha)\pi(\theta)}{(1-\beta_1\delta_1)(1-\beta_1)}$. Therefore, the value function at $\overline{T}+1$ is the following.

$$V_{\overline{T}+1}(\theta,\alpha,\pi)=\frac{\pi}{1-\beta_1\delta_1}+\frac{\exp(\alpha)\pi(\theta)}{(1-\beta_1\delta_1)(1-\beta_1)} \tag{9}$$

where, β_1 and δ_1 have different roles. β_1 is the discounting factor for exporters' future value of staying in the market. $\beta_1\delta_1$ is the discounting factor for profit flows of contracts.[25]

3.3.2 Value function V_T, $T \le \overline{T}$

For $T \le \overline{T}$, exporters' value function given importers' contract $\{p_T(\theta^s), q_T(\theta^s)$ is $V_T(\theta,\alpha,\pi)\}$.

$$\begin{aligned}
&V_T(\theta,\alpha,\pi)=\mathbb{E}_f \max_{s\in\{0,1\}} s\{V_T^e(\theta,\alpha,\pi)-f\}\\
&V_T^e(\theta,\alpha,\pi)=\pi+\mathbb{E}_{\theta^s}\max_{d\in\{0,1\}}\\
&\qquad\Bigg\{(1-d)\underbrace{\Big[\big[p_T(\theta^s)-c(\theta,q_T(\theta^s))\big]\exp(\alpha)+\beta_1V_{T+1}(\theta',\alpha',\pi'_h)\Big]}_{\text{value if exporters honor the contract}}\\
&\qquad+d\underbrace{\Big[p_T(\theta^s)\exp(\alpha)+\beta_1V_{T+1}(\theta',\alpha',\pi'_d)\Big]}_{\text{value if exporters breach the contract}}\Bigg\}
\end{aligned} \tag{10}$$

Here, s is a binary decision about whether to stay in the market or not. The exporter decides to stay in the market, i.e. $s=1$, if the expected payoff from staying is higher than the fixed cost that they have to pay. The value function $V_T^e(\theta,\alpha,\pi)$ is the discounted value conditional on staying in the market after paying f.

Exporters who are in the market draw a signal of their efficiency level, θ^s from a normal distribution with mean θ and standard deviation σ_s. $\{p_T(\theta^s), q_T(\theta^s)\}$ will be the contract they get

[25] Though I cannot estimate β_1 and δ_1 from the data, I allow the possibility of estimating them separately in the future work with more detailed data.

with signal θ^s and tenure T. d is a binary decision about whether an exporter breaches or honors the contract. Exporters honor the contract, i.e. $d = 0$, if the discounted value of a long-term relationship outweighs the short-term profits when defaulting. With $V_{\overline{T}+1}$ solved out explicitly, the value functions for all $T \leq \overline{T}$ can be calculated by backward induction.

I define the following useful control and policy functions[26] for exporters. Let $d_T(\theta, \alpha, \pi, \theta^s)$ be the optimal default decision of exporters at tenure T with state (θ, α, π) and signal θ^s. The policy function $\pi_{T+1}(\theta, \alpha, \pi, \theta^s)$ is the profit flow from the stock of contracts in period $T+1$, given signal θ^s.

$$\pi_{T+1}(\theta, \alpha, \pi, \theta^s) = \begin{cases} [p_T(\theta^s) - c(\theta, q_T(\theta^s))] \times \exp(\alpha) + \delta_1 \pi & \text{if } d_T(\theta, \alpha, \pi, \theta^s) = 0 \\ \delta_1 \pi & \text{if } d_T(\theta, \alpha, \pi, \theta^s) = 1 \end{cases}$$

The optimal exit decision at tenure T, $s_T(\theta, \alpha, \pi, f)$, depends on the state (θ, α, π), as well as the temporary cost shock f.

$$s_T(\theta, \alpha, \pi, f) = \begin{cases} 1 & \text{if } V_T^e(\theta, \alpha, \pi) \geq f \\ 0 & \textit{Otherwise} \end{cases}$$

$s_T()$ is not a function of θ^s, since exporters make their exit decision before the realization of signal.

Additionally, let $x_T()$ be the ex-ante stay probability at the end of each period, which is calculated based on $s_T(\theta, \alpha, \pi, f)$, $G(f|\alpha)$ and the exogenous exit rate $1 - \beta_1$.

$$x_T(\theta, \alpha, \pi) = \beta_1 \int_f s_T(\theta, \alpha, \pi, f) dG_f(f)$$

Define $P_T(\theta, \alpha, \pi, \theta', \alpha', \pi')$ as the transition probability from the state (θ, α, π) to the state (θ', α', π') for an exporter at tenure T, which is calculated according to $x_T(\cdot)$, $\pi_{T+1}(\cdot)$, and $G_s(\theta^s|\theta)$.

$$P_T(\theta, \alpha, \pi, \theta', \alpha', \pi') = \begin{cases} x_T(\theta, \alpha, \pi) \int_{\theta^s} \mathbf{1}\{\pi_{T+1}(\theta, \alpha, \pi, \theta^s) = \pi'\} dG_s(\theta^s|\theta) & \text{if } \theta' = \theta + \beta_\theta; \alpha' = \alpha + \beta_\alpha \\ 0 & \text{Otherwise} \end{cases}$$

3.4 Distribution of Exporters

With exporters' exit decision function $s_T(\theta, \alpha, \pi, f)$, I am ready to calculate the exporters' distribution of (θ, α, π) for each tenure cohort T $(T \leq \overline{T})$. Let $h_T(\theta, \alpha, \pi)$ be the density function of exporters' distribution at the beginning of each tenure T. After exporters choose to stay or exit,

[26] Control functions are optimal choices of exporters in each period. Policy functions characterize the transition of state variables.

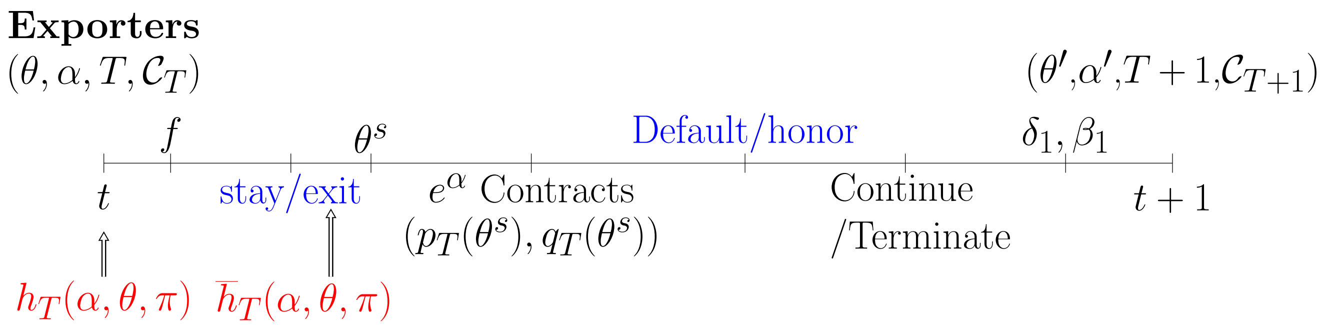


Figure 6: Exporter Distributions in the Timeline

the distribution of exporters who stay in the market is updated to $\overline{h}_T(\theta, \alpha, \pi)$ as illustrated in Figure 6.

$$\overline{h}_T(\theta, \alpha, \pi) = \frac{h_T(\theta, \alpha, \pi)\mathbb{E}_f s(\theta, \alpha, \pi, f)}{\int\int\int_{\theta,\alpha,\pi} h_T(\theta, \alpha, \pi)\mathbb{E}_f s(\theta, \alpha, \pi, f) d\theta d\alpha d\pi} \tag{11}$$

$\overline{h}_T(\theta, \alpha, \pi)$ equals the fraction of exporters at the state (θ, α, π) who have chosen to stay in the market as denoted by $h_T(\theta, \alpha, \pi)\mathbb{E}_f s(\theta, \alpha, \pi, f)$ out of the total measure of exporters who have decided to stay in the market, $\int\int\int_{\theta,\alpha,\pi} h_T(\theta, \alpha, \pi)\mathbb{E}_f s(\theta, \alpha, \pi, f) d\theta d\alpha d\pi$.

