Importing, Exporting, and Firms' Productivity Evolution in China

Yimin Yi*

Syracuse University

November, 2020

Click here for the latest version

Abstract

Firms display remarkable persistence in exporting and importing status. However, export and import status do not overlap perfectly, as some exporters do not import while some importers do not export. Motivated by these facts, I develop a dynamic discrete choice model of a firm's decision to import and export. A firm needs to pay either sunk costs to initiate an activity or fixed costs to maintain that activity, anticipating that the decision would impact its future productivity and expected revenue. Estimating the model for a range of Chinese industries, I find that both activities benefit a firm's future productivity. Then, I investigate the impact of trade liberalization and government subsidy policies on firms' importing and exporting behavior using the estimated model. A simulation of market expansion raises both exporting and importing participation rates and generates a modest increase in mean productivity. Subsidizing either the sunk costs or the fixed costs of one activity raises the activity's participation rate while discouraging the other activity. In addition, subsidizing the fixed costs of exporting generates a larger increase in total foreign market revenue than subsidizing the sunk costs of exporting.

*Email: yyi102@syr.edu. I am grateful to Devashish Mitra, Mary E. Lovely, and Mengxiao Liu for their continuous support and guidance throughout my Ph.D. I would also like to thank George Alessandria, Mostafa Beshkar, Kristy Buzard, Paola Conconi, Giovanni Maggi, David Kuenzel, Ahmad Lashkaripour, Philip Luck, Eric Verhoogen, Luhang Wang, and paticipants at the Syracuse University Trade Breakfast for helpful comments and discussions. Of course, I am responsible for all the errors.

1 Introduction

Understanding the relationship between firms' participation in international trade and performance remains a key question in international economics. A large trade literature has documented that exporting firms tend to be larger and more productive for a wide range of countries, e.g., Melitz (2003), Bernard et al. (2003), and Bernard et al. (2007).[1] There is also strong evidence showing that having access to imported inputs enhances firm performance (Amiti and Konings, 2007; Goldberg et al., 2010; De Loecker, 2011; Gopinath and Neiman, 2014; Blaum et al., 2018). Most of the literature on heterogeneous firms focuses on the static trade-off between export and not export or between import and not import. However, this neglects the dynamic trade-off that firms may face if there are learning by exporting or learning by importing effects. Some works have looked at one aspect of learning effects, such as Kasahara and Rodrigue (2008), Halpern et al. (2015), and Bøler et al. (2015) on the dynamic effect of importing or Van Biesebroeck (2005), Aw et al. (2011), De Loecker (2013), and Bai et al. (2017) on the dynamic effect of exporting, but little has been done to study these two dynamic effects jointly in a single framework.[2]

This article aims to fill in this gap by studying learning by importing and learning by exporting at the firm level within the same framework in the Chinese context. Learning by exporting refers to the mechanism whereby a firm boosts its performance after

[1] There seems a "paradox" for the world's largest exporter, China, as some evidence suggest that the opposite is true for Chinese exporters (e.g. Lu, 2010). However, Yu (2015) and Dai et al. (2016) argue that this "paradox" is entirely driven by the universality of processing exporters in China.

[2] Aw et al. (2011) also model firms' R&D activities and its effect on productivity. De Loecker (2013) also consider investment in the productivity process in one extension.

breaking into export markets. Similarly, learning by importing refers to the mechanism by which past import status has a positive effect on current productivity. Learning arises when connections to foreign consumers or suppliers facilitate the transmission or accumulation of knowledge that enables firms to improve product quality or enhance production technologies. Learning is more likely for firms in a developing country like China that sees plenty of room for improvement to catch up with the developed countries. Also, China's entry into the World Trade Organization (WTO) in 2001 enabled access to the world market for a large number of firms. In this sense, China provides an ideal context for studying this question.

Estimating the two dynamic effects within the same framework is important for the following reasons. First, there may be some common underlying factors that determine firms' import and export status. Without modeling the underlying determinants of import and export status, it is difficult to separate one activity's contributions from the other. Second, the knowledge learned by exporting and by importing may be complements or substitutes. Thus, the learning effect estimated by accounting for just one activity may be biased without explicitly controlling for the other. Third, simultaneously studying the two mechanisms provides additional insights regarding the evaluation and comparison of the effects of various policies, such as trade liberalization or government subsidies.

Using detailed firm-level data from a wide range of industries, I document a few facts regarding firms' import and export behavior in China.[3] First, only a small portion

[3] I select a few industries that contain a large number of firms and have a significant portion of exporters and importers each year. The industries selected are transportation equipment manufacturing, general machinery manufacturing, and the manufacture of plastics.

of firms engage in at least one activity, consistent with the literature that emphasizes substantial barriers to entering international markets. Second, firms display remarkable persistence in exporting and importing status. Firms that import in year t on average have at least 70% of probability to stay in the import market in year $t+1$, depending on which industry they are in. The probability of remaining in the export market in year t+1 is even larger for exporters in year t, surpassing 90%. High persistence of either activity may also suggest high sunk costs of entry, and the difference in the persistence between exporting and importing may reflect the difference in entry costs. Third, there is no perfect correlation between export and import status, as some exporters do not import while some importers do not export. No perfect correlation calls for heterogeneous factors in the determination of exporting and importing. Fourth, firms engaging in an activity in year t have a higher probability of adding a second activity in year $t+1$ than firms doing neither. The difference in the probability of adding an activity may suggest that the marginal return to one activity differs from the other activity's status.

Motivated by these stylized facts, I estimate a dynamic discrete choice model of importing and exporting in the spirit of Kasahara and Rodrigue (2008), Das et al. (2007), Aw et al. (2011), and De Loecker (2013), among others. The model emphasizes the substantial costs of participating in either activity and that firm-level import and export decisions evolve endogenously with firm-specific productivity and foreign market demand shocks. The model links importing and exporting through three mechanisms. First, the return to individual activity rises as the firm's productivity increases, which leads to the self-selection of more productive firms into both activities. Second, both activities' benign dynamic effects enhance firms' productivity over time for those who undertake imports or exports, reinforcing the selection effect. Third, trade liberalization or government subsidy can serve as exogenous catalysts that affect firms' incentives to invest in both activities and participation rates for both activities.

This paper structurally estimates the model in two stages. In the first stage, following the method by Das et al. (2007) and Aw et al. (2011), I estimate firm-level productivity consistently by accommodating an endogenous productivity process that incorporates both learning by importing and learning by exporting. De Loecker (2013) argues that econometric methods ignoring such an endogenous productivity process may lead to biased results and different conclusions. A critical insight of the method is to exploit firms' differential import and export behavior over time to identify the effect of importing and exporting on firm-level productivity. The firm-level productivity estimates, among other factors, are found to be significant and important determinants in import and export decisions.

In the second stage, with the estimates from the first stage, I solve firms' dynamic programming problems and estimate the sunk and fixed costs of importing and exporting and the process characterizing export demand shocks. The estimation relies on detailed information on firm-level import and export decisions and foreign market revenues among exporting firms. Intuitively, firms' entries of one activity provide information on the distribution of sunk costs of that activity. And firms' exits of an activity contain information on the fixed costs of that activity. Firms' foreign market revenues provide information on identifying the process characterizing export demand shocks. The model's dynamic parameters are estimated using both the Monte Carlo Markov chain method and the maximum likelihood method. The estimated model generates average import and export behavior across heterogeneous firms that matches well with the pattern found in the data.

The empirical results indicate that prior import and export status positively impact current productivity through the endogenous productivity process. For example, in the transportation equipment manufacturing industry, being an importer in year t raises mean productivity in year $t+1$ by 2.56% while the corresponding effect for exporting is 2.58%. Also, there are high sunk costs for both activities, and the sunk costs for exporting are much higher than those of importing. The sunk costs introduce a second inter-temporal linkage in firms' import and export decisions and explain import and export status persistence. The higher sunk costs of exporting rationalize the higher persistence of exporting.

The existence of the dynamic effects of import and export status on productivity and the substantial costs of engaging in both activities have important policy implications. Using the estimated model, I study the impact of trade liberalization and government subsidy policies on firms' import and export behavior. First, an expansion of foreign market size would increase the participation rates for exporting and importing by 4.828 and 0.781 percentage points, respectively, after 15 years. In addition, the expansion would lead to a 0.707% increase in mean productivity. The increase in mean productivity reflects the combination of increased export and import participation and benign dynamic effects on productivity after firms' self-selection into both activities. Second, subsidizing export costs raises the export participation rate but reduces the import participation rate, while subsidizing import costs has the opposite effect. For example, subsidizing the fixed costs of exporting by 25% leads to an increase in export participation rate by 2 percentage points but decreases import participation rate by 0.218 points after 15 years. The subsidy also leads to a 0.226% increase in mean productivity. However, *exporters* become less productive and sell less on foreign markets on average than when there is no subsidy. The reason is that firms with lower productivity are induced into the export market when there is a subsidy, while the positive effect of exporting on productivity is not enough to offset the decrease of mean productivity caused by self-selection.

This paper builds on the literature on export dynamics and learning by exporting. The early theoretical works by Baldwin and Krugman (1989), Dixit (1989a), and Dixit (1989b) suggest that sunk costs are important to explain the hysteresis in export markets. Roberts and Tybout (1997) and Bernard and Jensen (2004) provide empirical evidence of the sunk costs of exporting in Colombia and the United States, respectively. Das et al. (2007) develop and estimate a dynamic structural model of exporting incorporating firm heterogeneity and sunk costs of exporting. More recently, some papers have found evidence of learning by exporting (Van Biesebroeck, 2005; De Loecker, 2007, 2013).[4] Aw et al. (2011) estimate a structural model of R&D investment and exporting and find both activities have positive dynamic effects on productivity. Relatedly, Rho and Rodrigue (2016) investigate the role of investment in physical capital on export dynamics. In the Chinese context, Bai et al. (2017) compare the effects of learning by direct exporting and indirect exporting through intermediaries and provide cost estimates for each exporting mode. However, none of these papers has simultaneously looked at learning by exporting

[4] Most of the literature on the relationship between exporting and productivity finds little evidence of learning by exporting, e.g., Clerides et al. (1998), but more productive firms select into exporting, for example Bernard and Jensen (1999). See Greenaway and Kneller (2007) for a survey of this literature.

and learning by importing. This paper fills this gap and provides evidence that both learning effects are important in productivity evolution.

This paper is also related to the recent literature which structurally estimates models with heterogeneous firms to examine firms' importing decisions.[5] Kasahara and Lapham (2013) extend the work of Melitz (2003) to a dynamic model of exports and imports and provide estimates of sunk and fixed costs of trading. However, their model does not incorporate the linkage of importing and exporting on firms' future productivity and has nothing to say about learning effects. Ramanarayanan (2017) and Imura (2019) develop dynamic models of importing with sunk entry costs and find that these costs are important to explain the slow adjustments of trade flows. Halpern et al. (2015) use Hungarian data to study the effect of imported inputs on productivity and suggest that imported inputs contributed to one-quarter of Hungarian productivity growth for the period 1993 to 2002. Bøler et al. (2015) develop a model to analyze the relationship between investment in R&D and imports of intermediates inputs and find a complementary relationship between the two activities. A general message from this literature is that there are substantial entry costs of importing but importing also has substantial benefits. My paper also provides estimates of the sunk and fixed costs of importing. Moreover, I provide evidence of the interdependence between importing and exporting on firms' productivity.

This paper also contributes to a growing number of studies on the performance of Chinese manufacturing firms. Brandt et al. (2012) document that firms in China's

[5]There are also many reduced-form studies on this topic. In the Chinese context, Liu and Qiu (2016) and Chen et al. (2017) both study the impact of importing on Chinese firms' innovations but report mix results. Feng et al. (2016) find a positive effect of intermediate inputs on the volume and scope of exports.

manufacturing sector experienced dramatic growth in total factor productivity over the period 1998 to 2007. Brandt et al. (2017) look at China's accession to the WTO on the performance of manufacturing firms and find both cuts in output tariffs and input tariffs raise firms' productivity. Khandelwal et al. (2013) study the effect of eliminating export quotas on Chinese textile and clothing exporters and find that removing the quota leads to a substantial gain in productivity. Manova et al. (2015) show that foreign-invested firms perform better in the export market than private domestic firms in financially more vulnerable sectors and suggest that foreign direct investment contributes to China's export success. My paper complements this literature by providing evidence of the linkage between importing, exporting, and endogenous productivity growth of Chinese manufacturing firms.

The remainder of this paper proceeds as follows. In section 2, I describe data and stylized facts on firms' import and export activities, which motivates the development of the model. Section 3 presents a dynamic structural model of importing and exporting, and section 4 explains how I estimate the model using firm-level data of the transportation equipment manufacturing industry in China. Section 5 reports the estimation results and evaluate the model performance using the parameter estimates. Section 6 presents the results of two counterfactual experiments and discuss how different policies affect firms' outcomes. Finally, section 7 concludes.

2 Data and Stylized Facts

2.1 Data Source and Construction of the Sample

This study combines two datasets to explore firms' importing and exporting decisions over time. The first dataset is the Annual Survey of Industrial Enterprises (ASIE) collected by the National Bureau of Statistics of China starting from 1998. It is a typical firm-level data and has been widely used in economic researches related to China across various fields. The ASIE data investigates all state-owned enterprises (SOEs) and non-SOEs with annual revenue over 5,000,000 Chinese Yuan and contains firms' detailed information essential for productivity research, such as a firm's name, industry, ownership type, sales, capital stocks, and employment. The ASIE data also reports a firm's annual export value, which allows the inference of the firm's export status.

