Complementarity between Exporting, Importing and Productivity: Evidence from India

by
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Abstract

This paper tries to understand the export and import behavior of firms on three phenomenon: i) Sunk cost and self-selection: Ex-ante selection of higher productivity firms into export and import participation, ii) Learning-by-doing: Ex-post productivity benefits of participation in the export and import market and iii) Cost complementarity between exporting and importing: Decrease in costs to exporting if firm is importing and vice-versa. These hypothesis are analysed on panel data of Indian Manufacturing firms from Prowess, Centre for Monitoring Indian Economy (CMIE). I find that the Indian manufacturing firms exhibit: i) self-selection of higher productivity firms into exporting and importing, ii) Learning-by-doing phenomenon is observed for importing, but it is not observed for exporting and iii) lagged and contemporaneous cost complementarity between exporting and importing after controlling for firm-level characteristics.

Contents

1 Introduction

Exporting and importing are the two mediums through which firms participate in the international trade market. Exporting involves selling products and services of a firm to buyers in the international market, whereas importing involves purchasing intermediate goods for the use of a firm.

There is a vast empirical literature that has documented that exporters tend to out-perform non-exporters in terms of wages, capital, and productivity.[1] Bernard and Jensen (1999) suggest that this can be due to the following phenomenon:

- Self-selection (SS) of highly productive firms into exporting as participation in foreign market is costly. Exporting is accompanied by large sunk costs such as costs of establishing a distribution channel, cost of traversing bureaucracy etc, and higher variable cost due to transportation, and hence only the most productive firms can bear this additional cost.
- Learning-by-doing which states that exporters experience an increase in productivity after they enter foreign markets. This could be because they invest in productivity enhancing know-how to deal with the higher competition in international markets as compared to domestic market. In addition, participating in the international market could lead to knowledge flows from international buyers, which could further lead to gains in productivity.

However, most of the research in this field has been limited to exports and research on the link between firm productivity and imports has been relatively limited. The same hypothesis (self-selection and learning-by-doing) can apply to import behavior of firms. Since importing intermediaries also involves similar sunk costs like a search process for foreign suppliers, inspection of goods on top of fixed costs like transport costs, import duties etc., more productive firms are likely to *self-select* themselves into importing. Also, since a firm participating in the import market can have access to higher quality of intermediary goods, it might lead to productivity benefits i.e the firms might exhibit *learning-by-doing* phenomenon. Topalova and Khandelwal (2011) and Halpern, Szeidl, et al. (2011) find that improved access to foreign technology through importing intermediate inputs can boost productivity.

Moreover, Muuls and Pisu (2009) and Aristei et al. (2013) find that a large proportion on firm that export also participate in the import market. This might mean that participating in one trade activity can increase the probability of participating in the other.

[1] Wagner (2007) and Bernard, Jensen, et al. (2007) provide a survey in which most of the papers observe this phenomenon.

This is because firms could gain new information about global distribution network as they participate in either export or import markets, or because learning-by-doing fosters an increase in productivity which then leads to self-selection of firms. Therefore, there might cost complementarity between exports and imports. Therefore, it might be observed that there is decrease in costs to exporting at time t if a firm was importing in time $t-1$ (*lagged cost complementarity*) and the decrease in costs to exporting and importing at same time (*Contemporaneous cost complementarity*).

In this paper I aim to investigate the dynamic relationship between exporting, importing and firm productivity. I focus on understanding i) Learning-by-doing through exporting and importing, ii) self-selection of highly productive firms into exporting and importing and iii) cost complementarity, contemporaneous and lagged, between exporting and importing.

For the purpose of this analysis, I use data for Indian manufacturing firms sourced from from PROWESS, provided by the Centre for Monitoring Indian Economy (CMIE). India liberalised its economy in 1992 which resulted in lower export and import tariffs, deregulation of markets, reduction of taxes, and greater foreign investment. According to Topalova and Khandelwal (2011), *the government's trade policy under the Eighth Five-Year Plan (1992-97) ushered in radical changes to the trade regime by sharply reducing the role of the import and export control system. The share of products subject to quantitative restrictions decreased from 87 percent in 1987-88 to 45 percent in 1994-95, and the actual user condition on imports was discontinued.*. Thus there are many firms that transitioned into exporting and importing since the mid 1990s, and thus firm-level data of Indian firms provides a good opportunity to investigate productivity gains from participation in the trade market, self-selection of high productivity firms into exporting and importing and whether participation in one trade activity complements participation in the other activity.