The distribution $h_T()$ can be calculated by forward induction. For $T = 1$, $\mathcal{C}_T$ is empty and thus, $\pi = 0$ for all exporters. Therefore, the distribution of $h_1(\alpha, \theta, \pi)$ is directly derived from $g(\alpha, \theta)$ as specified in Eq (12) in Section 3.1.

$$h_1(\alpha, \theta, \pi) = \begin{cases} g(\alpha, \theta) & \text{if } \pi = 0 \\ 0 & \text{if } \pi > 0 \end{cases} \tag{12}$$

$h_T()$ (for $T \geq 2$) is updated accordingly with the distribution of signal θ^s and the policy function $\pi_T(\alpha, \theta, \pi, \theta^s)$.

$$\begin{aligned} h_T(\alpha', \theta', \pi') \quad = \quad & \int_{\theta,\alpha,\pi,\theta^s} \mathbf{1}\{\alpha + \beta_\alpha = \alpha'\}\mathbf{1}\{\theta + \beta_\theta = \theta'\}\mathbf{1}\{\pi_T(\alpha, \theta, \pi, \theta^s) = \pi'\} \\ & \overline{h}_{T-1}(\alpha, \theta, \pi) dG_s(\theta^s|\theta) d\alpha d\theta d\pi \end{aligned} \tag{13}$$

where $\mathbf{1}\{\cdot\}$ is an indicator function. It equals 1 if the argument in the bracket is true. The density of the state in the next period, (α', θ', π'), is the total fraction of exporters who will move to the state (α', θ', π') in the next period from all possible current states (α, θ, π) at tenure $T - 1$.

3.5 Importers

After characterizing the exporters' problem, I explain the importers' maximization problem in this section. The demand side is simplified such that homogeneous buyers are facing a static maximization problem.

Each foreign importer demands one unit of the product. The flow utility of a foreign importer is assumed to be a quasilinear function with a decreasing marginal utility of quality.

$$u(p,q) = \frac{1}{\gamma} q^{\gamma} - p \qquad \text{with } \gamma < 1$$

Here, q is the quality he/she receives and p is the price paid to exporters.

For $T \geq \overline{T}+1$, foreign importers observe θ of the exporter they meet. Foreign importers and exporters share the same discount factor $\delta_1\beta_1$. The optimal price and quality are chosen to maximize foreign importers' discounted utility subject to the incentive compatibility constraint of exporters specified in Eq (15).

$$\max \quad \frac{1}{1-\delta_1\beta_1} u(p,q) \tag{14}$$

$$s.t. \quad \frac{1}{1-\delta_1\beta_1}(p - c(\theta,q)) \geq p \tag{15}$$

Solving the maximization problem, the optimal price and quality are the following

$$q(\theta) = (\gamma\delta_1\beta_1 \exp(\theta))^{\frac{1}{1-\gamma}} \tag{16}$$

$$p(\theta) = \frac{1}{\delta_1\beta_1}\frac{q(\theta)}{\exp(\theta)} \tag{17}$$

The discounted profit of exporter θ is $\pi(\theta) = \left(\frac{1}{\delta_1\beta_1} - 1\right)(\gamma\beta_1\delta_1)^{\frac{1}{1-\gamma}} exp(\theta)^{\frac{\gamma}{1-\gamma}}$, which is increasing in θ.

For $T \leq \overline{T}$, the efficiency level θ is private information of exporters. Conditional on observing θ^s and T, foreign importers form their beliefs on the distribution of exporters' state (θ, α, π). Let $\tilde{h}(\theta, \alpha, \pi|\theta^s, T)$ be the density function of foreign importers' beliefs about exporters' state conditional on observing (θ^s, T). $\tilde{h}()$ depends on the distribution within the tenure T cohort, as well as the distribution of θ^s conditional on θ.

$$\tilde{h}(\theta,\alpha,\pi|\theta^s,T) = \frac{g_s(\theta^s|\theta)\int\int_{\alpha,\pi}\overline{h}_T(\alpha,\theta,\pi)d\alpha d\pi}{\int_{\tilde{\theta}} g_s(\theta^s|\tilde{\theta})\int\int_{\alpha,\pi}\overline{h}_T(\alpha,\tilde{\theta},\pi)d\alpha d\pi d\tilde{\theta}} \tag{18}$$

With beliefs on the distribution of exporters' type, the foreign importer chooses the optimal contract (p, q) that maximizes their expected discounted payoff, given that all other importers offer optimal contracts. More specifically, after observing (θ^s, T), an importer solves the maximization problem specified in Eq (19). Here, I abuse the notation of d as exporters' default decision. $d(\cdot)$ is function of (θ, α, π), tenure T and foreign importers' contract term (p, q). As before, $d(\cdot) = 1$ means breaching the contract.

$$\begin{aligned} \max_{p,q} \quad & \int\int\int_{\theta,\alpha,\pi} \Big[(1 - d(\theta, \alpha, \pi, T, p, q))[\frac{1}{\gamma}q^{\gamma} - p]\Delta_T(\theta, \alpha, \pi, \theta^s) \\ & + d(\theta, \alpha, \pi, T, p, q)(-p)\Big]\tilde{h}(\theta, \alpha, \pi|\theta^s, T)d\theta d\alpha d\pi \\ \text{s.t.} \quad & d(\theta, \alpha, \pi, T, p, q) = \mathbf{1}\{[p - c(\theta, q)]\,\Delta_T(\theta, \alpha, \pi, \theta^s) < p\} \end{aligned} \tag{19}$$

As importers are symmetric, it is reasonable to assume that all importers offer the same optimal contracts $\{p_T(\theta^s), q_T(\theta^s)\}$ in equilibrium.

In Eq (19), $\Delta_T(\theta, \alpha, \pi, \theta^s)$ is the compound discount factor for contracts with exporter (θ, α, π) at tenure T. The discount factor comes from two sources, the exogenous attrition rate of contracts, $1 - \delta_1$, and the probability of exporters exiting the market in the subsequent periods. Importers and exporters share the same compounding discount factor $\Delta_T(\theta, \alpha, \pi, \theta^s)$.

The endogenous exit decisions of exporters complicate the calculation of $\Delta_T(\theta, \alpha, \pi, \theta^s)$. In each period, exporters may either exit the market with an exogenous rate $1 - \beta_1$ or decide to exit due to a high market access cost shock. The endogenous exit rate depends on the states. Exporters with higher θ and α are more profitable on average and thus less likely to exit. Those with a larger π are willing to pay a higher market access cost. This is because exiting the market costs them a larger profit loss from existing contracts. T and θ^s also matter, as they determine the contracts that exporters receive in the current period. These contracts may continue into the future, and thus affect exit probability in the subsequent periods.

$$\Delta_T(\theta, \alpha, \pi, \theta^s) = \begin{cases} \frac{1}{1-\beta_1\delta_1} & \text{if } T = \overline{T} \\ 1 + \frac{1}{1-\beta_1\delta_1}\delta_1 x_{T+1}(\theta_{T+1}, \alpha_{T+1}, \pi_{T+1}(\theta, \alpha, \pi, \theta^s)) & \text{if } T = \overline{T} - 1 \\ 1 + \delta_1 x_{T+1}(\theta_{T+1}, \alpha_{T+1}, \pi_{T+1}(\theta, \alpha, \pi, \theta^s)) & \\ \quad + \sum_{t=T+2}^{\overline{T}-1} \delta_1^{t-T} \int_{\theta',\alpha',\pi'} x_t(\theta', \alpha', \pi') p_t^T(\theta', \alpha', \pi', \theta, \alpha, \pi) d\theta' d\alpha' d\pi' & \\ \quad + \frac{1}{1-\beta_1\delta_1} \int_{\theta',\alpha',\pi'} x_{\overline{T}}(\theta', \alpha', \pi') p_{\overline{T}}^T(\theta', \alpha', \pi', \theta, \alpha, \pi) d\theta' d\alpha' d\pi' & \text{if } T \leq \overline{T} - 2 \end{cases} \tag{20}$$

where, $\theta_{T+1} = \theta + \beta_\theta$ and $\alpha_{T+1} = \alpha + \beta_\alpha$. $p_t^T(\theta', \alpha', \pi', \theta, \alpha, \pi)$ is the probability of being (θ', α', π')

at t given that the exporter has a state of (θ, α, π) at T.