The second data is the transaction-level customs records collected by the General Administration of Customs of China. The data tracked exports and imports of Chinese firms through the customs between 2000 and 2006. A record includes product name, price, quantity, and f.o.b value in U.S. dollars at the Harmonized System 8-digit level. It also contains firm information necessary to match the ASIE data, such as the firm's name, address, zip code, and telephone number. Since the ASIE data lacks information about firms' import status, this information is inferred from the customs data. The customs data also provide information on whether an import or an export transaction is processing trade or ordinary trade, allowing classification of whether a firm is a processing or ordinary exporter.[6]

A challenge in the construction of the sample is to match the ASIE data with the

[6]There are mainly two types of processing trade, the first is pure assembly, and the second is processing with imported materials. Pure assembly is also referred to as "processing with supplied materials" or "processing with assembly".

customs data. Since these two data sets do not share the same firm identifier, some fuzzy matching techniques are needed. This study follows the procedure in Yu (2015) and uses a firm's name, zip code, and the last seven digits of the phone number to match the ASIE data with the customs data. Observing that there is a significant portion of firms missing names in the customs data, I enhance the matching procedure by first filling in missing names of firms using names available from other years.[7] Using this matching procedure, more than 50% of exporters (9, 523 out of 18, 387) in the ASIE data in industries of transportation equipment manufacturing, general machinery manufacturing, and manufacture of plastics between 2003 and 2006 can be matched to the customs data. These matched exporters account for around 61.6% of export value in the ASIE data for these three industries. The matching rate is higher than what Yu (2015) and Dai et al. (2016) report since the matching procedure has partly resolved the issue of missing firm names in the customs data.

After matching the two data sets, I impose a few restrictions on the matched data to construct the sample. First, since information on total sales, intermediate inputs, employment, and the real capital stock is necessary to estimate firm productivity, I exclude firms reporting missing or non-positive values for any of the above variables. Second, there is an attrition issue in the ASIE data partly because the National Bureau of Statistics of China only survey non-SOE firms with revenue of over 5 million Chinese Yuan. Since I need information about a firm's previous year state in the dynamic estimation and can not infer the firm's states in years that it does not appear in the survey, I exclude firms that intermittently appear in the dataset. Namely, firms appear only

[7] The details of the matching procedure are available upon request.

in a single year or more than two non-consecutive years are dropped from the sample. Exclude these firms would drop around 20% of the observations. Third, as Brandt et al. (2014) suggests, many private firms could only export through trade intermediaries before 2004 in China. The Chinese government gradually eliminated restraints on direct exporting following China's entry into the World Trade Organization. Bai et al. (2017) find that firms exporting through intermediaries incur significantly fewer costs to access the exporting market than firms exporting directly. Thus, I exclude pure producer intermediaries that do not report positive export in the ASIE data but have records in the customs data. Also, there is a large portion of Chinese exporting firms engages in processing export. Yu (2015) and Dai et al. (2016) find that processing exporting firms differ substantially from ordinary exporting firms in terms of sunk costs and learning opportunities. For this reason, I exclude these processing firms that import for processing purposes in the customs data from my main sample. Lastly, to have values comparable over the years, I use the input and output deflators from Brandt et al. (2012) to convert all monetary values to 1998 Chinese Yuan.

In the next section, I document a few facts about firms' importing and exporting behavior for three Chinese manufacturing industries during the sample period from 2003 to 2006. Of the wide range of industries covered by ASIE data, I focus on transportation equipment manufacturing (Chinese Industry Classification code, abbreviated as CIC afterward, 37), general machinery manufacturing (CIC 35), and plastics manufacturing (CIC 28). The reason is that these three industries all have a relatively large number of firms and a large percentage of importers and exporters each year. These industries were also growing fast during the period and contributed substantially to total exports in China.

2.2 Summary statistics and Stylized Facts about Importing and Exporting

This section documents three basic facts about firms' importing and exporting behavior in the data, which will guide the development of the formal model in section 3. I first explore the composition of firms by exporting and importing status over the years. Then I compare a few firm size measures by firm type. Finally, I examine how firms' importing and exporting status change over the years and how firms change their types.

Fact 1. *Only a small portion of firms export or import or do both.*

Table 1 presents firms' composition over the years for the transportation equipment manufacturing industry. The number of firms is increasing over the years except from 2005 to 2006, reflecting the Chinese economy's fast-growing feature.[8] The percentage of firms in each category generally remain stable. There are around 10% of firms engage in at least one activity every year. This fact is consistent with the evidence presented in the literature, e.g., Bernard and Jensen (1999) and Melitz (2003), that only a small percentage of firms exports. Because firms may encounter significant barriers such as high sunk costs or extensive competition pressure when entering the foreign market; thus, firms export only when they can break these barriers. Firms may also face enormous entry costs in the import market. Thus self-selection is also present in importing decisions.

[8] The decrease of observations from 2005 to 2006 is because the sample only includes firms with two or more than two years of consecutive appearance, which would lead to more observations in the years 2004 and 2005.

Table 1: Composition of different types of firms across years.

Year	Firm type								
	Neither		**Only import**		**Only export**		**Both**		Total
	No.	%	No.	%	No.	%	No.	%	No.
2003	3966	91.49	147	3.39	94	2.17	128	2.95	4335
2004	6812	89.50	248	3.26	247	3.25	304	3.99	7611
2005	7395	88.83	253	3.04	304	3.65	373	4.48	8325
2006	6550	89.12	219	2.98	288	3.92	293	3.99	7350

Notes: This table shows the number and percentage of each type of firm from 2003 to 2006 in the transportation equipment manufacturing industry.

Fact 2. *Firms that import or export are relatively larger than firms that do neither. In particular, firms that do both importing and exporting are among the largest in the industry.*

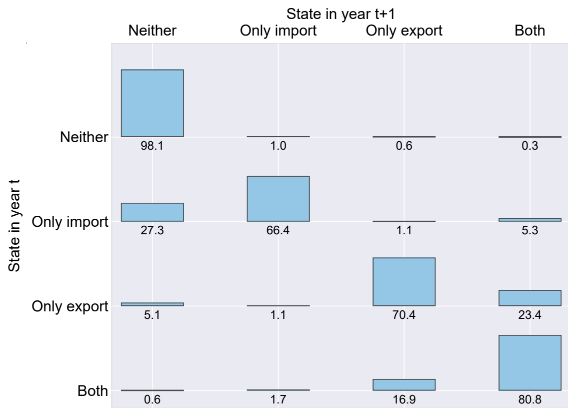
Table 2 reports some firm size measures by firm type. Firms that either import or export employ more workers, have larger capital stock, and sell more domestically than firms that neither import nor export, on average. Also, firms that both import and export are larger than firms that only engage in one activity. Table 2 also shows that the distributions of firm size measures are highly skewed to the right as the mean is significantly larger than the median for each measure of all firm types. It is even more so for firms that do both importing and exporting. For example, for domestic sales, the mean is more than ten times larger than the median for firms do both, while the corresponding number is around five for firms only export and three for firms only import.

The relatively larger size of importers and exporters has different interpretations. It may reflect high barriers to importing or exporting, namely only large firms can self-select to import or export. Alternatively, it may also be the result of learning effects, i.e., firms that import or export become larger as they learn by importing or exporting and grow faster than non-importers or non-exporters over the years. Most likely, both mechanisms contribute to the relatively larger size of importers and exporters.

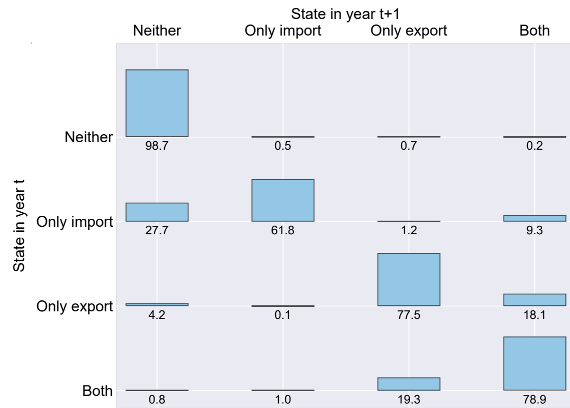
Exporters also demonstrate some differences from importers. Though firms that only import employ fewer workers than firms that only export, they have access to more capital and sell twice as much as firms that only export domestically. The correlation between firms' import values and export values is 0.275. The difference in import and export participation suggests that there may be different factors that are important determinants of each activity's return. Firms with favorable values of importing determinants self-select into importing while firms with favorable values of exporting determinants self-select into exporting.

Fact 3. *Firms' importing and exporting status are highly persistent over the years. In particular, firms' exporting status is more persistent than importing status.*

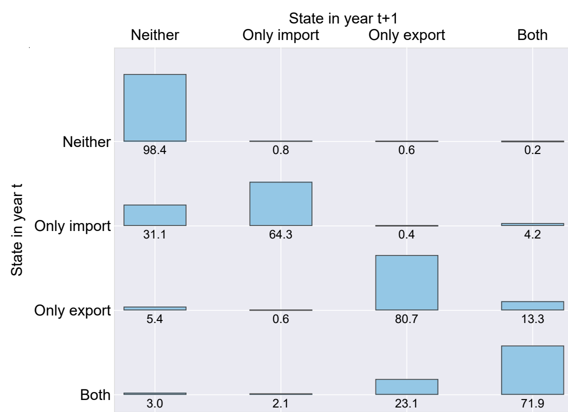
Subfigure (1a), (1b), and (1c) of figure 1 presents the transition pattern among importing and exporting in industry transportation equipment, general machinery, and manufacture of plastics, respectively. The first row of numbers in each subfigure shows the percentage of firms' status in year $t+1$ for firms did neither importing nor exporting in year t. Similarly, the second, third, fourth row of each subfigure report proportion of firms falling in each status in year $t+1$ if the previous year's status is only import, only export, and both, respectively.



(a) Transportation equipment (CIC 37)



(b) General machinery (CIC 35)



(c) Manufacture of plastics (CIC 30)

Figure 1: Annual transition rates of importing and exporting status.

Table 2: Summary statistics of firm size by firm type.

Variable	Firm type							
	Neither		**Only import**		**Only export**		**Both**	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Employment	198.58	98.00	321.03	149.00	377.77	160.00	742.47	278.00
Capital	15.92	3.73	63.90	20.28	27.23	6.17	154.30	24.38
Domestic revenue	60.02	17.09	208.24	66.32	103.15	19.19	527.77	47.29
Foreign revenue	0.00	0.00	0.00	0.00	22.64	8.23	55.67	14.14

Notes: This table presents mean and median of some firm size measure. Capital, domestic and foreign revenue are real values and in millions Chinese Yuan.

Several patterns are evident in these figures. First, firms' status is highly persistent over the years. Of the firms that engaged in neither activity in year t, more than 98% of them do not start any activity in the following year. There are only small probabilities, both close to 1%, for firms to start importing or exporting. Similarly, more than 61%, 70%, and 71% of the firms remain in the same category for the other three categories, and there is relatively little variation across industries. The high persistence of status over the years may reflect high sunk costs of starting importing or exporting or reflect a high degree of persistence in the determinants of firms' self select into these activities, or a combination of both.

Second, firms are more likely to remain exporting than remain importing. Of the firms that only import in year t, they have at least a 0.284 probability of stopping import, while the probability of stopping is at most 0.062 for firms that only export.[9]

[9]This probability of stopping import is the summation of the probability from only import to neither and the probability from only import to only export. The least is from the transportation equipment

The difference in the persistence of importing and exporting may come from different sunk/fixed costs for the two activities. It may also be from the difference in the long-run payoffs generated by learning-by-importing and learning-by-exporting effects.

Third, firms engaging in one of the activities in year t have a higher probability of undertaking the other activity in year $t+1$ than firms that do neither. Specifically, firms only import in year t have at least a 4.6% probability of starting export. Firms only export in year t have at least a 13.9% probability of importing while these probabilities are close to 1% for firms do neither.

Fourth, firms that undertake both activities are less likely to drop any activities than firms only do one of them. For example, in the industry of general machinery, firms do both importing and exporting in year t have a 0.201 probability of abandoning import and a 0.018 probability of dropping export in year $t+1$. In contrast, the corresponding probabilities are 0.289, and 0.043 for firms only import and only export, respectively. The third and fourth points combined to indicate the inter-dependence in importing and exporting decisions and highlight the need to model importing and exporting jointly.

Overall, these facts call for a model to explain how firms self-select into import and exporting and how these decisions are inter-connected.

3 A Dynamic Model of Importing and Exporting

Motivated by the stylized facts in the data section, I develop a dynamic structural model of exporting and importing. The model is based on the models of exporting developed

industry: $0.273 + 0.011$. Similarly, the largest probability of stopping export also come from the transportation equipment industry: $0.051 + 0.011$.

by Roberts and Tybout (1997), Das et al. (2007), and De Loecker (2011), the model of learning by importing of Kasahara and Rodrigue (2008), and the model of exporting and investing on R&D by Aw et al. (2011).

The model incorporates several key considerations. First, heterogeneous firms differ in their productivity, marginal cost, and export demand shocks they face. Second, in every period, a firm needs to pay sunk costs if it is not an exporter or fixed costs to maintain its exporting status. Also, the firm may choose to source intermediate inputs from foreign markets. If the firm wants to import, it also faces different sunk or fixed importing costs depending on its previous importing status. Third, a forward-looking firm undertakes both activities based on its current profit and future value. These actions, in turn, impact the evolution of their future productivity.

The model proceeds in two sections. The first section models the firm's static decisions, including how its demand and supply are determined and how its productivity determines its short-run profits in domestic and foreign markets. The second section then asks how the firm makes its dynamic decisions regarding exporting and importing, facing sunk costs or fixed costs.

3.1 Static Decisions

3.1.1 Firm's Demand

Firms are assumed to compete monopolistically in segmented domestic and foreign markets by selling a single product. Segmentation rules out the strategic competition but does allow firms to charge different markups across markets. In a monopolistic competitive domestic market, the demand curve faced by firm j is of the Dixit-Stiglitz form

$$Q_{jt}^d = Q_t^d(\frac{P_{jt}^d}{P_t^d})^{-\eta^d} = \frac{I_t^d}{P_t^d}(\frac{P_{jt}^d}{P_t^d})^{-\eta^d} = \Phi_t^d(P_{jt}^d)^{-\eta^d}, \tag{1}$$

where I_t^d is the aggregate expenditure in domestic market at period t (superscript d denotes domestic), which is the product of industry aggregate output Q_t^d and price index P_t^d. And η^d is the absolute value of the elasticity of demand. Collecting all industry-level aggregates into Φ_t^d, then firm j's domestic demand Q_{jt}^d is determined by aggregate market size Φ_t^d, the demand elasticity η^d, and the price of the firm P_{jt}^d.