To motivate the econometric analysis, Section 3 provides descriptive evidence that firms that participate in the trade market have higher capital, labor, and productivity than firms that do not participate in the trade market using density plots and fixed-effects regression. It also provides evidence of persistence in trading behavior of firms by observing the empirical transition probability observed in the data.

The main empirical analysis is divided into three parts: Section 5.1 shows the results of the analysis done for studying the learning-by-doing phenomenon, section 5.2 shows the analysis for the sunk cost and self-selection hypothesis as well as the lagged cost complementarity phenomenon and section 5.3 shows the results for the contemporaneous cost complementarity phenomenon.

I investigate the learning-by-doing hypothesis by endogenously accommodating the decision to export and import in the productivity evolution process. I use two productivity estimation procedures popular in the literature: Levinsohn and Petrin (2003) and Ackerberg et al. (2006). The results suggest the importing has a positive effect on productivity:

the discrete decision to import at $t-1$ increases the productivity on average by 3.6% and 2.7% at time t for the two methods respectively. The discrete decision to export at time $t-1$ does not have a significant effect on productivity at time t. This result suggests that firms experience learning-by-importing and do not experience learning-by-exporting.

To study the hypothesis that there are large sunk costs in exporting and importing, I estimate a dynamic random effects probit model of the discrete decision to export and import. I find that the lagged decision to export and import has the strongest and positive effect on the decision to export and import, respectively. This provides evidence for the presence of large sunk costs in participation in trade markets. Firm productivity, capital, and labor have a positive effect on the decision to export and import as well. This suggests the presence of self-selection of higher productivity, and bigger firms into exporting and importing.

I add the lagged decision to import on the dynamic random effects probit model for the decision to export and vice-versa. The results show that the lagged decision to import has a positive effect on the probability of exporting. The same pattern is observed for the effect of lagged decision to export on the decision to import. This suggests the presence of lagged cost complementarity between exporting and importing.

Finally, I estimate a dynamic bivariate probit model for the decision to export and import. The results show the same phenomenon observed in the dynamic random effects probit model. On top of that, it also provides evidence for the presence of contemporaneous cost complementarity as the shocks of the decision to export and import are positively correlated.

The structure of the rest of the paper is as follows: section 2 discusses the main contributions of the literature in this field, section 3 summarises the data used in this paper, section 4 displays the descriptive statistics of the data, section 5 displays the empirical analysis and section 6 summarises the main findings of the paper.

2 Literature Review

My paper contributes to the literature in the following areas:

1. The link between exporting and productivity
2. The link between importing and productivity
3. Complementarity between exporting and importing
4. Productivity estimation

Exporting and Productivity

Roberts and Tybout (1997) is one of the earliest papers that tests the sunk cost and self-selection hypothesis. They quantify the effect of prior exporting decision on the current exporting decision and test the sunk cost hypothesis of these activities. They develop a dynamic discrete- choice model of exporting behavior that separates the roles of profit heterogeneity and sunk entry costs in explaining plants exporting status and find that sunk costs are significant as prior export experience increases the probability of exporting by 60 percent.

The most popular research paper in this literature is Bernard and Jensen (1999). They test the self-selection and learning-by-doing hypothesis of exports on firms. They find that better plants become exporters i.e. learn to export. and find that exporting increases the survival probability but it does not contribute towards productivity growth.

Wagner (2007) and Wagner (2012) conducted a survey of the important research papers in international trade. They find there is self-selection of more productive firms into exporting in most of the literature, however there is mixed evidence for learning-by-exporting.

Some papers have tried to estimated the fixed and sunk costs of exporting by estimating dynamic model. One of the most popular papers in this field is Aw, M. Roberts, et al. (2011). They estimate a dynamic structural model that captures both the behavioral and technological linkages among R&D, exporting, and productivity. They find that relative to a plant that does neither activity, export market participation raises future productivity by 1.96 percent, R&D investment raises it by 4.79 percent, and undertaking both activities raises it by 5.56 percent.