$$p^T_{T+2}(\theta', \alpha', \pi', \theta, \alpha, \pi) = P_{T+1}(\theta_{T+1}, \alpha_{T+1}, \pi_{T+1}(\theta, \alpha, \pi, \theta^s), \theta', \alpha', \pi')$$
$$p^T_t(\theta', \alpha', \pi', \theta, \alpha, \pi) = \int\int\int_{\tilde{\theta}, \tilde{\alpha}, \tilde{\pi}} P_{t-1}(\tilde{\theta}, \tilde{\alpha}, \tilde{\pi}, \theta', \alpha', \pi') p^T_{t-1}(\tilde{\theta}, \tilde{\alpha}, \tilde{\pi}, \theta, \alpha, \pi) d\tilde{\theta} d\tilde{\alpha} d\tilde{\pi} \quad \text{for } t \geq T+3$$

3.6 Equilibrium

The equilibrium is characterized by the distribution of exporters' state $\overline{h}_T(\theta, \alpha, \pi)$; the contracts offered by importers $\{p_T(\theta^s), q_T(\theta^s)\}$ for $T \leq \overline{T}$ and $\{p(\theta), q(\theta)\}$ for $T \geq \overline{T}+1$; and exporters' exit decision and default decision, $s_T(\theta, \alpha, \pi, f)$ and $d_T(\theta, \alpha, \pi, \theta^s)$ such that the following conditions are satisfied.

(i) For $T \geq \overline{T} + 1$,

1. $\{p(\theta), q(\theta)\}$ solves foreign importers' optimization problem subject to the incentive compatibility constraint as in Eq (14) and Eq (15). In equilibrium, exporters do not breach contracts.

(ii) For $T \leq \overline{T}$,

2. Foreign importers' contract offer $\{p_T(\theta^s), q_T(\theta^s)\}$ maximizes their expected discounted utility as in Eq (19) given their beliefs on exporters' efficiency distribution $\tilde{h}(\theta, \alpha, \pi|\theta^s, T)$. The compound discount factor $\Delta_T(\theta, \alpha, \pi, \theta^s)$ is calculated by Eq (20).
3. Given importers' contract offer $\{p_T(\theta^s), q_T(\theta^s)\}$ for $T \leq \overline{T}$ and $\{p(\theta), q(\theta)\}$ for $T \geq \overline{T} + 1$, exporters make exit and default decisions, $s_T(\theta, \alpha, \pi, f)$ and $d_T(\theta, \alpha, \pi, \theta^s)$, to maximize their value function as in Eq (10).
4. Beliefs on exporters' types are consistent with the equilibrium distributions in the market. The beliefs of foreign importers conditional on (θ^s, T), $\tilde{h}(\theta, \alpha, \pi|\theta^s, T)$, are generated based on $\overline{h}_T(\theta, \alpha, \pi)$ and $g_s(\theta^s|\theta)$ according to Eq (18). $\overline{h}_T(\theta, \alpha, \pi)$ is updated based on exporters' optimal exiting decisions $s_T(\theta, \alpha, \pi, f)$ according to Eq (11).

I solve the model by iteration. Appendix E describes the algorithm that is used to solve the model.

The information asymmetry on efficiency type leads to adverse selection. Exporters with a lower θ require a higher price to stay honest given any quality q. Buyers make their quality and price offers to exporters knowing that for each quality and price offer there is some cutoff firm efficiency above which the Chinese suppliers will deliver the contracted quality because the supplier will value repeated dealings with that buyer and below which firms will breach the contract. When there are more inefficient exporters in the market, importers have a higher probability of being cheated for any given (p, q). To save the cost of incentivizing inefficient firms to produce high-quality goods, optimally, importers source lower price, lower quality goods from the market that is abundant in inefficient exporters.

In my model, there are two dimensions of profitability—the efficiency of quality production θ and demand α. The correlation between α_0 and θ_0 (i.e., ρ) and the market access cost parameter (i.e., η_1) govern the relationship between profitability and efficiency θ. Under certain parameter values, inefficient ones have smaller discounted profits from being in the market, as compared to efficient ones. For example, larger ρ and η_1 tend to generate a positive correlation between efficiency and profitability. This paper focuses on the case when higher efficiency in quality production implies larger profitability.

Empirical evidence also supports the intuition that efficient exporters are less likely to exit the market. In Chinese customs data, I find that the export price is positively correlated with revenue, and that exporters, when exiting the market, have a lower export price compared to those that continue.[27] Additionally, Manova and Zhang (2012) finds that exporters are more likely to drop low-price, low-quality goods in response to adverse economic conditions. Gervais (2015) shows that selection into exporting is driven mainly by quality rather than by low cost. Brooks (2006) also suggests that Colombian plants fail to export more due to their low-quality products.

When efficiency and profitability are positively correlated, the model has two important implications. First, the information asymmetry itself can generate an upward price-tenure slope. This is due to the early exit of low-efficiency participants: inefficient exporters may enter the market due to a draw of low market access cost f, but are more likely to exit at a young age when they draw new f over time. Efficient exporters are more resilient to these shocks, since they have higher discounted value from being in the market. As the efficiency distribution shifts to the right over tenure, tenure serves as a signal of exporters' efficiency type. Therefore, foreign buyers optimally source higher price, higher quality goods from more experienced exporters and thus, price rises with tenure.

Second, the model predicts a flatter price-tenure slope after the RoHS. The RoHS increases the entry cost of exporters. Inefficient exporters have lower expected profits in the future, and so higher entry cost affects their entry decision more compared to efficient ones, which leads to a more homogeneous and efficient distribution of new entrants. As efficient exporters are more resistant to temporary cost shocks, they are less likely to exit the market in the following years,

[27] See Appendix D for details.

and thus the efficiency composition shifts less alongside tenure. Therefore, tenure contains less information on exporters' efficiency level, and price increases less over time.

The variance of signal θ^s governs the magnitude of externalities. The more accurate the noisy signal θ^s is, the more weight foreign buyers will put on individual signals and vice versa. In the extreme case when buyers can perfectly observe the efficiency θ, the cohort distribution plays no role in foreign buyers' belief. The implementation of RoHS helps to identify the variance of signal θ^s, which will be explained in Section 4.

4 Identification and Estimation

In Section 4.1, I outline the intuition of the model identification. For each parameter in the model, I explain which data variation helps pin down the value intuitively. Then in Section 4.2, I present the estimation results. Let Θ be the parameters to be estimated from the data.

$$\Theta = \{\mu_\theta, \sigma_\theta, \mu_\alpha, \sigma_\alpha, \rho, \beta_\theta, \beta_\alpha, \sigma_s, \mu_f, \sigma_f, \eta_1, \eta_2, \gamma\}$$

$\mu_\theta, \sigma_\theta, \mu_\alpha, \sigma_\alpha, \rho, \beta_\theta, \beta_\alpha$ are the parameters characterizing distributions and processes of θ and α defined in Eq (5), (6) and (7). σ_s^2 is the variance of the noisy signal θ^s. $(\mu_f, \sigma_f^2, \eta_1)$ are parameters governing f. γ is the elasticity of quality in the utility function. η_2 is the parameter for the heterogeneous impact of the RoHS on the exporters with different efficiency level θ.