Similarly, if firm j participates in the export market, its foreign demand has the form of

$$Q_{jt}^f = \Phi_t^f(P_{jt}^f)^{-\eta^f} \times \exp(\nu_{jt}), \tag{2}$$

which says foreign demand Q_{jt}^f is determined by the export market aggregate (superscript f denotes foreign) Φ_t^f, the absolute value of the export demand elasticity η^f, and the export price P_{jt}^f. One additional component is the foreign demand shock ν_{jt}, which allows a firm's relative demand in the domestic and foreign markets to varying across firms and over time. The foreign demand shock can be interpreted as factors that impact the foreign market differently from the domestic market or affect the foreign demand relative to the domestic demand. The firm is assumed to make its export decision after observing ν_{jt}, but ν_{jt} is not observable to the researcher.

3.1.2 Firm's Supply

On the supply side, following Das et al. (2007), I assume marginal costs are identical across domestic and foreign markets and are not responsive to output shocks for a firm.

This assumption implies that shocks affecting the domestic demand do not impact the optimal level of export. Thus, a firm's domestic revenue and profit are independent of the output level of export. As in Bai et al. (2017), the short-run marginal cost takes the form of

$$C_{jt} = C(K_{jt}, W_{jt}) \times \exp(-\omega_{jt}) \tag{3}$$

where W_{jt} denotes a vector of firm-year specific factor prices such as intermediate input prices, and K_{jt} is the firm's capital stock. The inclusion of a firm's capital stock captures marginal cost heterogeneity arising from firm size difference. In addition, marginal cost is decreasing in firm-specific productivity ω_{jt}. Since firm-specific factor prices are not observable in the data, I use year dummies and 4-digit Chinese industry dummies as proxies. Use lowercase variables to denote log values; the short-run marginal cost is specified as

$$c_{jt} = \beta_0 + \beta_k k_{jt} + \sum_{t=1}^{T} \beta_t D_t + \sum_{o=1}^{O} \beta_o D_o - \omega_{jt}, \tag{4}$$

where D_t denotes year dummy, and D_0 is industry dummy at the 4-digit CIC level.

After observing its demand curves and marginal cost, firm j chooses prices in each market to maximize its profits. For the specific demand curves faced by the firm, maximize profits will lead to the following pricing rules: $P^d_{jt} = \frac{\eta^d}{\eta^d - 1} C_{jt}$ and $P^f_{jt} = \frac{\eta^f}{\eta^f - 1} C_{jt}$, i.e., the firm charges constant but different markups for the domestic market and foreign market depending on the elasticity of demand in the domestic market and foreign market. The pricing rule in the domestic market implies that domestic market revenue

$$r^d_{jt} = \phi^d_t + (1 - \eta^d) \ln(\frac{\eta^d}{\eta^d - 1}) + (1 - \eta^d)(\beta_0 + \beta_k k_{jt} + \beta_t D_t + \beta_o D_o - \omega_{jt}), \tag{5}$$

and foreign market revenue

$$r_{jt}^{f}=\phi_{t}^{f}+(1-\eta^{f})\ln(\frac{\eta^{f}}{\eta^{f}-1})+(1-\eta^{f})(\beta_{0}+\beta_{k}k_{jt}+\beta_{t}D_{t}+\beta_{o}D_{o}-\omega_{jt})+\nu_{jt}. \quad (6)$$

The above two equations suggest firm's revenue depends on the aggregate market condition in each market (captured by ϕ_t^d and ϕ_t^f for domestic and foreign market, respectively), firm's capital stock (k_{jt}), and productivity (ω_{jt}). The term ω_{jt} enters both equations and is referenced as "productivity". However, it could include factors that impact a firm's marginal cost and revenue in domestic and foreign markets. These factors may include characteristics of the firm's product, e.g., product quality, that would affect the firm's product demand in both markets. There is an additional term ν_{jt} in the foreign revenue equation (6). Since this term affects foreign market demand and thus, revenue from the foreign market alone, I will refer to it as foreign demand shocks henceforth. Foreign demand shocks capture firm-time specific heterogeneities from either the demand or cost side that operates in the foreign market alone.

Given that firms compete monopolistically in both markets and the Dixit-Stiglitz form of consumer preference, a firm's profit can be linked to the firm's revenue in each market. The firm's domestic market profit is

$$\Pi_{jt}^{d}=Q_{jt}^{d}P_{jt}^{d}-Q_{jt}^{d}C_{jt}=Q_{jt}^{d}P_{jt}^{d}(1-\frac{\eta^{d}-1}{\eta^{d}})=\frac{1}{\eta^{d}}R_{jt}^{d}(\Phi_{t}^{d},k_{jt},\omega_{jt}), \quad (7)$$

and the potential foreign market profit is

$$\Pi_{jt}^{f}=\frac{1}{\eta^{f}}R_{jt}^{f}(\Phi_{t}^{f},k_{jt},\omega_{jt},\nu_{jt}). \quad (8)$$

Observing its potential profit in the foreign market, together with the firm's drawing of sunk or fixed costs from the corresponding distributions and anticipating how exporting would impact its productivity evolution, the firm decides whether to export.

3.2 Transition of State Variables

Before solving the firm's dynamic optimization problem for exporting and importing, I first describe how the firm's state variables evolve over time. The state variables include productivity ω_{jt}, foreign demand shocks ν_{jt}, capital stock k_{jt}, and aggregate market variables ϕ_t^d and ϕ_t^f.

I assume the firm's current productivity depends on its previous period productivity, exporting status as in Aw et al. (2011) and De Loecker (2013), and importing status as in Kasahara and Rodrigue (2008). Specifically, it is assumed that productivity follows a Markov process where productivity at time $t+1$ consists of an expected component given the firm's information set at time $t+1$ and a random component as:

$$\begin{aligned}\omega_{j,t+1} &= g(\omega_{jt}, i_{jt}, e_{jt}) + \xi_{j,t+1} \\ &= \alpha_0 + \sum_{n=1}^{3} \alpha_n \omega_{jt}^n + \alpha_4 i_{jt} + \alpha_5 e_{jt} + \alpha_6 i_{jt} \times e_{jt} + \xi_{j,t+1} \qquad (9)\end{aligned}$$

where i_{jt} and e_{jt} represent whether the firm engages in importing and exporting at time t, respectively. The g function is the component anticipated by the firm given its information set while $\xi_{j,t+1}$ the random component. The term $\xi_{j,t+1}$ represents a i.i.d random shock with zero mean and variance σ_ξ^2. Moreover, by assumption, it is uncorrelated with any lagged choice variables of the firm and captures how randomness plays in the evolution of a firm's productivity.

The second line of equation (9) gives the specific functional form of the Markov process: a cubic polynomial of lagged productivity and a full set of interactions between lagged importing and lagged exporting. First, by including the lagged importing dummy i_{jt}, I examine the possibility of "learning by importing" as in Kasahara and Rodrigue (2008). Learning by importing refers to the mechanism whereby a firm's performance (productivity here) improves after bursting into the import market. Hence, α_4 is expected to be positive if there is learning by importing. Second, the inclusion of lagged exporting dummy e_{jt} allows me to examine the possibility of "learning by exporting". Learning by exporting may happen if a firm can gain knowledge or expertise and improve its future productivity by participating in the export market.[10] I also include an interaction term between lagged importing and lagged exporting to examine the relationship between two learning mechanisms. If learning by importing further enhances knowledge gaining in the export market, namely, the two learning effects complement each other, I expect the coefficient of the interaction term α_6 to be positive. Otherwise, if two learning mechanisms are not complements but substitutes, the coefficient α_6 will be negative. This may happen when, for example, part of knowledge or expertise gaining could come from either activity. Or having access to imported high-quality varieties may reduce the firm's incentive to expand its knowledge capacity. Lastly, by including lagged productivity ω_{jt} and two lagged decision variables, I can separate the roles of the sorting of productivity into two activities and two learning mechanisms. A common observation

[10] De Loecker (2013) argues that one could not detect learning by exporting if not accommodate it endogenously into the productivity process. Here I include both lagged dummies and try to incorporate both learning effects endogenously.

established by recent trade literature is that firms are sorted into different exporting modes based on their productivity levels (Melitz, 2003). Sorting may also happen for importing if breaking into international sourcing needs to pay high sunk costs. Thus, the inclusion of lagged productivity controls for potential sorting into exporting and importing.

Another state variable is the demand shocks faced by the firm in the export market. The export demand shock is assumed to follow a first-order Markov process

$$\nu_{j,t+1} = \rho_\nu \nu_{jt} + \mu_{j,t+1}, \mu_{j,t+1} \sim N(0, \sigma_\mu^2). \tag{10}$$

An AR(1) process for export demand shock will capture the source of persistent firm-level heterogeneity and allows no perfect cross-section correlation between domestic and foreign market revenue. The persistence may arise because of firms' productivity characteristics, brand effects, or set of destination countries they export to. Also, together with stochastic sunk entry cost and fixed cost, it allows imperfect sorting into exporting.

State variables remaining are k_{it}, ϕ_t^d, and ϕ_t^f. It is quite reasonable that firms also make dynamic choices accumulating capital. However, given the paper's focus and the relatively short period of the data, capital stocks will be treated as fixed over time. For computational simplicity, the other two market aggregate variables will be treated as fixed and controlled by time dummies.

3.3 Dynamic Decisions–Export and Import Market Participation Rule

This section analyzes how a firm makes dynamic decisions about whether to export and import. The firm's dynamic decision-making hinges on comparing the marginal cost and the marginal benefit for each activity. The marginal cost is the cost of participating in an activity. The marginal benefit depends on the difference between the expected value of taking an activity and the expected value of not taking that activity.

The firm's cost structure takes the following form. A firm that is not already in the import market needs to incur the sunk costs of importing, including learning about international suppliers, establishing a supply network, and dealing with bureaucratic procedures. A firm that is an importer already also needs to pay some fixed costs each period to maintain its importing status. These fixed costs may include, e.g., the costs of maintaining the distribution network and monitoring suppliers' product quality. Similarly, a firm that does not participate in the export market also needs to pay a nonrecoverable sunk cost to become an exporter, as in Roberts and Tybout (1997) and Das et al. (2007). While an exporter can exit the export market, it needs to incur some fixed costs if it wants to stay.

In every period, a forward-looking firm chooses actions $a_{jt} \in A$ to maximize the expected profit based on the state variables s_{jt}. The value function is defined as the maximum of the discounted sum of expected profits as

$$V(s_{jt}) \equiv \max_{\{a_{jt}, a_{j,t+1}, \dots\}} E\left[\sum_{\tau=t}^{\infty} \delta^{\tau} U(s_{j\tau}, a_{j\tau} | a_{jt}, s_{jt})\right] \tag{11}$$

where $U(s_{jt}, a_{jt})$ is the current period profit function of choosing action a_{jt}. Then, the value function can be obtained by applying Bellman's principle of optimality using the recursive expression

$$V(s_{jt}) = \max_{a_{jt}} \left\{ U(s_{jt}, a_{jt}) + \delta \int V(s_{j,t+1}) dF(s_{j,t+1} | a_{jt}, s_{jt}) \right\}. \tag{12}$$

A firm decides whether to export or import at time t based on the state variables s_{jt}. An action here is a combination of exporting and importing, namely $a_{jt} = (e_{jt}, i_{jt})$. To simplify estimation, I follow Aw et al. (2011) and make a timing assumption that the firm first makes its exporting decision. After that, it decides whether to import.[11] The state variables before a firm's exporting decision are

$$s_{jt} = (\omega_{jt}, \nu_{jt}, k_{jt}, \phi_t^d, \phi_t^f, i_{j,t-1}, e_{j,t-1}).$$

That is, the firm observes its current productivity, demand shocks, capital stock, aggregate market conditions, and past import and export status before deciding whether to export. Past export status becomes part of the state variables because it will determine whether the firm needs to incur sunk costs to become a new exporter or fixed costs to maintain its exporting status. In addition, as shown in equation (9), the firm's import and export decisions can impact its future productivity, establishing an additional inter-temporal linkage through the endogenous productivity process.

Knowing s_{jt}, the firm's value function before it observes its realization of sunk cost

[11] Alternatively, a firm may choose whether to import or export at the same time. In this case, four combinations of importing and exporting are possible, and the model becomes a multinomial model. However, this makes the computation of the probability of each outcome more difficult.

or fixed cost of exporting can be written as an integral over these costs as

$$V(s_{jt}) = \int \max_{e_{jt}\in\{0,1\}} \Big\{ U(s_{jt}|e_{jt}=1,\gamma_{jt}) + V^f(s_{jt}), U(s_{jt}|e_{jt}=0,\gamma_{jt}) + V^d(s_{jt}) \Big\} dG_\gamma \quad (13)$$

where $U(s_{jt}, e_{jt}|\gamma_{jt})$ is the current period payoff as

$$U(s_{jt}|e_{jt},\gamma_{jt}) = \begin{cases} \Pi^d_{jt} + \Pi^f_{jt} - e_{j,t-1}\gamma^F_{jt} - (1-e_{j,t-1})\gamma^S_{jt}, & \text{if } e_{jt}=1 \\ \\ \Pi^d_{jt}, & \text{if } e_{jt}=0, \end{cases} \quad (14)$$

and $V^f(s_{jt})$ and $V^d(s_{jt})$ nest the discounted expected value part in Equation (12), namely $\delta \int V(s_{j,t+1}) dF(s_{j,t+1}|a_{jt}, s_{jt})$, for exporter or non-exporter after it make its optimal importing decision, respectively.[12] The firm draws sunk or fixed costs from a known joint distribution G_γ in each period.[13] Following Aw et al. (2011), I assume the distributions of sunk costs and fixed costs are of different exponential distributions, of which the positional parameters characterizing these exponential distributions are estimated in the empirical section.