In terms of work in this field with Indian firm level data, Haidar (2012) and Gupta et al. (2018) find evidence of self-selection of more productive firms into exporting, but they do not find evidence of learning-by-exporting. My paper is the first paper that endogenously accommodates the decision to export and import into the productivity estimation procedure and tries to understand the complementarity between exporting and importing.

Importing and Productivity

A firm that imports intermediate inputs can have access to higher-quality inputs and therefore exhibit the learning-by-importing phenomenon. The arguments in favor of self-selection of more productive firms says that importing behavior is associated with fixed and sunk costs as it involves a search process for potential foreign suppliers, inspection of goods, negotiation, contract formulation, etc. And therefore, only the most productive firms will self-selection into participating in the import market.

One of the most important papers in this field is Topalova and Khandelwal (2011). They find that the pro-competitive effects of the import tariffs led firms to become more productive, the larger impact appears to have come from increased access to foreign inputs. The learning-by-doing and self-selection for importing has also been observed by Muuls and Pisu (2009), and Kasahara and Rodrigue (2008).

Halpern, Szeidl, et al. (2011) studies effect of imports on productivity by estimating a structural model of importers in a panel of Hungarian firms. They find that imports have a significant and large positive effect on firm productivity, about one-half of which is due to imperfect substitution between foreign and domestic goods. This research paper finds evidence of the learning-by-doing phenomenon.

Complementarity between Exporting and Importing

Importing might pave the way for future exporting by increasing the productivity or by providing cost-complementarity between the two activities and vice-versa. In my knowledge, there have been two major papers in this field i.e Aristei et al. (2013) and Kasahara and Lapham (2013).

Aristei et al. (2013) estimate a bivariate probit model to understand the two-way relationship between exporting and importing. They use firm-level data for a group of 27 Eastern European and Central Asian countries from the World Bank Business Environment and Enterprise Performance Survey (BEEPS) over the period 2002-2008, and after controlling for size (and other firm-level characteristics), find that firms exporting activity does not increase the probability of importing, while the latter has a positive effect on foreign sales (exporting).

Kasahara and Lapham (2013) estimate a stochastic model of exporting and importing that incorporates heterogeneity in transport costs and estimate export and import complementarity between the two trade activities. They find that policies which inhibit the import of foreign intermediates can have a large adverse effect on the export of final goods.

Some other papers such have also found complementary effects between exporting and importing. Vogel and Wagner (2010) provide evidence of imported intermediate inputs in firm productivity and export scope. Muuls and Pisu (2009) find existence of self-selection and sunk cost behavior in importing and find an effect of the lagged decision to import on exporting.

I add to this literature by differentiating the two phenomenon through which exporting could complement importing, and vice-versa. I try to observe the impact of cost complementarity and productivity benefits of importing on the probability to export.

Productivity Estimation

Most of the literature uses the following methods for productivity estimation: Olley and Pakes (1992), Levinsohn and Petrin (2003), Ackerberg et al. (2006) and Wooldridge (2009). These papers take inspiration from one another and are based on a similar methodology. The method mentioned in Olley and Pakes (1992) have been explained in section 7.2.

With regards to effect of the decision to export on productivity, De Loecker (2013) highlights the importance of accommodating the export decision endogenously in the minimisation problem of the productivity estimation procedure.

3 Data

I use annual firm level data for Indian manufacturing firms from PROWESS,[2] provided by Centre for Monitoring Indian Economy (CMIE). This dataset has been used in a number of important paper studying exporter and importer performance in India [3].