Some parameters are taken from the literature. The exogenous exit rate for exporters, $1 - \beta_1$, is 0.05. The exogenous break-up rate of a contract, $1 - \delta_1$, is 0.20. Both Bernard et al. (2018) and Monarch and Schmidt-Eisenlohr (2016) find that the break-up rate drops dramatically in the first two years of relationship and is around 0.1-0.2 after three years. $\overline{T}$ is set at ten.[28]

4.1 Identification

I model the implementation of the RoHS as an increase of the market access cost in the first year. As shown in column (3) of Table 3, there are 15% fewer new entrants into the market after the RoHS. The entry cost f_{lb} is pinned down such that the entry rate is down by 15% following the regulation, given other parameters.

A key parameter to be estimated is the variance of efficiency signal, σ_s^2, which governs the magnitude of negative externalities on the quality provision. The magnitude of the change in

[28]In the data, there are very few large exporters with tenure longer than ten periods. For these exporters, it is reasonable to assume that they are well-established players in the market and information is no longer a problem.

price-tenure slope before and after the RoHS identifies σ_s^2. The larger σ_s^2 is, the more weight foreign buyers would put on tenure when forming beliefs on exporters' efficiency type. The composition of entrants is more homogeneously efficient and thus, tenure contains less information on efficiency type after the RoHS. Therefore, if buyers rely more on tenure, the change in price-tenure slope would be larger after the implementation of RoHS. Take an extreme example where $\sigma_s^2 = 0$, i.e., foreign buyers perfectly observe the efficiency level of exporters. Since foreign importers do not take cohort distribution into account when offering sourcing contracts, the tenure profile of log price will not change when the efficiency composition shifts.

Other parameters are identified as follows. I use the price distribution to identify parameters regarding θ since it is related to the contracted quality and price offered by foreign buyers. The mean and variance of price identify the mean and variance of θ, i.e., μ_θ and σ_θ. The parameter governing θ's exogenous process, β_θ, is identified through the price-tenure slope before the RoHS. Similarly, I use the quantity distribution to identify the parameters of α. The mean and variance help identify μ_α and σ_α, and the tenure slope of log quantity to identify β_α. ρ is identified by the correlation between price and quantity.

γ, the marginal utility from quality, as well as the risk aversion of foreign importers, governs the profit margin of exporters. Foreign importers with a higher γ value quality more and are willing to pay a higher price to ensure quality provision. Therefore, this affects the average price, and thus the profit margin of exiting exporters. Given the market access cost f, the price of exiting exporters tends to be lower when the profit margin is higher.

The mean of μ_f is identified through the average survival rate conditional on tenure. Given other parameters, the higher μ_f is, the lower the survival rate would be.

The variance of log market access cost σ_f^2 is identified through the variance of price of exiting exporters, as well as the change in variance of price in different tenure cohorts. With a larger σ_f^2, the probability of exiting depends more on the fat tail. Thus, the variance of exiting exporters' price tends to be larger. Also, the variances of price change less over tenure since exiting exporters are more similar to the ones who continue.

η_1 is identified by the change in the variance of quantity along tenure. When η_1 is smaller, exporters with small demand are more likely to exit the market. The variance of quantity decreases faster over tenure.

η_2 measures the heterogeneous impact of the RoHS on entry cost of exporters with different efficiency θ. This captures the intuition that it is more difficult for inefficient exporters to comply with the regulation. I use the change in exit rate before and after the RoHS to identify η_2. The exit rate is lower when more inefficient exporters are out of the market, because efficient ones are less likely to be driven out of the market by temporary cost shocks. Given other parameters, the change in exit rate implies the change in efficiency composition of exporters who enter the market.

4.2 Estimation

In this section, I use the information on exports in Chinese customs data to estimate the model. The main variables used in the estimation are price, quantity, and tenure at the HS-6-digit-destination level. The sample is the same as in the triple-difference regression in Section 2.5.

The price, quantity and exit decision of exporters cannot be solved as an explicit function of unobservables, i.e., α, θ and f. To address this, I estimate the model by using the method of simulated moments. More specifically, I choose Θ to minimize the distance between data moments and their simulated counterparts.

$$\min_{\Theta} \quad N\left(\mathbf{m}(\Theta)-\hat{\mathbf{m}}\right)'\widehat{W}\left(\mathbf{m}(\Theta)-\hat{\mathbf{m}}\right)$$

where, $\hat{\mathbf{m}}$ is the data moments, while $\mathbf{m}(\Theta)$ is the simulated ones. N is the sample size. Given a set of parameters, I simulate 1,000,000 exporters for five years before and after the regulation separately to construct $\mathbf{m}(\Theta)$. W is the optimal weighting matrix for the estimation, which is the inverse of the variance-covariance matrix. $\widehat{W}$ is the optimal weighting matrix approximated by the data counterparts.

Before constructing moments, I first take logs of price and quantity and then run the following regressions with the full sample to take out country and HS-6-digit product fixed effect.

$$y_{fpdt} = \mu_{1p} + \mu_{2d} + \varepsilon_{fpdt}$$

where, y_{fpdt} is either log price or log quantity of product p of exporter f exporting to the destination country d at year t. Product p is defined at HS-6-digit level. μ_{1p} is the fixed effect of product p and μ_{2d} is the fixed effect of the destination country d. $\hat{y}_{fpdt} = y_{fpdt} - \mu_{1p} - \mu_{2d}$ is used in the following estimation. Let $\ln\widehat{price}$ and $\ln\widehat{quantity}$ be the demeaned log price and log quantity.

I estimate the distribution of θ, α and f by targeting the moments constructed from export data of RoHS products to the EU market before the RoHS. σ_s and the policy related parameter η_2 are identified by moments based on triple-difference regressions.

The first moment is to identify σ_s with the tenure slope change before and after the RoHS. The triple-difference regression in column (3) of Table 2 in Section 2.5 is the auxiliary regression. I construct the first moment by targeting the estimate of the interaction term $RoHS_p \times After_t \times EU_d \times Tenure_{fpdt}$.

The second set of moments identify the distribution of efficiency θ and demand α. The mean and variance of log price and log quantities of exporters at $T = 1$[29] serve as moments to identify $\mu_\theta, \sigma_\theta, \mu_\alpha, \sigma_\alpha$. To identify the correlation between θ and α, I run the log price on log quantity while controlling for tenure dummies. I use the estimate of β from the following auxiliary regression as one moment.

$$\widehat{\ln price}_{fpdt} = \beta \widehat{\ln quantity}_{fpdt} + \sum_{T=1}^{5} \delta_T \{Tenure_{fpdt} = T\} + \varepsilon_{fpct}$$

The exogenous process of θ and α, governed by β_θ and β_α, are identified by the tenure slope of log price and log quantity. I construct the moments with the estimates of δ from the following auxiliary regression.

$$\hat{y}_{fpdt} = \beta Tenure_{fpdt} + \mu_{fpd} + \varepsilon_{fpdt}$$

where, $\hat{y}_{fpdt}$ is either $\widehat{\ln price}$ and $\widehat{\ln quantity}$.

The third set of moments are to identify γ, μ_f, σ_f and η_1. I first construct moments with the probability of staying in the market in the next year conditional on tenure $T = \{1, 2, .., 4, 5\}$.

I then use the average difference between exiting and staying exporters' log price as a moment. More specifically, the estimate of β from the following auxiliary regression is used as a moment.

$$\widehat{\ln price}_{fpdt} = \beta Exit_{fpdt} + \sum_{T=1}^{5} \delta_T \{Tenure_{fpdt} = T\} + \varepsilon_{fpdt}$$

where, $Exit_{fpct} = 1$ if the exporter f exits the HS-6-digit-country market at t. In the regression, I use tenure dummies to control for the tenure effects.

The variance of log price of exiting exporters is a moment for σ_f. Additionally, I construct the variance of log price and log quantity at each tenure $T = 1, 2, ..., 5$ as moments, which help identify σ_f and η_1.

Finally, the fourth moment is to characterize the heterogeneous impact of the RoHS on exporters with different θ, i.e., η_2. I take the estimate of the coefficient of $RoHS \times After \times EU$ in Column (4) of Table 3 as the last moment to identify η_2.