Equation (14) suggests that the firm will only obtain domestic profit if it chooses not to export at the current period. Otherwise, it can reap additional foreign market profit but at the expense of some cost depending on its prior export status. The firm pays either the sunk cost γ^S_{jt} ($e_{j,t-1}=0$) or the fixed cost γ^F_{jt} ($e_{j,t-1}=1$) if it chooses to

[12] Specifically, $V^f(s_{jt}$ is the value that a_{jt} takes the value of ($e_{jt}=1, i_{jt}=i^*_{jt}$), i.e., $V^f(s_{jt}) = \delta \int V(s_{j,t+1}) dF(s_{j,t+1}|a_{jt}=[1,i^*_{jt}], s_{jt})$, where i^*_{jt} refers to the optimal importing decision the firm makes. Analogously, $V^d(s_{jt}) = \delta \int V(s_{j,t+1}) dF(s_{j,t+1}|a_{jt}=[0,i^*_{jt}], s_{jt})$.

[13] Here G_γ is a general form of the cumulative distribution function of the four different costs. Namely, γ could be one of $\gamma^F, \gamma^S, \gamma^G$ or γ^R.

export. The firm chooses to export if the relevant sunk or fixed cost is lower than the current plus expected gain in future export profits, namely

$$e_{j,t-1}\gamma_{jt}^{F} + (1 - e_{j,t-1})\gamma_{jt}^{S} < \Pi_{jt}^{f} + V^{f}(s_{jt}) - V^{d}(s_{jt}). \tag{15}$$

The trade-off is that the firm needs to pay either sunk costs or fixed costs (depending on $e_{j,t-1}$) but can reap export profit and change its productivity path, hence the value of the firm, through the link between productivity and exporting as shown in equation (9). After making its export decision, the state vector before the firm's import decision becomes

$$s_{jt} = (\omega_{jt}, \nu_{jt}, k_{jt}, \phi_t^d, \phi_t^f, i_{j,t-1}, e_{jt}).$$

An important distinction from the state vector before exporting is that not the past export status but the *current* export status enters the state vector because of the timing assumption of exporting and importing. The value of importing is subsumed in $V^f(s_{jt})$ and $V^d(s_{jt})$. Specifically,

$$\begin{aligned} V^f(s_{jt}) = \int \max_{i_{jt}\in\{0,1\}} \Big\{ & \delta E_t V(s_{j,t+1} | e_{jt} = 1, i_{jt} = 1) - i_{j,t-1}\gamma_{jt}^{G} - (1 - i_{j,t-1})\gamma_{jt}^{R}, \\ & \delta E_t V(s_{j,t+1} | e_{jt} = 1, i_{jt} = 0) \Big\} dG_\gamma. \end{aligned} \tag{16}$$

This says that the firm needs to incur some costs, which depend on its prior importing status if it chooses to import at the current period. If the firm was not an importer ($i_{jt} = 0$), it pays the sunk entry cost γ_{jt}^R, otherwise ($i_{jt} = 1$), it pays the fixed cost γ_{jt}^G. The trade-off is that investing in importing may have a beneficial effect on the firm's future productivity, as in equation (9), hence changes its productivity path and improves its future value. The larger the beneficial effect of importing on future productivity, the larger the differential benefit between importing versus not importing, the more likely the firm will participate in the import market. Similarly, the value of importing for a non-exporter is

$$V^d(s_{jt}) = \int \max_{i_{jt}\in\{0,1\}} \Big\{ \delta E_t V(s_{j,t+1}|e_{jt}=0, i_{jt}=1) - i_{j,t-1}\gamma^G_{jt} - (1-i_{j,t-1})\gamma^R_{jt}, \\ \delta E_t V(s_{j,t+1}|e_{jt}=0, i_{jt}=0) \Big\} dG_\gamma \tag{17}$$

where a non-exporter faces the same trade-off but may experience different future productivity paths and expected values compared to an exporter. Finally, the expected future value function based on different choices of exporting and import is

$$E_t V(s_{j,t+1}|e_{jt}, i_{jt}) = \int_{\Phi'}\int_{\nu'}\int_{\omega'} V(s')f(\omega'|\omega_{jt}, e_{jt}, i_{jt})f(\nu'|\nu)f(\Phi'|\Phi)d\omega' d\nu' d\Phi'. \tag{18}$$

The expected value can be computed as we have assumed the transition rules of ω, ν, and Φ in section 3.2.

Given the expected values, for any state vector, the marginal benefit of importing can be defined as

$$MBI(s_{jt}|e_{jt}) = E_t V(s_{j,t+1}|e_{jt}, i_{jt}=1) - E_t V(s_{j,t+1}|e_{jt}, i_{jt}=0). \tag{19}$$

The firm will choose to import if the (discounted) marginal benefit of importing exceeds the marginal cost of importing. The marginal cost is the sunk cost of importing $\gamma^R_{j,t}$ if the firm import in the prior period or the fixed cost of importing $\gamma^G_{j,t}$ if the firm does not import in the prior period. Namely, the firm will import if

$$i_{j,t-1}\gamma^G_{jt} + (1 - i_{j,t-1})\gamma^R_{jt} < \delta * \Big[E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 1) - E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 0)\Big]. \quad (20)$$

Two things worth noting here. First, the marginal benefit of importing depends on how importing affect future productivity. Better learning-by-importing effect increases the continuation value as an importer and thus increases $MBI(s_{jt}|e_{jt})$. Second, $MBI(s_{jt}|e_{jt})$ will be generally different for exporters and non-exporters because of the inter-temporal link created by the sunk costs of exporting and the direct impact of exporting on future productivity. In a special situation where there is no sunk costs of exporting ($\gamma^s_{jt} = 0$) and no dynamic effect of exporting on productivity ($\alpha_5 = \alpha_6 = 0$ in equation (9)), exporting will not be a dynamic decision and $MBI(s_{jt}|e_{jt})$ no longer a function of e_{jt}, namely, exporters and non-exporters will not value importing differently.

Similarly, we can also define the marginal benefit of exporting for any state vector as

$$MBE(s_{jt}|i_{j,t-1}) = \Pi^f_{jt}(s_{jt}) + V^f(s_{jt}|i_{j,t-1}) - V^d(s_{jt}|i_{j,t-1}), \quad (21)$$

which suggests that there are two parts of benefits from exporting. First, exporting provides static foreign market profits $\Pi^f_{jt}(s_{jt})$ as in Equation (8). In addition, there is a dynamic benefit that captures the difference in the future payoff between being in the foreign market $V^f(s_{jt}|i_{j,t-1})$ and selling only domestically $V^d(s_{jt}|i_{j,t-1})$. The marginal benefit of exporting also depends on prior importing choice, in general, if there is a sunk cost to break into import market. In a special case of no sunk of importing ($\gamma^R_{jt} = 0$)

and importing has no dynamic effect on productivity ($\alpha_4 = \alpha_6 = 0$ in equation (9)), $V^f(s_{jt}|i_{j,t-1})$, $V^d(s_{jt}|i_{j,t-1})$ and thus $MBE(s_{jt}|i_{j,t-1})$ will be independent of $i_{j,t-1}$, i.e., importers and non-importers will have the same valuation of exporting.

In this model, both importing and exporting's net benefits increase as the firm's current productivity rises, which leads to the selection channel where high productivity firms self-select into exporting and importing.

In addition, since there are two choice variables in the model, another interesting aspect is how the two decision variables are interdependent. As we have noted earlier, generally, $MBI(s_{jt}|e_{jt})$ are different for exporters and non-exporters and $MBE(s_{jt}|i_{j,t-1})$ also vary for importers and non-importers. Two factors determines the difference of $MBI(s_{jt}|e_{jt})$ between exporters and non-exporters. The first is the sunk cost of exporting, and the second is the interaction effect between importing and exporting on productivity, which is defined by the coefficient α_6 in equation (9). The incremental effect of exporting on the return to importing can be defined as

$$\Delta MBI(s_{jt}) = MBI(s_{jt}|e_{jt} = 1) - MBI(s_{jt}|e_{jt} = 0).$$

Similarly, the difference in the marginal benefit of exporting between importers and non-importers can be defined as

$$\Delta MBE(s_{jt}) = MBE(s_{jt}|i_{j,t-1} = 1) - MBE(s_{jt}|i_{j,t-1} = 0)$$

If importing and exporting are compliments on the firm's productivity, then α_6 will be positive, and importing will be more valuable to exporters and $\Delta MBI(s_{jt}) > 0$. This is possible if the firm could learn distinct knowledge by importing than by exporting. For example, the firm may obtain expertise to improve its production process by importing but acquire knowledge to enhance its product quality by exporting. These two types of knowledge could complement each other. Then, there are increasing returns to activities, i.e., productivity will increase more when the firm adds the second activity.[14] As α_6 decrease, $\Delta MBI(s_{jt})$ will also decline or may even become negative. α_6 becomes negative when importing and exporting are substitutes for the firm's productivity. The interpretation could be that importing and exporting are two tools to learn about the international market. Engage in one activity worsen the return to the other, and thus there are decreasing returns to activities. If this is the case, the firm's productivity will decline as it adds the second activity.

To summarize the model, firms differ in their productivity, capital stocks, foreign demand shocks, and prior export market participation experience. These factors determine both short-run domestic and foreign market profits. Firms make optimal dynamic decisions about whether to participate in the import market and export market, which require some sunk or fixed costs, in return for productivity improvement and, thus, a rise in future profits.

4 Empirical Model and Implementing of Estimation

To estimate the parameters characterizing the theoretical model, I employ a two-stage approach following Das et al. (2007), Aw et al. (2011), and Bai et al. (2017). The

[14] Bøler et al. (2015) estimate a model of R&D and international sourcing and find evidence that R&D and international sourcing are complements on firm performance. Aw et al. (2011) report results that exporting and R&D are substitutes on plants' productivity for the electronics industry in Taiwan.

model's key parameters include the sunk and fixed costs of exporting and importing and the parameters characterizing the foreign market shocks and the productivity evolution process.

In the first stage, following the proxy literature of productivity estimation, e.g., Levinsohn and Petrin (2003) and Ackerberg et al. (2015), I estimate the domestic revenue function and the productivity evolution process jointly in a two-step procedure. This two-step procedure's outcomes include a measure of firm productivity and parameter estimates characterizing the productivity evolution process, as in Equation (9), both of which are needed in the second stage.

The second stage estimates a dynamic discrete choice model of exporting and importing and recovers the sunk and fixed costs of exporting and importing and the process characterizing the foreign market shocks. The key to this second stage estimation is to construct the likelihood function of parameters, which depends on the firm's exporting and importing probabilities. These probabilities can be computed using Equations (15) and (20). The estimation then searches for the set of parameters that maximizes the likelihood function. The second stage estimation gives parameter estimates characterizing the distributions of fixed and sunk costs of exporting and importing and the foreign market demand shocks.

4.1 First Stage: domestic revenue and productivity evolution

To estimate the impact of importing and exporting on productivity, I proceed in two steps. The first step is to estimate the domestic revenue equation using material as a proxy for unobserved productivity and then construct a measure that contains productivity. The second step then uses this measure to estimate the productivity evolution process.

4.1.1 Elasticities of Demand

Since the domestic market demand elasticity is needed when estimating the domestic revenue equation (5), I estimate the demand elasticities first. Under profit maximization, a firm's marginal costs equal marginal revenue in both domestic and foreign markets. Also, marginal cost is constant with respect to output quantity. Thus, I can write each firm's total variable cost as

$$\begin{aligned} TVC_{jt} &= C_{jt}Q^d_{jt} + C_{jt}Q^f_{jt} \\ &= (1 - \frac{1}{\eta^d})P^d_{jt}Q^d_{jt} + (1 - \frac{1}{\eta^f})P^f_{jt}Q^f_{jt} \\ &= (1 - \frac{1}{\eta^d})R^d_{jt} + (1 - \frac{1}{\eta^f})R^f_{jt} + \varepsilon_{jt}, \end{aligned} \tag{22}$$

where the first line in Equation (22) is equality by definition, and the second line uses the pricing rules that how firms set prices in each market in terms of marginal cost. The last line uses the definition of revenue and adds an error term ε_{jt} to reflect possible measurement error in total variable costs.

I estimate this equation by OLS using data of total variable costs TVC_{jt}, domestic revenue R^d_{jt}, and foreign market revenue R^f_{jt} and then recover the elasticities of demand η^d and η^f.

4.2 Marginal Cost and Productivity Transition Parameters

I estimate the domestic revenue equation (5) to recover the marginal cost and productivity transition parameters. Add an i.i.d. error term u_{jt} reflecting measurement error in revenue or capital in Equation (5),

$$r_{jt}^d = \phi_t^d + (1-\eta^d)\ln(\frac{\eta^d}{\eta^d - 1}) + (1-\eta^d)(\beta_0 + \beta_k k_{jt} + \beta_t D_t + \beta_o D_o - \omega_{jt}) + u_{jt}. \quad (23)$$

where firm productivity $(1-\eta^d)\omega_{jt}$ would enter the composite error term. As is well known, OLS estimates of this function would suffer from simultaneity bias, as firm productivity ω_{jt} likely to be correlated with some regressors. Therefore, I utilize the insight from Levinsohn and Petrin (2003) that demand for some static inputs like materials can be used to recover unobserved firm productivity. The main idea behind Levinsohn and Petrin (2003) is that more productive firms will use more materials, hence under some conditions, one can invert the use of materials for productivity. However, Ackerberg et al. (2015) argue that the estimation method of Levinsohn and Petrin (2003) may suffer from a functional dependence problem and suggest that one should invert input material demand functions conditional on choice of labor input, so I invert ω_{jt} as $f^{-1}(k_{jt}, l_{jt}, m_{jt})$ and substitute it into the revenue function and rewrite the revenue equation as

$$\begin{aligned} r_{jt}^d &= \lambda_0^d + \sum_{t=1}^{T} \lambda_t^d D_t + \sum_{o=1}^{O} \zeta_o^d D_o + (1-\eta^d)\Big[\beta_k \ln k_{jt} - f^{-1}(k_{jt}, l_{jt}, m_{jt})\Big] + u_{jt} \\ &= \lambda_0^d + \sum_{t=1}^{T} \lambda_t^d D_t + \sum_{o=1}^{O} \zeta_o^d D_o + h(k_{jt}, l_{jt}, m_{jt}) + v_{jt} \end{aligned} \quad (24)$$

where $\lambda_0^d = (1-\eta^d)\ln(\frac{\eta^d}{\eta^d-1}) + (1-\eta^d)\beta_0$, $\lambda_t^d = \phi_t^d + (1-\eta^d)\beta_t$ is used to control for time-varying factor prices and the domestic market size, and $\zeta_o^d = (1-\eta^d)\beta_o$ denotes 4-digit CIC industry effect and also controls for part of the time-varying factor prices. And $h(k_{jt}, l_{jt}, m_{jt}) = (1-\eta^d)(\beta_k k_{jt} - \omega_{jt})$ captures the effect of capital and productivity on domestic revenue. I specify $h(\cdot)$ as a cubic function of its arguments and estimate the above equation using OLS. This gives me estimates of λ_0^d, λ_t^d, and $\hat{h}(k_{jt}, l_{jt}, m_{jt})$.