To estimate the model, I use the Markov Chain Monte Carlo (MCMC) estimator developed by Chernozhukov and Hong (2003). The usual minimization algorithms may not work, as the objective function potentially has numerous local maximizers. To tackle the problem, I follow Das

[29] I only use the first-year exporters to construct the moments such that there is no composition effect across different tenure cohorts.

et al. (2007) and Piveteau (2016) and use MCMC estimator. For each parameter, the prior is a uniform distribution over a bounded interval.

The estimated results are shown in Table 4. I report both the mean and the 95% confidence intervals for MCMC estimates. The variance of the signal governing the magnitude of externalities is 2.39. To interpret the estimates, suppose the variance of the signal decreases by half, that is, the information asymmetry is reduced by 50%. The total sales of exports increase by 6.3%, the profits of exports increase by 2.2%. The average export price increases by 40% and the average quality increases by 12%. In contrast, the number of entrants decreases by 2.9%.

Table 4: Estimation

Parameter		**Estimates**	**95% Confidence Interval**		**Prior**
			Lower bound	Upper bound	
Variance of signal	σ_s	2.39	2.37	2.41	$U[0.01, 10]$
Distribution of initial draws	μ_θ	4.19	4.17	4.22	$U[-5, 10]$
of (θ_0, α_0)	σ_θ	3.46	3.44	3.47	$U[1, 10]$
	μ_α	0.72	0.70	0.75	$U[-5, 10]$
	σ_α	2.32	2.30	2.33	$U[1, 10]$
	ρ	-0.63	-0.63	-0.62	$U[-1, 1]$
Exogenous process	β_θ	0.002	1.48E-05	0.006	$U[0, 0.5]$
of θ, α	β_α	-0.20	-0.22	-0.20	$U[-1, 1]$
Distribution of	μ_f	2.68	2.64	2.74	$U[-15, 25]$
market access cost	σ_f	6.71	6.64	6.79	$U[0.5, 25]$
	η_1	1.00	0.99	1.01	$U[0, 2]$
Utility of quality	γ	0.33	0.33	0.33	$U[0.1, 0.9]$
Parameter of RoHS	η_2	1.89	0.91	3.86	$U[0, 5]$

4.3 Model Fit

Overall, the simulated moments are well-matched to the data moments, as shown in Table 5. The change of the price-tenure slope is estimated at -0.0178 from the data, and -0.0134 from the simulated model. The discrepancy is reasonable considering the large standard deviation of the estimate from the triple-difference regression. There are discrepancies in other data moments as well, for example, the moments of the conditional surviving probability at $T = 2, ..., 5$. The substantial increase of surviving probability from $T = 1$ to $T = 2$ in the data is potentially due to exporters learning about their appeals or productivity when selling in the destination market, which has been well studied in the literature (Fitzgerald et al., 2016; Eaton et al., 2014; Bastos et al., 2017; Berman et al., 2015; Arkolakis et al., 2018; Albornoz et al., 2012; Rauch and Watson, 2003). This model captures importers learning exporters' efficiency type over tenure, but does not consider learning on exporters' side. A potential research agenda in the future will be to build a model incorporating both exporters' and importers' learning processes, which will better describe exporter dynamics and better evaluate policies quantitatively.

5 Counterfactuals

In this section, I explore the policy implications of export subsidies under information asymmetry by counterfactual exercises.

The Chinese government is known for its pervasive export promotion policies, providing subsidies in different forms to help firms enter the export market. For example, in 2015, the U.S. and ten other western countries complained to the WTO about China's "Demonstration Bases Common Service Platform" program, which provides prohibited export subsidies to Chinese enterprises located in 179 industrial clusters throughout China, known as "Demonstration Bases".[30] The subsidies contingent on export performance have various forms, such as free or discounted services, and cash grant measures. It was estimated that Chinese governments granted subsidies of some $1 billion over a three-year period.[31] In the literature, Kalouptsidi (2017) detects substantial subsidies to the Chinese Shipbuilding industries by the government.

Effectiveness of export subsidies is supported by the reasoning that subsidies reduce friction in the export market due to entry barriers. Some papers (Itskhoki and Moll 2018; Fan et al. 2015) in the literature find that credit constraints hamper the exporting activity of small and medium firms. They argue that alleviating credit constraints via export subsidies improves export performance and efficiency of resource allocation.

However, policy implications under this model with externalities due to information asymmetry potentially differ. The intuition is the following. Export subsidies induce inefficient firms that

[30] Source: https://ustr.gov/about-us/policy-offices/press-office/fact-sheets/2016/april/-agreement-terminate-export-subsidies-under-China-DB-platform

[31] Source: https://www.reuters.com/article/us-usa-china-trade-idUSKCN0XB1UQ

Table 5: Model Fit

	Data Moments	**Model Simulated Moments**
Change of Tenure slope of log Unit Price	-0.0178	-0.0134
Mean of log Unit Price at $T = 1$	0.99	0.98
Variance of log Unit Price at $T = 1$	2.30	2.05
2	1.77	1.79
3	1.68	1.58
4	1.70	1.38
5	1.76	1.16
Tenure Slope of Unit Price Before RoHS	0.051	0.067
Mean of log Quantity at $T = 1$	0.37	0.47
Variance of log Quantity at $T = 1$	5.51	5.17
2	4.98	4.72
3	4.87	4.41
4	5.05	4.17
5	4.69	3.98
Tenure Slope of Quantity	0.12	0.10
Corr. bet. log Unit Price and Quantity	-0.34	-0.30
Diff. of log Unit Price Bet. Staying and Exiting Exporters	-0.14	-0.36
Var. of log Unit Price of Exiting Exporters	2.49	1.90
Staying Probability at $T = 1$	0.42	0.48
2	0.67	0.51
3	0.73	0.53
4	0.74	0.56
5	0.80	0.60
The Change of Exit Rate Before and After	-0.022	-0.022

otherwise may not find it profitable to enter the market. Entries of inefficient exporters pollute the pool of exporters in the market and thus exacerbate the negative externalities on the quality provision of efficient exporters. There is a possibility that export sales and profits can fall because of lower export price and quality, even though subsidies encourage more exporters to enter the export market.

In the following counterfactual exercise, I explore the effect of a higher entry cost on export performance in terms of total sales, profits, average price, quality and the number of entrants.

Equivalently, higher entry costs can be interpreted as fewer subsidies for firms to enter the foreign market.[32]

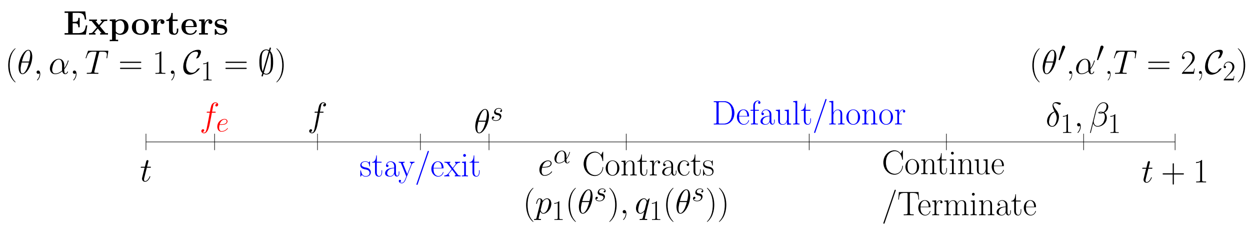


Figure 7: Timeline for exporters at $T = 1$

More specifically, at the first year $T = 1$, firms need to pay an additional entry cost of f_e to be a potential exporter in the market. After that, firms continue as the model describes in Section 3. The timeline of $T = 1$ is illustrated in Figure 7. The entry cost in the counterfactual exercise is drawn from a log-normal distribution.[33] The randomness of entry cost captures the reality that policy impacts are usually heterogeneous among firms.

$$\log(f_e) \sim N(\mu_e, \sigma_e)$$

The increase of entry cost has different implications for extensive and intensive margins. On the one hand, sales and profits tend to fall when there are fewer entrants in the market. On the other hand, the higher price due to fewer externalities from inefficient exporters leads to larger sales of entrants. The overall effect of a higher entry cost depends on which force outweighs the other, under the estimated parameters.

In the first exercise, I set σ_e as a small number, $\sigma_e = 0.01$, i.e., firms are facing a similar additional entry cost. Figure 8 shows the change of entry rate, quality, price, sales and profits when increasing μ_e. As shown in panel (a), a small μ_e does not affect the economy since it does not change exporters' entry decisions. When entry cost μ_e rises, the least profitable exporters, who are on average less efficient, exit the market. The average price for new entrants rises when the efficiency composition improves, as shown in panel (b) in Figure 8. The average prices of other tenure groups exhibit similar patterns.

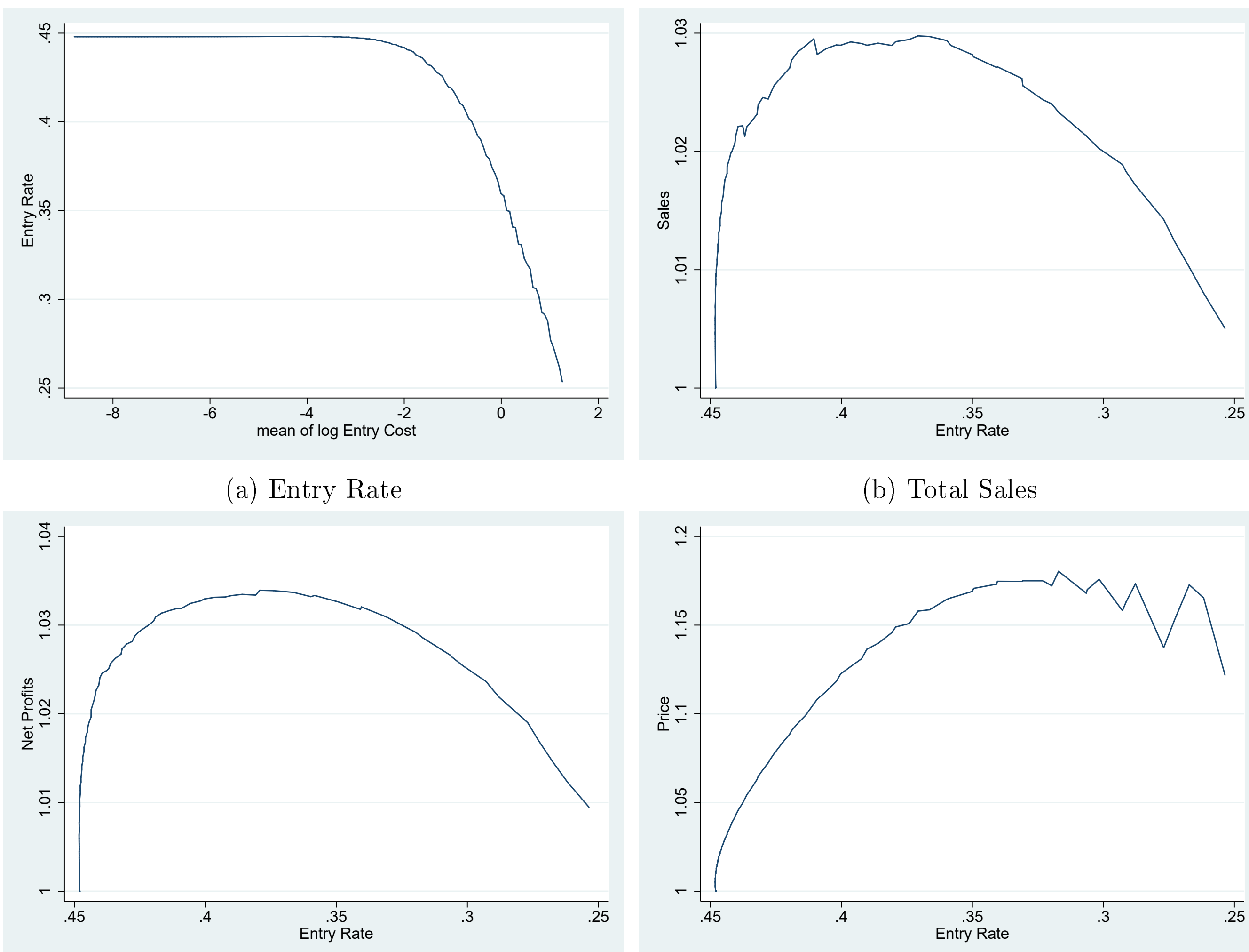
I then compute the total sales and profits of exporters in the economy. The additional entry cost is a transfer from firms to the government and thus is included in the profits. Panel (c) and

[32] It is difficult to detect government subsidies, and in China even more so. This is partly because international trade agreements, such as the WTO, prohibit subsidies. Therefore, the magnitude of subsidies is often unknown. In this paper, instead, I consider a hypothetical case in which entry costs rise due to fewer subsidies.

[33] Due to the discretized grid of θ, the randomness of entry cost creates a smooth distribution of entrants, and this aids model convergence

(d) of Figure 8 present the counterfactual results under the estimated parameters. The total sales and profits first increase and then decrease. This is because the intensive margin is stronger than the extensive margin at the beginning but is dominated by the latter as more exporters exit the market. The turning point is around $\mu_e = -0.38$ where the number of entrants is reduced by 15%. At the optimal entry cost, the total sales and profits increase by 3.1% and 3.7%, respectively. The average price for new entrants increases by 10% at the peak.

The counterfactual exercise with entry costs implies that there are excessive entrants at the status quo. By reducing subsidies for potential entrants and thus increasing entry costs, negative externalities will be alleviated. Although fewer firms engage in exporting activities, the total sales and profits increase as the average price rises and quality is improved for efficient exporters.



(a) Entry Rate

(b) Total Sales

(c) Net Profits

(d) Prices

Figure 8: Entry Rate, Sales, Profits and Prices as Entry Cost Rises

The figures in Panel (b)–(d) are not smooth because of the discretized grids of α and θ. The price change in Panel (d) fluctuates and decreases when entry rate is greater than 0.32. This is because of the composition change of α and μ. The α and μ are two dimensions of profitability and are negatively correlated. When entry costs increase, firms with low θ and α drop out first. Price finally falls as exporters with small α and large θ are driven out from the market. However, the turning points for sales and profits are smaller than that for prices.

The policy effect of entry cost also depends on the variance σ_e. I do the following counterfactual exercises to explore the role of σ_e. Keeping the reduction of the number of entrants at 10%, I take different values of σ_e from 0.01 to 2.

As shown in Table 6, the larger σ_e is, the less the price rises. Thus, increases in sales and profits are also attenuated. This is due to a smaller composition change when σ_e is large. Given the same entry rate, with a fat tail of entry cost, efficient exporters have a higher probability of getting a high entry cost shock and choose to stay out of the market. Thus, the extensive margin, compared to the intensive margin, plays a more substantial role in sales and profits.

Table 6: The Effect of σ_e in the Counterfactual Exercie

	Sales (%)	Net Profits (%)	Price (%)
$\sigma_e = 0.01$	2.78	1.95	7.86
$\sigma_e = 0.5$	2.73	1.67	7.01
$\sigma_e = 1$	1.96	0.87	4.99
$\sigma_e = 2$	0.45	-0.50	2.89

[1] The Number of entrants is reduced by 10%.

6 Conclusion

In this paper, I have studied how asymmetric information between foreign buyers and Chinese producers limits trade in high-quality goods. I propose a novel identification strategy to identify the extent of information asymmetry from Chinese Customs Data. I employ a triple-difference regression treating the implementation of the RoHS in the EU market as a natural experiment. The idea is that as entry costs to the EU market rose for Chinese exporters due to the RoHS, the efficiency composition of market entrants became more homogeneously efficient. As a result, tenure contains less information about exporters' efficiency type. The estimates from the triple-difference regression show that the price-tenure slope of exports to the EU market flattens after the RoHS.