Given our estimate of demand elasticity $\hat{\eta}^d$, $\hat{h}(k_{jt}, l_{jt}, m_{jt})$ and since we know firm's capital stock k_{jt}, my goal next is to estimate the coefficient of capital in the marginal cost function β_k, coefficients governing the productivity evolution process (namely, α_0 to α_6 in equation (9)) and the variance of ξ_{jt}. Rewrite ω_{jt} as a function of k_{jt} and $\hat{h}_{jt}$,

$$\omega_{jt} = \beta_k k_{jt} - \frac{1}{1-\eta^d}\hat{h}_{jt}. \tag{25}$$

Then substitute $\omega_{j,t+1}$ and ω_{jt} using equation (25) into equation (9) gives

$$\begin{aligned} \hat{h}_{j,t+1} =& \beta_k^* \ln k_{j,t+1} - \alpha_0^* - \sum_{n=1}^{3}(\frac{1}{1-\hat{\eta}^d})^{n-1}\alpha_n(\hat{h}_{jt} - \beta_k^* \ln k_{jt})^n \\ & - \alpha_4^* i_{jt} - \alpha_5^* e_{jt} - \alpha_6^* i_{jt} \times e_{jt} - \xi_{j,t+1}^* \end{aligned} \tag{26}$$

where coefficients with superscript $*$ represent the original coefficients multiplied by $(1-\hat{\eta}^d)$. I estimate the above equation using non-linear least squares to recover coefficients β_k, α_0 to α_6, and the variance of $\xi_{j,t+1}$ by the sample variance of the residuals.

4.3 Second Stage: Dynamic Parameters Estimation

Given the productivity and parameter estimates from the first stage, I utilize information on the transition of exporting and importing states, foreign market revenues of exporting firms to identify dynamic parameters. Intuitively, firms' decisions to break into the export and import market provide information about sunk cost parameters of exporting and importing (γ^S, γ^R), respectively. Moreover, firms' exit decisions from exporting and importing provide information on identifying fixed cost parameters (γ^F, γ^G).[15] In addition, firms' export revenue provides insights of exporting market intercepts (ϕ_t^f) and conditional foreign market demand process for firms exporting, which can be used to infer about unconditional foreign market demand process (ρ_ν and σ_μ).

Formally, the observed data for firm j contains the firm's exporting history $\{e_{jt}\}_{t=1}^T$, export revenue $\{r_{jt}^f\}_{t=1}^T$, importing dynamics $\{i_{jt}\}_{t=1}^T$. In addition, the firm's productivity series $\{\omega_{jt}\}_{t=1}^T$ have been recovered from in the first stage. Then, the observed data are $Y_{N,T} \equiv \{e_{jt}, i_{jt}, r_{jt}^f, \omega_{jt}\}_{t=1,j=1}^{T,N}$. For any variable M, use M_s^t to denote $(M_s, M_{s+1}, \ldots, M_t)$. Based on the observed data, firm j's contribution to the likelihood

[15] Since I follow Aw et al. (2011) and assume these sunk costs and fixed cost are i.i.d draws from separate exponential distributions, what we are estimating are the mean parameters of these distributions.

function can be written as

$$
\begin{aligned}
&P(e_{j1}^T, r_{j1}^{fT}, i_{j1}^T | \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}) \\
&= P(e_{j1}^T, \nu_j^+, i_{j1}^T | \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}) \\
&= P(e_{j1}^T, i_{j1}^T | \nu_j^+, \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}) h(\nu_j^+) \\
&= \left[\int_{z_j} P\Big[e_{j1}^T, i_{j1}^T | \nu_1^T(\nu_j^+, z_j), \omega_{j1}^T, k_{j1}^T, \phi_1^{fT} \Big] \cdot f(z_j) dz_j \right] \cdot h(\nu_j^+), \qquad (27)
\end{aligned}
$$

where ν_j^+ denotes the time series of export shocks when firm j exports. The first equality comes from the fact that $(e_{j1}^T, r_{j1}^{fT} | \omega_{j1}^T, k_{j1}^T, \phi_1^{fT})$ and $(e_{j1}^T, \nu_j^+ | \omega_{j1}^T, k_{j1}^T, \phi_1^{fT})$ provides the same information, as can be seen from the export revenue equation (6). The second equality breaks the probability expression for $(e_{j1}^T, \nu_j^+, i_{j1}^T | \omega_{j1}^T, k_{j1}^T, \phi_1^{fT})$ into the production of the conditional distribution of $(e_{j1}^T, i_{j1}^T | \nu_j^+, \omega_{j1}^T, k_{j1}^T, \phi_1^{fT})$ and the marginal distribution of ν_j^+. The last equality is based on the fact that ν_j^+ is censored as it is only observable for exporters. However, combined with standard normal distributions z_j, it can be used to construct the uncensored export profit shocks.[16] I can simulate export market shocks and calculate the likelihood function once we know how to construct ν_1^T from ν_j^+. The details of the calculation of likelihood function can be found in Appendix (A.1).

The estimation procedure consists of two steps.[17] The first step is to solve the dynamic programming problem and construct the likelihood according to Equation (27),

[16]See Das et al. (2007) for details of the derivation.

[17]The literature of dynamic discrete choice models has developed different methods estimating these models. See Aguirregabiria and Mira (2010) for a survey.

which is usually called the inner loop.[18] The second step is the estimation of the parameter vector, which can be done by the maximum likelihood method or Markov Chain Monte Carlo simulation method. Das et al. (2007) and Aw et al. (2011) suggest that the likelihood function may not be globally concave in the parameters, so they use a Bayesian MCMC algorithm to evaluate the likelihood function and search for parameter estimates. However, Bai et al. (2017) estimate the model using the maximum likelihood estimation method. In this paper, I will use both methods and contrast parameter estimates generated by each method.

5 Results

5.1 Productivity Evolution

Table 3 reports the results of the first stage estimation of equations (22) and (24) for each of the three industries. The parameters estimated include demand elasticities, parameters from the domestic revenue function, and parameters characterizing the productivity process. Under each industry, the first column shows the estimates, and the second column reports the standard errors.

For the transportation equipment industry, the absolute value of demand elasticities for the domestic (η^d) and foreign market (η^f) are 4.836 and 4.367, respectively. These elasticities imply a markup of 26.1% in the domestic market and 29.7% in the foreign market. The capital coefficient β_k is negative and significant, suggesting that the higher the capital stock a firm has, the lower its marginal costs and higher its revenue. The

[18] Appendix (A.2) provides details about the inner step.

effect of lagged productivity on current productivity, captured by coefficients α_1, α_2, and α_3, is strong, indicating a non-linear relationship and high serial correlation in ω_{jt}. Of most interest are coefficients for lagged importing and exporting in productivity evolution, namely, α_4, α_5, and α_6. The impact of lagged importing on current productivity, measured by α_4, is 2.56% and significant. This is a measure of learning-by-importing and implies past importers have productivity that is 2.56% higher. Similarly, α_5 captures the effect of past exporting on current productivity and is a measure of learning-by-exporting. It is also significant, and its magnitude, 2.58%, is only slightly larger than the magnitude of α_4. The interaction term's coefficient, α_6, measures the marginal effect on future productivity by adding a second activity. It is negative but not significant, and its magnitude is smaller than the magnitude of α_4 and α_5. This suggests that firms engaging in both importing and exporting have the largest intercept in the productivity process but also means the marginal effect of adding a second activity to future productivity is lower than the marginal contribution of engaging in the same activity when firms do neither importing nor exporting. Given the estimates of α_4, α_5, and α_6, I can calculate the mean long-run productivity for firms of different status.[19] Compared to a firm that never import or export $(i = 0, e = 0)$, a firm that always import and export $(i = 1, e = 1)$ will have long-run productivity 80.2 percent higher. For a firm that only import $(i = 1, e = 0)$ or a firm that only export $(i = 0, e = 1)$) every year, the long-run productivities are 49.1 percent and 49.5 percent higher than a firm that does neither, respectively.

Columns (3-4) and columns (5-6) of table 3 report the estimates for industry general

[19]The mean long-run productivities for different types of firms can be calculated by letting $\omega_{j,t+1}$ equal to $\omega_{j,t}$ in the productivity process equation (9) for different combinations of i and e.

Table 3: Estimates of demand elasticities, marginal cost, and the productivity process.

Parameter	Transportation equipment		General machinery		Manufacture of plastics	
	Estimate	Std. Error	Estimate	Std. Error	Estimate	Std. Error
$1 - \frac{1}{\eta^d}$	0.7932	0.0331	0.7265	0.0349	0.7290	0.0190
$1 - \frac{1}{\eta^f}$	0.7710	0.1260	0.8519	0.1026	0.8892	0.0780
β_k	-0.0693	0.0022	-0.0826	0.0021	-0.0989	0.0028
α_0	0.0768	0.0040	0.0751	0.0041	0.0027	0.0035
α_1	0.8236	0.0090	0.7834	0.0074	0.8803	0.0113
α_2	0.0972	0.0156	0.1712	0.0079	0.2088	0.0145
α_3	-0.0336	0.0093	-0.0380	0.0061	-0.1482	0.0152
α_4	0.0256	0.0062	0.0268	0.0088	0.0216	0.0084
α_5	0.0258	0.0061	0.0223	0.0049	0.0218	0.0080
α_6	-0.0107	0.0102	-0.0265	0.0113	-0.0279	0.0150
ϕ^d	5.9330		7.0238		7.6488	
SE(ξ_{jt})	0.5498		0.4756		0.4721	
N	18752		30982		16841	

Notes: This table presents estimates of demand elasticities and parameters characterizing the domestic revenue function and productivity transition process for three industries: transportation equipment, general machinery, and manufacture of plastics.

machinery and manufacture of plastics, respectively. Firms in these two industries generally charge higher markups in the foreign market than in the domestic market. The productivity processes show a similar pattern as transportation equipment, except that the interaction terms' coefficients are relatively large in magnitude.

5.2 Sorting and Determination of Importing and Exporting

Given the productivity estimate, I ask how firms sort into different importing and exporting states according to productivity? Figure 2 shows the kernel density distributions of different types of firms. A clear pattern is that the distributions shift gradually to the right from firms that neither import nor export, firms that only export, firms that only import, to firms that do both. A Kolmogorov-Smirnov test that compares any two types of firms' productivity distributions rejects the null, suggesting that any two distributions are not the same.

Inspired by the policy functions (Equations (15) and (20)) of the model, I run a bivariate probit regression of importing and exporting on the firm' productivity, capital stock, lagged import dummy, lagged export dummy, and a set of year dummies. The regression share similarities with the policy functions except that the export market shocks $\nu_{j,t}$ are not observable here. Table 4 presents the estimates of the regression. The results suggest that productivity, capital stock, prior import status, and prior export status all positively and significantly affect firms' decisions on importing and exporting. The lagged import dummy's effect is larger than the lagged export dummy's effect on importing determination, and the opposite is true on exporting determination. Prior import status may have a large effect on a firm's importing decision since it determines

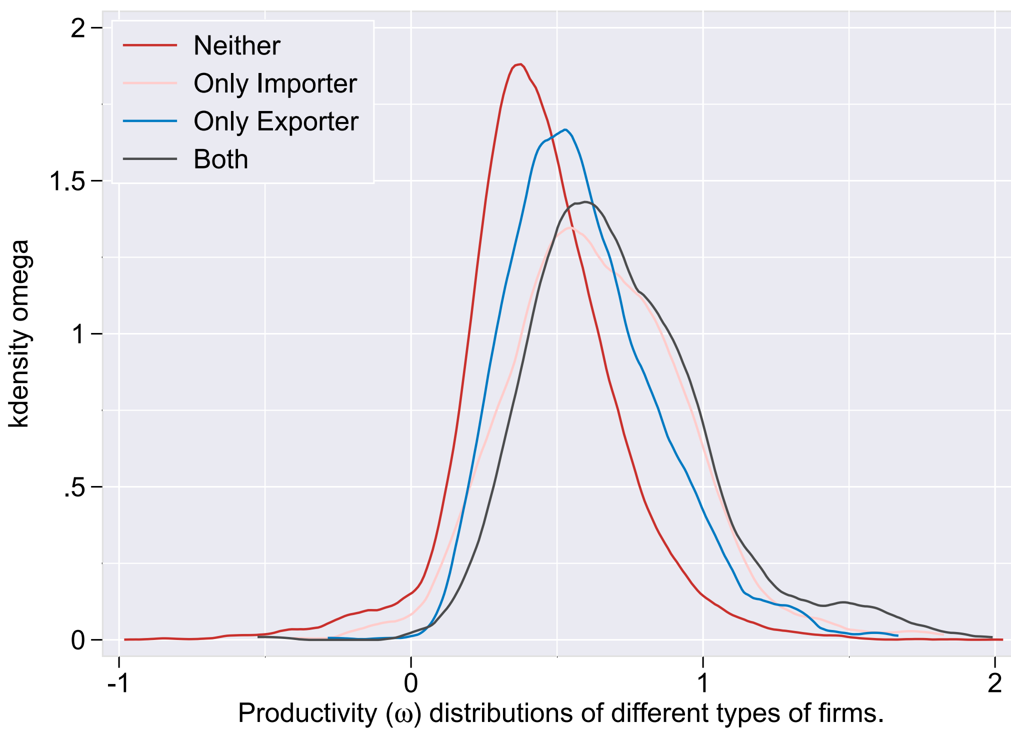


Figure 2: Productivity estimates of different types of firms.

whether the firm should pay the fixed cost or sunk cost when deciding to import and impact its productivity evolution. While prior export status only indirectly affects the firm's expected value of importing through the productivity process. A similar rationale applies to exporting. The correlation in the errors, measured by ρ, is positive, indicating there may be some common factors driving the decisions. Since $\nu_{j,t}$ is not controlled, it enters into the error terms and is part of these common factors.