Motivated by the empirical evidence, I then built an exporter dynamic model, incorporating both moral hazard and adverse selection. As information asymmetry is high for new entrants but then gradually fades as idiosyncratic cost shocks drive inefficient firms from the market. Thus, a firm's tenure in export markets is a signal of its efficiency. Consequently, the price that it can obtain rises with tenure. I estimated this exporter dynamic model with a GMM estimation procedure, wherein the extent of information asymmetry was identified by the price-tenure change after RoHS. Using the estimated model to study the implication of export promotion policy, I have found that, with the existence of information asymmetry, subsidies inducing inefficient, low-quality exporters into the market may pollute the pool of entrants and thus hurt overall export performance, compromising quality provision, prices, export sales and total net profits. This finding is different from the conventional wisdom that export subsidies, in helping small exporters to overcome export barriers (e.g., credit constraints), improve export performance.

Information asymmetry in international trade is under-studied, due to data limitations. However, as shown in this paper, accounting for information asymmetry is profoundly important with respect to policy implications. My paper also sheds light on industry policies for domestic markets, wherein the problem of information asymmetry is severe: for experienced goods (such as the baby care industry, drug industry, and so on), whose quality is evaluated after consumption, information problems carry the potential to hurt the development of the entire industry. For example, China's infant formula market has been overwhelmed with foreign brands since consumers lost confidence in domestic ones after the 2008 Chinese milk scandal[34]. Because of information asymmetry, high-quality domestic firms in this industry that were not involved in the scandal have also been affected.

This paper plants the seed for a broader research agenda. First, a general equilibrium model is needed to better quantify aggregate welfare implications. In order to achieve this, the improved model should be extended with a more fully specified demand system from the importers. Second, a model with endogenous signaling by exporters will be helpful for understanding the recent merger and acquisition activities of Chinese firms. This is based on the observation that establishing a reputation by purchasing foreign brands is one of the important strategies used by Chinese firms to break into foreign markets. Third, a model with information asymmetry, when incorporating heterogeneous foreign buyers, will also speak to the global value chain. Foreign buyers who value quality more are less likely to source high-quality goods from developing countries.

[34] The scandal involved milk, infant formula, etc. being adulterated with melamine. The total number of victims was estimated at 300,000. Six babies died from kidney stones and other kidney damage.

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Appendices

A Details of RoHS in EU Market

RoHS restricts the use of specific hazardous materials found in electrical and electronic products such as lead, mercury, cadmium, etc to a low level and encourage producers to substitute these hazardous substances with safer alternatives.

- Lead (Pb): < 1000 ppm
- Mercury (Hg): < 100 ppm
- Cadmium (Cd): < 100 ppm
- Hexavalent Chromium: (Cr VI) < 1000 ppm
- Polybrominated Biphenyls (PBB): < 1000 ppm
- Polybrominated Diphenyl Ethers (PBDE): < 1000 ppm

RoHS covers the following product categories and electric light bulbs, and luminaries in households[35].

- Large household appliances: refrigerators, washers, stoves, air conditioners
- Small household appliances: vacuum cleaners, hair dryers, coffee makers, irons
- IT and telecommunications equipment: computers, printers, copiers, phones
- Consumer equipment: TVs, DVD players, stereos, video cameras
- Lighting equipment: lamps, lighting fixtures, light bulbs
- Electrical and electronic tools (with the exception of large-scale stationary industrial tools): drills, saws, nail guns, sprayers, lathes, trimmers, blowers
- Toys, leisure and sports equipment: video games, electric trains, treadmills
- Automatic dispensers: Automatic dispensers for hot drinks, hot or cold bottles or cans and etc

[35] Certain exemptions are given due to the technical difficulties

According to RCADIS ECOLAS & RPA (2008), The following groups of products identified by SITC are covered by RoHS.

- 75: office machines and automatic data-processing machines
- 76: telecommunications and sound-recording and reproducing apparatus and equipment
- 774: electrodiagnostic apparatus for medical, surgical, dental or veterinary purposes, and radiological apparatus
- 775: household-type electrical and non-electrical equipment, n.e.s.
- 778: electrical machinery and apparatus, n.e.s.
- 885: watches and clocks
- 89426: toy musical instruments and apparatus
- 89431: video games of a kind used with a television receiver

I then use the Conversion and Correlation Tables from UN Trade Statistics to find the corresponding Harmonized System codes.

By August 13, 2004, all Member States had to implement provisions of RoHS Directive and made it national law, and the substance ban entered into force on 1 July 2006.[36] Studies by the European Commission find that the RoHS Directive has resulted in reducing the quantities of the banned substances being disposed of and potentially released into the environment by 89800 tonnes of lead, 4300 tonnes of cadmium, 537 tonnes of hexavalent chromium, 22 tonnes of mercury and 12600 tonnes of Octa-BDE estimated in a 2008 study by the Europe Commission[37].

Any business that sells applicable electronic products, sub-assemblies or components directly to the EU, or sells to resellers, distributors or integrators that in turn sell products to EU countries, is impacted if they utilize any of the restricted materials[38]. Violation and/or non-compliance could result in a tarnished brand image, fines, penalties, product recalls or even imprisonment of responsible company officials[39].

Therefore, it is important for importers in the EU market to make sure that suppliers overseas produce products with RoHS compliance. They required exporters to show supporting evidence

[36] Though RoHS transpositions are quite divergent in different member states, the European Commission continues its effort to put pressure on national governments to ensure a harmonized application of the directive.

[37] Source: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008SC2930&from=EN

[38] http://www.rohsguide.com/rohs-faq.htm

[39] Source: https://www.reedsmith.com/en/perspectives/2013/01/rohs-2-new-obligations-for-manufacturers-impo

such as lab tests to prove that their products meet RoHS requirements. Exporters will send their sample products to some reputed laboratories for compliance certificates. RoHS compliance is not applicable to an entire company, but only to specific products. Thus, one batch may be RoHS compliant, while the other is not - even if both come from the same supplier. To ensure compliance, sending each batch sample for lab testing will be necessary.

The cost of RoHS compliance for firms includes both compliance costs and technical costs (RCADIS ECOLAS & RPA, 2008). The compliance or non-technical costs are related to facilitating the practical implementation of the technological changes in the production chain. In practice, the compliance costs are the costs of getting acquainted with the Directive's requirements, the costs incurred by the provision of training and information to the different actors in the chain and the costs of collecting, organizing and reviewing information. A large administrative burden is caused by the firms' obligation to request the RoHS conformity throughout the whole supply chain of components from suppliers and sub-suppliers. The technical costs consist of (1) capital expenditures to either upgrade/modify or replace existing equipment; (2) operating expenditures such as more expensive alternative materials and substances, greater energy costs and certificate costs; (3) expenditures on research and development to find, test and employ substitutes to replace restricted materials and substances.

According to a study on European companies by ARCADIS/RPA (2008), the average one-time cost is 2% of turnover and 5.2% for small and medium firms. The future yearly costs on average are 0.04% of turnover and also disproportionately higher for small and medium firms. The similar estimates are also found in a study done for the Consumer Electronics Association by Technology Forecasters Inc[40]. For Chinese private firms, the compliance cost is potentially higher since they are usually smaller in size and less capable of R&D. Also, it is hard to source high tech, eco-friend input in China. The increase of production cost due to RoHS is estimated from 5% to 20% based on a report by AEDE (Asia Eco-design Electronics)[41].

The compliance cost is high compared to the profit margin in the industry of electrical and electronic equipment. Based on a study by the ECSIP consortium for DG Enterprise and Industry, the average profit margin ranges from 5.5% to 9.1% for European companies and from 2.4% to 6.2% for Chinese companies. It is reported that the RoHS has forced some small and medium manufacturers to pull out of the EU market since they cannot meet the stringent requirements

[40] Technology Forecasters Inc. (2008). Study of the economic impact of the EU RoHS on the electronics industry, commissioned by the Consumer Electronics Association (CEA)

[41] AEDE (Asia Eco-design Electronics), 2007, Country report on the Chinese electronics sector, Issues and capacity building needs in relation to international and national product-related environmental regulations and other requirements

that are posed by RoHS[42].

Other countries have worked out their versions of RoHS as well, for example, Japan, Korea, Norway and Turkey. California is the only state in the United States who has a regulation similar to RoHS. The federal regulation, known as the bill of the Environmental Design of Electrical Equipment Act (EDEE) (the US version of RoHS) has been introduced in 2009, but have not passed yet.

B HS Code List of RoHS products

Table A.1 lists all HS 6-digit codes which are treated as RoHS products.

Table A.1: The HS Code List of RoHS Products

HS 63									
630110									
HS 84									
841810	841821	841829	841830	841840	842211	844331	844332	844339	844399
845011	845012	845019	845121	846721	846722	846729	846900	847010	847021
847029	847030	847050	847090	847130	847141	847149	847150	847160	847170
847180	847190	847210	847230	847290	847310	847321	847329	847330	847340
847350									
HS 85									
850511	850519	850520	850590	850610	850630	850640	850650	850660	850680
850690	850710	850720	850730	850740	850780	850790	850811	850819	850860
850870	850940	850980	850990	851010	851020	851030	851090	851110	851120
851130	851140	851150	851180	851190	851210	851220	851230	851240	851290
851610	851621	851629	851631	851632	851633	851640	851650	851660	851671
851672	851679	851680	851690	851711	851712	851718	851761	851762	851769
851770	851810	851821	851822	851829	851830	851840	851850	851890	851920
851930	851950	851981	851989	852110	852190	852210	852290	852550	852560
852580	852610	852691	852692	852712	852713	852719	852721	852729	852791
852792	852799	852841	852849	852851	852859	852861	852869	852871	852872
852873	852910	852990	853010	853080	853090	853110	853120	853180	853190
853210	853221	853222	853223	853224	853225	853229	853230	853290	853910
853921	853922	853929	853931	853932	853939	853941	853949	853990	854310
854320	854330	854370	854390	854511	854519	854520	854590	854810	854890

[42] AEDE (Asia Eco-design Electronics) report, 2007.

C Quality Upgrade

In this section, I study the price-tenure relationship with an alternative specification which controls for the HS-6-digit-destination-year fixed effect, μ_{pdt}. The tenure slope is identified by the variation within a HS-6-digit-destination-year cohort. This specification may suffer from endogeneity problem. It is likely that exporters who survive longer in the market are inherently more capable exporters selling better quality goods. To deal with the selection, I demean the log price by the average over the lifetime of the exporter (The results do not change when I normalize the log price by the value at the first year, or put the individual mean as a control variable). The regression is the following.

$$d \ln p_{fpdt} \quad = \quad \delta Tenure_{fpdt} + \mu_{pdt} + \varepsilon_{fpdt} \tag{21}$$

I first look at the price-tenure slope of exports. In the regression, I additionally control for spells (the total number of years an exporter stay in the market). Column (1) of Table A.2 reports the results from the regression of Eq 21. The coefficient of $Tenure_{fpdt}$ is 0.061 with standard deviation 0.004. That is, the price increases by 6.1% as an exporter stay in a HS 6-digit-destination market for an additional year. Furthermore, I group exporters by the spell, and then I run the regression for each group. Table A.3 reports the coefficients of $Tenure_{fpdt}$ for each spell group. For all groups, the coefficients of $Tenure_{fpdt}$ are positive. When the spell is larger than 7, the coefficients are insignificant, which is probably due to the small sample size for these groups.

Table A.2: The Price-Tenure Slope in the Alternative Specification

	(1) Exports	(2) Imports by Exporters
Tenure	0.061	0.011
	[0.004]***	[0.002]***
FE	Yes	Yes
R-sq	0.121	0.721
Obs	257399	136262

[1] The HS-6-digit-destination-year fixed effect is controlled in both columns.

[2] Standard deviations are clustered at the exporter-HS-2-digit level.

Secondly, I run Eq (21) for the price of imported inputs as well. In this regression, I additionally include total export sales at year t to control for the importers' size.. The estimate is shown in

Table A.3: The Price-Tenure Slope for Each Spell Group

	(1)	(2)	(3)	(4)
Spell =	2	3	4	5
Tenure	0.018	0.049	0.058	0.073
	[0.010]*	[0.010]***	[0.01]***	[0.02]***
FE	Yes	Yes	Yes	Yes
R-sq	0.219	0.339	0.401	0.557
Obs	42934	24745	17212	9154
	(5)	(6)	(7)	
Spell =	6	7	8	
Tenure	0.044	0.052	0.10	
	[0.02]**	[0.05]	[0.4]	
FE	Yes	Yes	Yes	
R-sq	0.648	0.775	0.756	
Obs	6189	3501	1585	

[1] Standard deviations are clustered at exporter-HS-2-digit level.

Column (2) of Table A.2. The price of imported inputs is increasing by 1.1% as exporters stay in the HS 6-digit-country market for one more year.

D Exiting Exporters

In this section, I show that exporters, when exiting the market, have a lower export price compared with those that continue. This is consistent with the intuition that exporters who produce low-quality goods are more likely to drop out of the market.

More specifically, I run the following regression.

$$\log \text{price}_{fpdt} = \beta Exit_{fpdt} + \sum_{T=1}^{5} \delta_T \{Tenure_{fpdt} = T\} + \mu_{pdt} + \varepsilon_{fpdt}$$

where, $Exit_{fpdt} = 1$ if the exporter f exits the HS-6-digit-destination market at t. μ_{pdt} is the HS-6-digit-destination-year fixed effect. Additionally, I use tenure dummies to control for the tenure effects.

The estimate of β is -0.34 (SD = 0.006). On average, prices charged by exiting exporters are 34% lower than exporters who continue.

E Algorithm to Solve the Model

I first solve the optimal contract for $T \geq \overline{T}+1$ and exporters' value function at $\overline{T}+1$. With Assumption 2, the optimal contracts by foreign importers $(p(\theta), q(\theta))$ has the functional form of Eq (17) and Eq (16). The value function of exporters at $\overline{T}+1$, $V_{\overline{T}+1}(\theta, \alpha, \pi)$, is calculated according to Eq (9).

Then, I solve for the optimal contract $\{p_T(\theta^s), q_T(\theta^s)\}$ of foreign importers for $T \leq \overline{T}$ by iteration. The initial guess for the foreign importers' optimal contract is $\left\{p_T^{(0)}(\theta^s), q_T^{(0)}(\theta^s)\right\}$ for $T \leq \overline{T}$, where the superscript (n) is the number of iterations.

Step 1. Given $\left\{p_T^{(n)}(\theta^s), q_T^{(n)}(\theta^s)\right\}$ for $1 \leq T \leq \overline{T}$, I calculate $V_T^{(n)}(\theta, \alpha, \pi)$ $(1 \leq T \leq \overline{T})$ by backward induction based on Eq (10).

Step 2. Solve for the entry and exit decision of firms with state (θ, α, π) at all tenure T and calculate the distribution of states of exporters in the market, $\overline{h}(\theta, \alpha, \pi)$ according to Eq (11), Eq (12) and Eq (13).

Step 3. Update foreign importers' contract $\left\{p_T^{(n+1)}(\theta^s), q_T^{(n+1)}(\theta^s)\right\}$ by solving the optimal contract for the maximization problem in Eq (19) with beliefs on exporters' efficiency decision $\tilde{h}(\theta, \alpha, \pi|\theta^s, T)$. The conditional belief on exporters' efficiency distribution, $\tilde{h}(\cdot)$, is calculated based on Eq (18).

Step 4. Check whether $\left\{p_T^{(n+1)}(\theta^s), q_T^{(n+1)}(\theta^s)\right\}$ is close to $\left\{p_T^{(n)}(\theta^s), q_T^{(n+1)}(\theta^s)\right\}$ based on some tolerance level. If not, go back to Step 1. Continue the process until buyers' optimal contracts are converging.

Though I cannot prove the uniqueness of equilibrium, by starting with a different initial guess of $\left\{p_T^{(0)}(\theta^s), q_T^{(0)}(\theta^s)\right\}$ for $T \leq \overline{T}$, the algorithm always produces the same equilibrium.