Table 4: Reduced form bivariate probit regression of exporting and importing determination.

	(1)	(2)
	Importing (i_{jt})	Exporting (e_{jt})
ω_{jt}	0.0152***	0.0188***
	(0.0041)	(0.0044)
k_{jt}	0.0090***	0.0018**
	(0.0008)	(0.0008)
$i_{j,t-1}$	0.4930***	0.0494***
	(0.0199)	(0.0099)
$e_{j,t-1}$	0.1323***	0.9102***
	(0.0139)	(0.0104)
Observations	18752	18752
ρ	0.487	0.487
Year fixed effects	Yes	Yes

Notes: This table presents results from a bivariate probit regression of regressing importing and exporting on productivity measure, capital stock, lagged import dummy, and lagged export dummy.
Significance levels: * 0.10 ** 0.05 *** 0.01.

5.3 Dynamic Estimates

I use two methods to estimate dynamic parameters: the first is the Markov chain Monte Carlo (MCMC) method used by Das et al. (2007) and Aw et al. (2011), the second is the maximum likelihood estimation (MLE) method employed by Bai et al. (2017). Table 5 reports the estimates by the two methods. For the MCMC estimates, I report the means and standard deviations of the posterior distribution parameters. The two sets of estimates from the two methods are quite close to each other except for the foreign market intercept ϕ^f, which displays a relatively large disparity.

Table 5: Dynamic estimates using MCMC and maximum likelihood estimation.

	Estimation method		
	MCMC		**MLE**
Parameter	Mean	Standard deviation	Estimate
γ^F	26.474	0.665	26.351
γ^S	3144.206	127.073	3185.950
γ^G	24.252	0.451	24.238
γ^R	1032.249	27.488	1018.839
ϕ^f	1.257	0.075	0.829
ρ_ν	0.943	0.000	0.950
$log(\sigma_\mu)$	0.008	0.015	0.024

Note: This table reports fixed costs and sunk cost of importing and exporting, foreign market intercept, and coefficients related to export shock process, estimated by Markov chain Monte Carlo (MCMC) method and maximum likelihood estimation.

The estimates of γ^F, γ^S, γ^G, and γ^R reported in table 5 are the mean parameters for each of the four distinctive exponential distributions. A few patterns appear from these estimates. First, the sunk costs to start an activity (importing or exporting) are substantially larger than the fixed costs of maintaining the same activity. For example, the sunk costs estimate for exporting is $\gamma^S = 3144.206$ while the fixed costs estimate is $\gamma^F = 26.474$. Second, the sunk costs to start importing, $\gamma^R = 1032.249$, is only one-third of the sunk costs of exporting while the fixed costs of maintaining importing, $\gamma^S = 24.252$, is close to the fixed costs of maintaining exporting. This is consistent with the observed transition patterns in the data, as shown in Figure 1, i.e., exporting status is more persistent than importing status. Thus, it is much more costly for non-exporters to enter the exporting market than for non-importers to enter the importing market, and once non-exporters become exporters, they are more likely to maintain their exporting status.

As discussed in section 3.3 of the model, firms differ in their state variables will have different expected future values. Differences in the expected future value will generate differences in the marginal benefit of taking an activity. Since firms only undertake an activity when their drawn costs are below the marginal benefit of participating, firms with different state variables will face different thresholds in fixed/sunk costs when making participation decisions. The means of these fixed/sunk costs are the truncated means of exponential distributions where the location parameters are given in table 5 and truncation points given by those marginal benefits.

Table 6 shows the mean export costs for importers and non-importers and the mean import costs for exporters and non-exporters for firms with different values of productivities ω. First, these mean export costs and mean import costs are increasing in a firm's productivity. For example, an importer with productivity of -0.190 needs to pay a mean fixed cost of 12.28 million to maintain its exporting status. In contrast, the mean fixed cost increases to 16.52 million for an importer with productivity of 1.077. The increase in the mean fixed cost reflects the increase in the marginal benefits of exporting. Second, the difference between sunk costs and fixed costs is lower than the difference in exponential distributions' location parameters. The reason is that only firms with lucky draws under their marginal benefits will take the option to undertake an activity. Thus the truncated means are much lower than the location parameters of exponential distributions, especially sunk costs. Third, the mean export costs are higher for non-importers than for importers at the same productivity level. The underlying rationale is that non-importers with the same productivity have a slightly higher value of the marginal benefit of exporting. A similar finding is true when looking at the mean import costs for exporters and non-exporters. For example, for the productivity level $\omega_t = 0.760$), the mean fixed cost and sunk cost are 10.72 millions and 28.44 millions for exporters, respectively. The corresponding numbers are 13.70 million and 40.07 million for non-exporters.

Besides the cost parameters, the last three rows of Table 5 reports the mean foreign market intercept and parameters describing the stochastic process of the export market shocks ν. The estimate of ϕ^f is smaller than ϕ^d, which is consistent with the finding in Table 2 that exporters sell much less in the foreign market than in the domestic market. The estimates of parameters characterizing the first-order autoregression process of ν are $\rho_\nu = 0.943$ and $\sigma_\mu = e^{(0.008)} = 1.008$, which suggests firm-level demand shocks are

Table 6: Cost of exporting and importing.

	Mean export costs				Mean import costs			
	Importers		Non-importers		Exporters		Non-exporters	
ω_t	Fixed	Sunk	Fixed	Sunk	Fixed	Sunk	Fixed	Sunk
-0.824	10.754	44.814	11.014	46.947	5.120	8.025	6.710	11.347
-0.507	11.405	50.717	11.760	53.345	5.940	9.836	7.726	13.830
-0.190	12.284	59.868	12.781	63.211	6.990	12.345	9.036	17.295
0.127	13.378	74.249	14.079	78.624	8.242	15.796	10.606	22.115
0.444	14.585	98.357	15.549	104.228	9.557	20.790	12.256	29.180
0.760	15.710	142.147	16.943	149.934	10.717	28.444	13.700	40.072
1.077	16.525	220.945	17.947	230.086	11.526	38.671	14.685	54.551
1.394	16.918	339.052	18.404	347.616	11.854	47.132	15.096	66.236
1.711	17.040	472.346	18.481	479.230	11.800	50.087	15.063	70.015
2.028	17.148	607.681	18.479	613.287	11.587	49.462	14.821	68.653

Notes: This table reports mean export costs for importers ($i_{t-1} = 1$) and non-importers ($i_{t-1} = 0$), and mean import costs for exporters ($e_t = 1$) and non-exporters ($e_t = 0$). Values of costs are in millions Chinese Yuan.

highly persistent over years.[20] The high persistence of demand shocks in the foreign market also partly rationalize the persistence in firms' exporting status.

5.4 In Sample Model Performance

With estimates in Table 3 and 5, I assess the model's overall performance by simulating firms' productivity trajectories, decisions about importing and exporting, and transition patterns between the choices. In each simulation, I use the first year of actual data as given, draw shocks to productivity and foreign market demand, and fixed and sunk costs of importing and exporting based on each of the underlying distributions. Then I solve firms' dynamic programming problems and simulate each year of firms' productivities joint with importing and exporting decisions for the following three years. To reduce arbitrariness, I run the simulation 50 times and report the average of the 50 simulations.

Table 7 shows the average industry productivity, export market participation rate, and import market participation rate from the actual data and the simulations. The predicted average productivity and export market participation rate matches the actual data pretty close. The model slightly over-predict the mean import participation rate, especially for the last year of the data. Overall, the model performs well, replicating these patterns found in the data.

Figure 3 compares the transition patterns of firms' import and export status between the data and the simulations. First, for firms account for around 90% of the data, namely firms engaging in neither activity, the predicted transition pattern matches well

[20]The serial correlation parameter found here is larger than what Bai et al. (2017) reports for Chinese industry Rubber and Plastic, a possible reason is the relatively shorter period in this research. This may also be due to the difference in industries studied.

Table 7: Importing rates, exporting rates, productivity.

		2004	**2005**	**2006**
Average Productivity	Data	0.447	0.460	0.492
	Model	0.452	0.471	0.504
Export market participation rate	Data	0.072	0.081	0.079
	Model	0.072	0.083	0.083
Import market participation rate	Data	0.073	0.075	0.070
	Model	0.076	0.083	0.083

Note: This table compares the average productivity, export market participation rate, and import participation rate from the data with what predicted by the model for years 2004 to 2006.

with the data. The model predicts a larger proportion of firms engage in importing than in exporting, in line with the data, though slightly over the corresponding proportions in the data. Second, through the model somewhat overestimates the persistence of exporting and importing states, the model predicts that firms' persistence in exporting status is higher than firms' persistence in importing status, consistent with the data. In addition, the model also captures the interdependence of importing and exporting. Firms engaging in one of the activities in year t have a higher probability of starting the other activity than firms do neither. What the model underperforms is the prediction of the proportion of firms undertaking in both activities, especially for the group of firms only export in year t. Overall, the model is able to generate transition patterns that match well with the data.

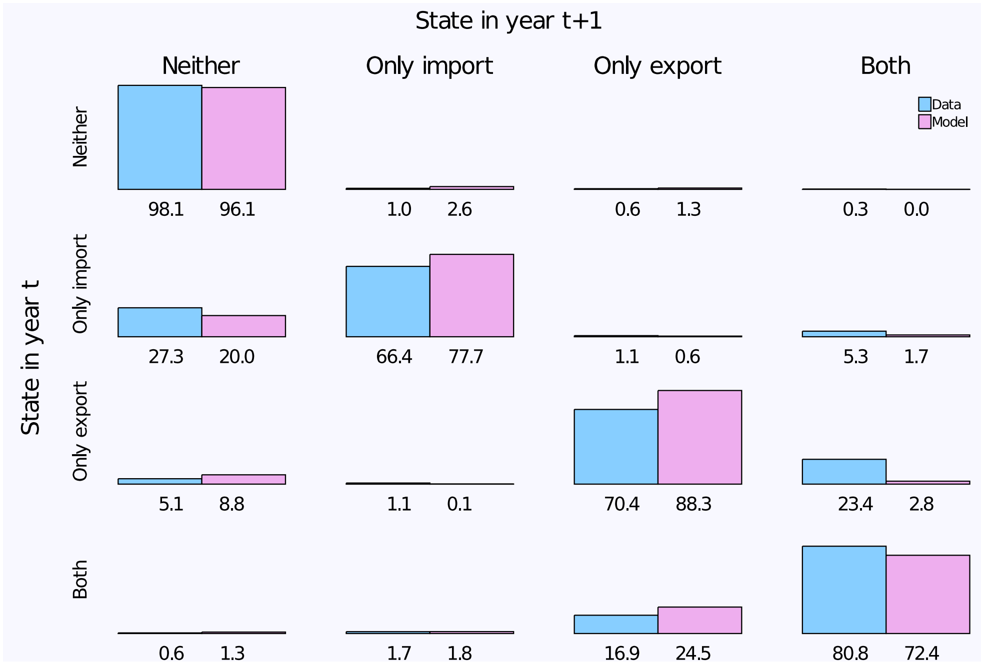


Figure 3: Model prediction of transition rates compared with actual rates.

6 Counterfactual Experiments

In this section, I use the estimated model to conduct two kinds of counterfactual experiments. The first is to simulate a one-shot exogenous trade liberalization. The second is to run a series simulation of subsidy policy schemes on fixed and sunk costs. In each of the experiments, I use the initial year of data as given, repeat the simulations 50 times, and report the average outcomes of interest by averaging over 50 simulations.

6.1 Trade Liberalization

Starting from its negotiations with WTO members about joining the WTO, China has embarked on a radical trade liberalization path by reducing tariffs and eliminating nontariff barriers. Trade liberalization results in a substantial decrease in firms' trade costs, and it has important implications for firms' decisions on participating in the international market. In the model, a reduction in trade cost will lead to an increase in foreign market profits for potential exporters through an increase in ϕ^f.

In this section, I conduct a counterfactual exercise by increasing the value of ϕ^f by 0.58. Then I evaluate its effect on firms' decisions to export and import and firms' productivity trajectories for 15 years forward following the trade liberalization. I also ask how this market expansion will affect firms' decisions when the productivity process is allowed to have different endogenous forms, which would enable me to evaluate the importance of different channels that impact firms' outcomes when facing trade liberalization. Table 8 reports the results of three outcomes under each productivity process specification over different years forward in the future. The top panel shows the results when both firms' prior importing and exporting decisions could impact productivity, as in Equation (9). The second and third panels demonstrate an environment where only prior import status or export status can affect productivity; namely, there is only learning-by-importing or learning-by-exporting, respectively. The bottom panel provides the results of an exogenous process where neither prior decisions affect productivity.

First, the proportion of exporters rises gradually over the years under each of the four different productivity processes. Though the increase in the proportion of exporters is only 0.778 percentage points after two years in the top panel, lower than the bottom panel of 0.824 points, after 15 years the increase raises to 4.828 points, which is the largest among all four settings. After 15 years, there are also higher increases in the proportion of exporters when the productivity is endogenous with either learning-by-

Table 8: Firms' response to exogenous trade liberalization.

Productivity process	Years since 2003				
	2	5	8	10	15
$\omega_{j,t+1} = g(\omega_{j,t}, i_{j,t}, e_{j,t}) + \xi_{j,t+1}$					
Change in proportion of exporters	0.778	2.02	3.164	3.759	4.828
Change in proportion of importers	0.263	0.402	0.539	0.608	0.781
Percentage changes in mean productivity	0.025	0.164	0.337	0.453	0.707
$\omega_{j,t+1} = g(\omega_{j,t}, i_{j,t}) + \xi_{j,t+1}$					
Change in proportion of exporters	0.839	2.029	3.091	3.628	4.593
Change in proportion of importers	0.269	0.473	0.661	0.784	0.991
Percentage changes in mean productivity	0.009	0.041	0.074	0.096	0.143
$\omega_{j,t+1} = g(\omega_{j,t}, e_{j,t}) + \xi_{j,t+1}$					
Change in proportion of exporters	0.765	2.01	3.134	3.708	4.762
Change in proportion of importers	0.278	0.348	0.441	0.496	0.648
Percentage changes in mean productivity	0.019	0.142	0.307	0.42	0.668
$\omega_{j,t+1} = g(\omega_{j,t}) + \xi_{j,t+1}$					
Change in proportion of exporters	0.824	2.013	3.052	3.582	4.527
Change in proportion of importers	0.28	0.324	0.401	0.46	0.595
Percentage changes in mean productivity	0.0	-0.0	-0.0	-0.0	0.0

Notes: This table illustrates firms' response to trade liberalization by looking at, under each productivity process, how firms' participation rates in exporting, importing, and mean productivity will change over years.

exporting or learning-by-importing only, compared with the case of no learning. The higher increases in exporters' proportion when productivity is endogenous reflect how endogenous productivity evolution plays a role in making firms more productive and attracting more firms to enter the export market.

Second, though the proportion of importers increase after the foreign market expansion, the increases are much less than the increase in exporters. For example, in the second panel, after ten years, the proportion of exporters is higher by 3.628 points while the proportion of importers only rises by 0.784 points. Moreover, after 15 years, the largest increase in importers' proportion happens when only prior import status impacts productivity. This is because when only import status impacts productivity, more firms are induced into the importing market. In addition, compared with the bottom panel, there is a more considerable increase in the proportion of importers when there is learning-by-exporting alone. The reason is that though there is no incentive to import to improve productivity, exporting plays a role as it improves future productivity. As a result, more firms self-select into importing when they become more productive.

Third, productivity increases when productivity processes are endogenous, with the most significant increase come from when there are effects of both import and export status on productivity. This is not surprising given that the estimates of productivity process parameters show both positive learning by importing and learning by exporting effects. When comparing the second panel with the third panel, we see a much larger increase in productivity when only exporting plays a role in the productivity process. This is so because even though the impact of export status on productivity is only slightly larger than the impact of import status, the exporting status is more persistent than importing status. Thus the same percentage increase in the proportion of exporters will have a much larger impact on productivity than the same increase in the importers over the years. In this sense, learning by exporting plays a more critical role than learning by importing in raising productivity.

6.2 Subsidies on Export and Import Costs

Subsidies have been widely used in developing countries like China to induce industry development or encourage export growth. In this section, I simulate policy programs that encourage firms' participation in some activities by subsidizing firms' fixed cost or sunk cost of either exporting or importing by 25% or 50% each year. Then I compare all the results to the situation where there is no subsidy.

Table 9 provides the results of different subsidy policies on the proportion of exporters, the proportion of importers, and the mean productivity across firms over the years. Several patterns are apparent in the results. First, subsidies on export costs raise the exporting market participation rate but decrease the importing market participation rate, while subsidies on importing costs have the opposite effect. For example, after 15 years, a 25% subsidy on the fixed cost of exporting increases the export participation rate by 2 percentage points but decrease the import rate by 0.218 points. This is because subsidizing one activity will make this activity more attractive than the other activity. As a result, more firms choose the subsidized activity instead of the other. Though raising the participation rate for one activity improves productivity through the learning effect. As firms' productivity rises, more of them can participate in the other activity. However, this effect is not large enough to offset the decrease in the other activity's participation rate caused by the subsidy. Second, a larger subsidy has a more massive effect on the increase in the encouraged activity's participation rate and has a larger negative effect on the other activity. Third, subsidies on the fixed cost of exporting ($\gamma^F_{j,t}$) have a smaller effect than subsidies on the sunk cost of exporting ($\gamma^S_{j,t}$) of the same percentage. While subsidies on the fixed cost of importing ($\gamma^G_{j,t}$) of the same level have a larger impact on export participation rate and import participation rate but not for productivity than subsidies on the sunk cost of importing ($\gamma^R_{j,t}$). The reason is that the sunk cost of exporting is substantially higher than the sunk cost of importing. Thus importers are more likely to drop out than exporters. So subsidy on the sunk cost of exporting is more effective in encouraging export participation while subsidy on the fixed cost of importing more effect on maintaining import participation.

Though we see an increase in mean productivity across firms because of subsidies, how do *exporters* perform under each policy? Table 10 reports the effects of different subsidy policies on the percentage change in mean productivity and percentage change in exporters' mean foreign market revenue. When subsidizing the fixed cost of exporting, exporters are on average less productive and sell less in the foreign market. This is because subsidy on the fixed cost would help less productive exporters maintain their exporting status while they actually should drop out of the export market. Helping the less productive exporters maintain their exporting status lowers average productivity lower and average foreign revenue. Though productivity first increases when subsidizing on the sunk cost of exporting, its increase eventually becomes negative as more years accumulate. The reason is that subsidy on the sunk cost lowers the bar of entering the export market. Less productive firms also enter the export market, which lowers the

Table 9: Firms' response to different subsidy programs.

Subsidy policy	**Outcome**	**Years since 2003**				
		2	5	8	10	15
25% subsidy on $\gamma^F_{j,t}$	Δ Exp. rate	0.287	0.725	1.134	1.405	2.001
	Δ Imp. rate	-0.019	-0.048	-0.093	-0.132	-0.218
	$\Delta\omega$	0.006	0.046	0.099	0.135	0.226
50% subsidy on $\gamma^F_{j,t}$	Δ Exp. rate	0.575	1.564	2.518	3.131	4.612
	Δ Imp. rate	-0.033	-0.078	-0.166	-0.235	-0.407
	$\Delta\omega$	0.012	0.098	0.215	0.300	0.520
25% subsidy on $\gamma^S_{j,t}$	Δ Exp. rate	0.707	1.449	1.997	2.240	2.508
	Δ Imp. rate	-0.032	-0.136	-0.249	-0.320	-0.419
	$\Delta\omega$	0.019	0.106	0.189	0.237	0.316
50% subsidy on $\gamma^S_{j,t}$	Δ Exp. rate	2.050	4.060	5.373	5.925	6.431
	Δ Imp. rate	-0.100	-0.385	-0.687	-0.852	-1.082
	$\Delta\omega$	0.056	0.302	0.527	0.647	0.835
25% subsidy on $\gamma^G_{j,t}$	Δ Exp. rate	-0.004	-0.021	-0.046	-0.069	-0.117
	Δ Imp. rate	0.788	1.543	2.069	2.361	2.853
	$\Delta\omega$	0.018	0.106	0.196	0.250	0.354
50% subsidy on $\gamma^G_{j,t}$	Δ Exp. rate	-0.009	-0.044	-0.112	-0.158	-0.276
	Δ Imp. rate	1.783	3.676	5.109	5.942	7.456
	$\Delta\omega$	0.039	0.241	0.467	0.607	0.903
25% subsidy on $\gamma^R_{j,t}$	Δ Exp. rate	-0.006	-0.031	-0.062	-0.072	-0.108
	Δ Imp. rate	1.297	2.008	2.239	2.271	2.320
	$\Delta\omega$	0.041	0.186	0.282	0.320	0.359
50% subsidy on $\gamma^R_{j,t}$	Δ Exp. rate	-0.016	-0.088	-0.157	-0.187	-0.255
	Δ Imp. rate	3.736	5.538	6.015	6.070	6.100
	$\Delta\omega$	0.120	0.531	0.783	0.877	0.971

Notes: This table shows how firms' export participation rate, import participation rate, and mean productivity will evolve over years when different subsidy schemes are introduced. Under each subsidy scheme, the three rows report change in proportion of exporters, change in proportion of importers, and percentage change in mean productivity, respectively, compared to no subsidy.

mean productivity and average sales of exporters. On the contrary, subsidizing importing costs improves the mean productivity and average export revenue for exporters. Because importing, instead of exporting, becomes more attractive for not so productive firms. As less productive firms become importers instead of exporters, exporters become more productive and sell more on the foreign market.

When subsidizing export costs, the export participation rate increases while the average foreign revenue decreases; one may wonder how the total foreign revenue changes and whether the subsidy cost pays off? Table 11 shows the change in total export revenue and the ratio of gain in total revenue over total subsidies cost for different exporting subsidy policies. First, subsidizing exporters generally generates more foreign revenue than no subsidy, and the increase gets larger as the subsidy percentage rises. Second, the increase in foreign revenue per Chinese Yuan spent on subsidies is higher when subsidizing the fixed cost, but it drops when the subsidy level increases.

7 Conclusion

The literature has well documented the relationship between firms' export status and some performance measures. There is also substantial evidence on the impact of imported intermediates on firms' productivity. However, we know less about the dynamic effects of exporting and importing, especially how the two forces work in the same framework. This paper attempts to fill in this gap. Motivated by a few stylized facts about firms' export and import status, this paper has developed a dynamic structural discrete choice model of importing and exporting. The two activities are allowed to have an

Table 10: Exporters performance under different subsidy policy programs.

Subsidy policy	**Outcome**	**Years since 2003**				
		2	5	8	10	15
25% subsidy on $\gamma_{j,t}^{F}$	$\Delta\omega$	-1.690	-2.523	-2.527	-2.396	-2.372
	ΔR^{f}	-3.230	-6.253	-8.037	-7.885	-10.354
50% subsidy on $\gamma_{j,t}^{F}$	$\Delta\omega$	-3.582	-5.569	-5.563	-5.268	-5.374
	ΔR^{f}	-6.260	-12.653	-16.218	-16.929	-21.007
25% subsidy on $\gamma_{j,t}^{S}$	$\Delta\omega$	0.615	0.186	-0.569	-0.859	-1.130
	ΔR^{f}	-6.867	-11.009	-12.777	-13.174	-12.177
50% subsidy on $\gamma_{j,t}^{S}$	$\Delta\omega$	1.466	0.202	-1.681	-2.273	-2.517
	ΔR^{f}	-17.784	-25.625	-27.814	-28.519	-26.225
25% subsidy on $\gamma_{j,t}^{G}$	$\Delta\omega$	0.055	0.215	0.351	0.399	0.529
	ΔR^{f}	0.134	0.625	0.602	0.653	1.474
50% subsidy on $\gamma_{j,t}^{G}$	$\Delta\omega$	0.152	0.493	0.808	0.901	1.208
	ΔR^{f}	0.282	1.164	1.460	1.589	4.680
25% subsidy on $\gamma_{j,t}^{R}$	$\Delta\omega$	-0.003	0.078	0.185	0.236	0.348
	ΔR^{f}	0.214	0.646	0.798	0.836	1.202
50% subsidy on $\gamma_{j,t}^{R}$	$\Delta\omega$	-0.039	0.217	0.556	0.735	0.903
	ΔR^{f}	0.400	1.764	2.465	2.761	2.914

Notes: This table presents results of exporters' performance measures under different subsidy schemes. Under each subsidy, the first row is the percentage change in mean productivity and the second row reports the percentage change in mean export revenue, both relative to no subsidy.

Table 11: Comparison of subsidy costs and gain in export revenue.

Subsidy policy	**Change in export revenue compared to no subsidies (%)**	**Gain in revenue to total subsidy costs**
25% subsidy on $\gamma^F_{j,t}$	1.196	40.960
50% subsidy on $\gamma^F_{j,t}$	1.324	19.636
25% subsidy on $\gamma^S_{j,t}$	0.476	9.988
50% subsidy on $\gamma^S_{j,t}$	1.200	9.492

impact on future productivity evolution. Estimation results using Chinese firm-level data show that firms need to incur high sunk costs to start either activity or pay fixed costs to maintain their status. However, both decisions have a beneficial effect on firms' future productivity.

The main caveat to the analysis is that the structural framework needs to impose a full set of restrictions. However, one benefit of estimating a structural model is that it allows for explicit counterfactual analysis. Giving what had happened during the study period in China, the paper has conducted two counterfactual experiments. A trade liberation that increases foreign market size pushes a large portion of firms to participate in the export market and a relatively small portion of firms to join the import market, which results in a modest increase in mean productivity across all firms. Subsidy policies of various forms that aim to encourage exports have been popular in developing countries. The analysis suggests that subsidies aiming to encourage one activity raise the participation rate of that activity but discourages the other since subsidies lower the bar of joining the subsidized activity. Subsidies in the costs of exporting generate total export revenue gains. Moreover, these export revenue gains cover the total subsidy costs. However, whether these subsidy policies have generated a positive aggregate effect for the economy calls for future analysis.

References

Ackerberg, Daniel A, Kevin Caves, and Garth Frazer, "Identification properties of recent production function estimators," *Econometrica*, 2015, *83* (6), 2411–2451.

Aguirregabiria, Victor and Pedro Mira, "Dynamic discrete choice structural models: A survey," *Journal of Econometrics*, 2010, *156* (1), 38–67.

Amiti, Mary and Jozef Konings, "Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia," *American Economic Review*, 2007, *97* (5), 1611–1638.

Aw, Bee Yan, Mark J Roberts, and Daniel Yi Xu, "R&D investment, exporting, and productivity dynamics," *American Economic Review*, 2011, *101* (4), 1312–44.

Bai, Xue, Kala Krishna, and Hong Ma, "How you export matters: Export mode, learning and productivity in China," *Journal of International Economics*, 2017, *104*, 122–137.

Baldwin, Richard and Paul Krugman, "Persistent trade effects of large exchange rate shocks," *The Quarterly Journal of Economics*, 1989, *104* (4), 635–654.

Bernard, Andrew B and J Bradford Jensen, "Exceptional exporter performance: cause, effect, or both?," *Journal of international economics*, 1999, *47* (1), 1–25.

_ and _ , "Why some firms export," *Review of economics and Statistics*, 2004, *86* (2), 561–569.

_ , _ , Stephen J Redding, and Peter K Schott, "Firms in international trade," *Journal of Economic perspectives*, 2007, *21* (3), 105–130.

_ , Jonathan Eaton, J Bradford Jensen, and Samuel Kortum, "Plants and productivity in international trade," *American economic review*, 2003, *93* (4), 1268–1290.

Biesebroeck, Johannes Van, "Exporting raises productivity in sub-Saharan African manufacturing firms," *Journal of International economics*, 2005, *67* (2), 373–391.

Blaum, Joaquin, Claire Lelarge, and Michael Peters, "The gains from input trade with heterogeneous importers," *American Economic Journal: Macroeconomics*, 2018, *10* (4), 77–127.

Bøler, Esther Ann, Andreas Moxnes, and Karen Helene Ulltveit-Moe, "R&D, international sourcing, and the joint impact on firm performance," *American Economic Review*, 2015, *105* (12), 3704–39.

Brandt, Loren, Johannes Van Biesebroeck, and Yifan Zhang, "Creative accounting or creative destruction? Firm-level productivity growth in Chinese manufacturing," *Journal of development economics*, 2012, *97* (2), 339–351.

_ , _ , and _ , "Challenges of working with the Chinese NBS firm-level data," *China Economic Review*, 2014, *30*, 339–352.

_ , _ , Luhang Wang, and Yifan Zhang, "WTO accession and performance of Chinese manufacturing firms," *American Economic Review*, 2017, *107* (9), 2784–2820.

Bray, Robert L, "Strong convergence and dynamic economic models," *Quantitative Economics*, 2019, *10* (1), 43–65.

Chen, Zhiyuan, Jie Zhang, and Wenping Zheng, "Import and innovation: Evidence from Chinese firms," *European Economic Review*, 2017, *94*, 205–220.

Clerides, Sofronis K, Saul Lach, and James R Tybout, "Is learning by exporting important? Micro-dynamic evidence from Colombia, Mexico, and Morocco," *The quarterly journal of economics*, 1998, *113* (3), 903–947.

Dai, Mi, Madhura Maitra, and Miaojie Yu, "Unexceptional exporter performance in China? The role of processing trade," *Journal of Development Economics*, 2016, *121*, 177–189.

Das, Sanghamitra, Mark J Roberts, and James R Tybout, "Market entry costs, producer heterogeneity, and export dynamics," *Econometrica*, 2007, *75* (3), 837–873.

Dixit, Avinash, "Entry and exit decisions under uncertainty," *Journal of political Economy*, 1989, *97* (3), 620–638.

_ , "Hysteresis, import penetration, and exchange rate pass-through," *The Quarterly Journal of Economics*, 1989, *104* (2), 205–228.

Feng, Ling, Zhiyuan Li, and Deborah L Swenson, "The connection between imported intermediate inputs and exports: Evidence from Chinese firms," *Journal of International Economics*, 2016, *101*, 86–101.

Goldberg, Pinelopi Koujianou, Amit Kumar Khandelwal, Nina Pavcnik, and Petia Topalova, "Imported intermediate inputs and domestic product growth: Evidence from India," *The Quarterly journal of economics*, 2010, *125* (4), 1727–1767.

Gopinath, Gita and Brent Neiman, "Trade adjustment and productivity in large crises," *American Economic Review*, 2014, *104* (3), 793–831.

Greenaway, David and Richard Kneller, "Firm heterogeneity, exporting and foreign direct investment," *The Economic Journal*, 2007, *117* (517), F134–F161.

Halpern, László, Miklós Koren, and Adam Szeidl, "Imported inputs and productivity," *American Economic Review*, 2015, *105* (12), 3660–3703.

Imura, Yuko, "Reassessing trade barriers with global value chains," Technical Report, Bank of Canada Staff Working Paper 2019.

Kasahara, Hiroyuki and Beverly Lapham, "Productivity and the decision to import and export: Theory and evidence," *Journal of international Economics*, 2013, *89* (2), 297–316.

_ **and Joel Rodrigue**, "Does the use of imported intermediates increase productivity? Plant-level evidence," *Journal of development economics*, 2008, *87* (1), 106–118.

Khandelwal, Amit K, Peter K Schott, and Shang-Jin Wei, "Trade liberalization and embedded institutional reform: Evidence from Chinese exporters," *American Economic Review*, 2013, *103* (6), 2169–95.

Levinsohn, James and Amil Petrin, "Estimating production functions using inputs to control for unobservables," *The review of economic studies*, 2003, *70* (2), 317–341.

Liu, Qing and Larry D Qiu, "Intermediate input imports and innovations: Evidence from Chinese firms' patent filings," *Journal of International Economics*, 2016, *103*, 166–183.

Loecker, Jan De, "Do exports generate higher productivity? Evidence from Slovenia," *Journal of international economics*, 2007, *73* (1), 69–98.

_ , "Product differentiation, multiproduct firms, and estimating the impact of trade liberalization on productivity," *Econometrica*, 2011, *79* (5), 1407–1451.

_ , "Detecting learning by exporting," *American Economic Journal: Microeconomics*, 2013, *5* (3), 1–21.

Lu, Dan, "Exceptional exporter performance? Evidence from Chinese manufacturing firms," *manuscript, University of Chicago*, 2010.

Manova, Kalina, Shang-Jin Wei, and Zhiwei Zhang, "Firm exports and multinational activity under credit constraints," *Review of Economics and Statistics*, 2015, *97* (3), 574–588.

Melitz, Marc J, "The impact of trade on intra-industry reallocations and aggregate industry productivity," *econometrica*, 2003, *71* (6), 1695–1725.

Ramanarayanan, Ananth, "Imported inputs, irreversibility, and international trade dynamics," *Journal of International Economics*, 2017, *104*, 1–18.

Rho, Youngwoo and Joel Rodrigue, "Firm-level investment and export dynamics," *International Economic Review*, 2016, *57* (1), 271–304.

Roberts, Mark J and James R Tybout, "The decision to export in Colombia: An empirical model of entry with sunk costs," *The American Economic Review*, 1997, pp. 545–564.

Rust, John, "Using randomization to break the curse of dimensionality," *Econometrica: Journal of the Econometric Society*, 1997, pp. 487–516.

Yu, Miaojie, "Processing trade, tariff reductions and firm productivity: evidence from Chinese firms," *The Economic Journal*, 2015, *125* (585), 943–988.

A Dynamic Estimation Details

A.1 The Calculation of Likelihood Function

By the assumption that fixed costs and sunk costs are i.i.d draws from distribution G_γ, the joint probability of $P\Big[e_{j1}^T, i_{j1}^T | \nu_1^T(\nu_j^+, z_j), \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}\Big]$ can be rewritten as

$$
\begin{aligned}
& P\Big[e_{j1}^T, i_{j1}^T | \nu_1^T(\nu_j^+, z_j), \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}\Big] \\
& = P(e_{j1}^T | \nu_1^T(\nu_j^+, z_j), \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}) \times P(i_{j1}^T | \nu_1^T(\nu_j^+, z_j), \omega_{j1}^T, k_{j1}^T, \phi_1^{fT}) \\
& = \prod_{t=1}^{T} P(e_{jt} = 1 | s_{jt})^{e_{jt}} \Big[1 - P(e_{jt} = 1 | s_{jt})\Big]^{1-e_{jt}} \\
& \times \prod_{t=1}^{T} P(i_{jt} = 1 | s_{jt})^{i_{jt}} \Big[1 - P(i_{jt} = 1 | s_{jt})\Big]^{1-i_{jt}},
\end{aligned}
$$

namely, the joint probability can be expressed as the product of the choice probabilities for exporting and importing each year. These choice probabilities are based on the state variables in the corresponding year. The state variables are $\omega_{jt}, \nu_{jt}, k_{jt}, \phi_t^d, \phi_t^f$, and prior choices of exporting and importing. The prior exporting and importing status become part of the state vector since they determine what kind of cost at time t the firm needs to pay: sunk costs to enter or fixed costs to remain. However, note that there is one slight difference of the state variables. Prior exporting and importing status $(e_{j,t-1}, i_{j,t-1})$ enter for the state vector of exporting while current period exporting and prior importing status $(e_{j,t}, i_{j,t-1})$ enters for the state vector of importing because of the timing assumption of the theoretical model.

Based on the model developed above, the probability of exporting can be calculated in terms of the costs of exporting and the value functions for exporter and non-exporters as

$$\begin{aligned}
&P(e_{jt} = 1|s_{jt}) \\
&= P\Big[e_{j,t-1}\gamma_{jt}^F + (1 - e_{j,t-1})\gamma_{jt}^S \leq \pi_{jt}^f + V^f(s_{jt}) - V^d(s_{jt})\Big] \\
&= G_\gamma\Big(\pi_{jt}^f + V^f(s_{jt}) - V^d(s_{jt})\Big),
\end{aligned} \tag{28}$$

where the first equality comes from equation (13) and (14). It states the probability depends on comparing the expected profits from exporting relatively to selling only in the domestic market with the costs to be an exporter in the current period. The costs to be an exporter is γ_{jt}^F for previous exporters or γ_{jt}^S for previous non-exporters. The second equality comes from our distribution assumption that these costs are i.i.d. draws from exponential distributions. Similarly, the probability of importing can be obtained from equations (17) and (16) as

$$\begin{aligned}
&P(i_{jt} = 1|s_{jt}) \\
&= P\Big[i_{j,t-1}\gamma_{jt}^G + (1 - i_{j,t-1})\gamma_{jt}^R \leq \delta E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 1) - \delta E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 0)\Big] \\
&= G_\gamma\Big(\delta E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 1) - \delta E_t V(s_{j,t+1}|e_{jt}, i_{jt} = 0)\Big),
\end{aligned} \tag{29}$$

where the expected continuation value depends the firm's exporting status at the current period e_{jt} and the costs to pay depends on prior importing status $i_{j,t-1}$. Clearly, expressions (28) and (29) allows one to calculate $\{P(e_{jt} = 1|s_{jt})\}_{t=2}^T$ and $\{P(i_{jt} = 1|s_{jt})\}_{t=2}^T$, respectively. However, $P(e_{j1} = 1|s_{j1})$ and $P(i_{j1} = 1|s_{j1})$ needs some special treatment since e_{j0} and i_{j0} are not observed. This creates an initial condition problem. I follow

Das et al. (2007) to model the decision to export and import in the initial year with two separate probit equations using state variables $(\omega_{j1}, \nu_{j1}, k_{j1})$ as explanatory variables. Specifically, I calculate the initial probabilities as a function of $(\omega_{j1}, \nu_{j1}, k_{j1})$ as

$$P(e_{j1} = 1|s_{j1}) = a_0 + a_1\omega_{j1} + a_2\nu_{j1} + a_3k_{j1},$$

and

$$P(i_{j1} = 1|s_{j1}) = b_0 + b_1\omega_{j1} + b_2\nu_{j1} + b_3k_{j1}.$$

Dealing with the initial year probability would introduces another eight parameters, $(a_0, a_1, a_2, a_3, b_0, b_1, b_2, b_3)$, to be estimated. Collect all the parameters to be estimated in the second stage as θ, then $\theta = (\gamma^F, \gamma^S, \gamma^G, \gamma^R, \rho_\nu, \sigma_\mu, \phi_t^f, a_0, a_1, a_2, a_3, b_0, b_1, b_2, b_3)$.

A.2 The Inner Loop-Value Iteration

Given a parameter vector θ, a fixed point $V(\cdot, \theta)$ is guaranteed by the contracting property of the Bellman operator T_θ:

$$T_\theta V(s, \theta) \equiv \max_a \left\{ U(s, a, \theta) + \delta \int V(s', \theta) dF(s'|a, s) \right\}.$$

The procedure typically takes several steps.

1. Take an initial guess of the value function $V^0(s, \theta)$.

2. Calculate $EV^0(s, \theta)$ according to equation (18). Since the productivity ω and the exporting market shock process ν are all continuous, I discretize them into a pseudo-random Sobol sequence by following the method of Rust (1997).

3. Calculate V_t^{f0} based on equation (16) as

$$V_t^{f0} = P(i_{jt}=1|s_{jt}) * \Big[\delta EV^0(e_{jt}=1, i_{jt}=1) - i_{j,t-1}\gamma_{jt}^G - (1-i_{j,t-1})\gamma_{jt}^R\Big] + \Big(1 - P(i_{jt}=1|s_{jt})\Big) * \Big[\delta EV^0(e_{jt}=1, i_{jt}=0)\Big]$$

Similarly, calculate V_t^{d0} based on equation (17) as

$$V_t^{d0} = P(i_{jt}=1|s_{jt}) * \Big[\delta EV^0(e_{jt}=0, i_{jt}=1) - i_{j,t-1}\gamma_{jt}^G - (1-i_{j,t-1})\gamma_{jt}^R\Big] + \Big(1 - P(i_{jt}=1|s_{jt})\Big) * \Big[\delta EV^0(e_{jt}=0, i_{jt}=0)\Big]$$

where $P(i_{jt}=1|s_{jt})$ can be obtained analytically from equation (29).

4. Calculate V^1 based on equations (13) and (14) as

$$V^1(s,\theta) = P(e_{jt}=1|s_{jt}) * \Big[\pi_{jt}^d + \pi_{jt}^f - e_{j,t-1}\gamma_{jt}^F - (1-e_{j,t-1})\gamma_{jt}^S + V^{f0}\Big] + \Big(1 - P(e_{jt}=1|s_{jt})\Big) * \Big[\pi_{jt}^d + V^{d0}\Big]$$

where $P(e_{jt}=1|s_{jt})$ can be obtained from equation (28) analytically.

5. repeat the iteration steps 2-4 until convergence. As Bray (2019) and Kasahara and Rodrigue (2008) points out, the convergence can be based on the “span-seminorm" criterion as

$$sp(V^{i+1} - V^i) \equiv \max_{s\in S}\{V^{i+1}(s) - V^i(s)\} - \min_{s\in S}\{V^{i+1}(s) - V^i(s)\} \le \epsilon$$

rather than the traditional $|V^{i+1} - V^i| \leq \epsilon$ for some small ϵ. Because only the relative differences of value function across states not the levels of value function determine the conditional choice probabilities.