[2] Prowess is a database of the financial performance of companies. Annual Reports of companies, stock exchanges and regulators are the principal sources of the data. It delivers data for over 40,000 Indian companies. This includes listed companies, unlisted public companies and private companies of all sizes and ownership groups

[3] De Loecker et al. (2016), Topalova and Khandelwal (2011), Gupta et al. (2018) and Haidar (2012) are some of the papers which use this data set

Table 1 Data Variables

Variable	Indicator
sa_company_name	Prowess company name
sa_finance1_year	Year
sa_sales	Sales
sa_rawmat_exp	Raw material expenses
sa_power_and_fuel_exp	Power & fuel expenses
sa_salaries	Salaries & wages
sa_pat	Profit after tax
sa_gross_fixed_assets	Gross fixed assets
sa_export_goods	Export of goods
sa_export_serv	Export of services
sa_import_rawmat	Import of raw materials
sa_import_stores_spares	Import of stores and spares
sa_import_fg	Import of finished goods
nic.2digit	Broad industry classification code
Note:	Variables are in INR Million

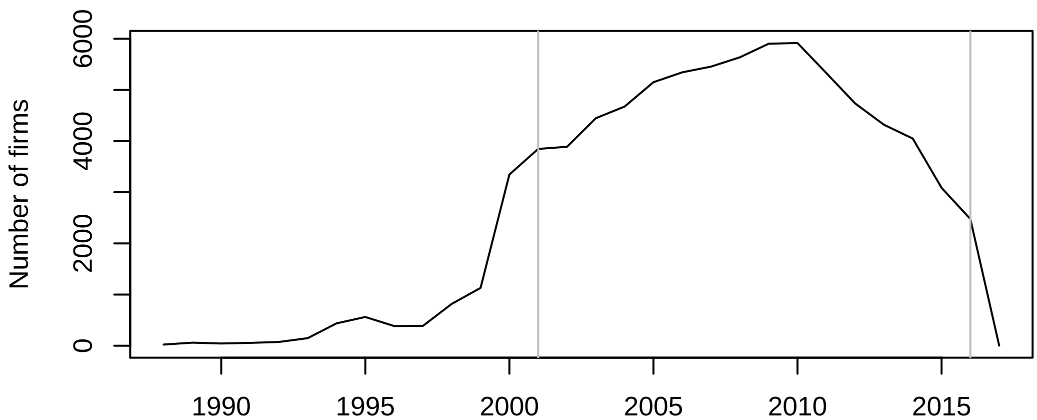
Table 1 shows the variables I use from the database and defines them. I deflate nominal values with the yearly Wholseale Price Index (WPI) to obtain real values. I remove firm-year observations with missing values of any of the key variables and as result, large number of firms are removed from the dataset. Figure 1 shows the composition of firms by year in the cleaned dataset. Since the number of firms in the data from 1988 to 2000 are relatively low, I restrict the time period of the analysis from 2001 to 2016.

In Prowess, firms are under no legal obligation to report their finances, and hence it is difficult to identify entry and exit of firms. Therefore in this paper, I do not analyse the effect of export and import on the survival probability of firms. The non-compulsory disclosure also creates a bias in favour of large and publicly listed firms. However, since exporters and importers are generally large, the results could be biased downwards.

I create two additional variables *Export Value* and *Import Value* by adding the following variables from Table 1.

1. Export Value: Sum of the exports of goods and services ($sa\_export\_goods + sa\_export\_serv$)

Figure 1 Number of firms by year



2. Import Value: Sum of imports of raw materials, stores and spares, finished goods and capital goods ($sa\_import\_rawmat + sa\_import\_stores\_spares + sa\_import\_fg + sa\_import\_cap\_goods$)

Using these value variables, I create dummies for trade market participation as follows:

- Export Dummy: $d_{it}^{X} = 1$ if *Export Value* > 0, otherwise 0
- Import Dummy: $d_{it}^{M} = 1$ if *Import Value* > 0, otherwise 0

Finally, I divide firms in the dataset into the following four categories:

- None: Firms that do not participate in the export and import market
- Export only: Firms that participate in the export market only
- Import only: Firms that participate in the import market only
- Both: Firms that participate in both export and import market

Table 2 displays the composition of firms according to their trade market participation status. The number of firms that do not participate in the trade market is low, around 20 to 35 %. Surprisingly, the number of firms that participate in the trade market is as high as 75%. Another interesting feature is that the number of firms that participate only in the import market is higher than the firms that participate only in the export market. This can mean that the demand for foreign intermediaries is relatively high. Also, almost 50 % of firms in each year participate in both export and import market. There is a very

Table 2 Composition of firms based on trade market participation

Year	None	Export only	Import only	Both	Total
2001	0.28	0.08	0.18	0.46	3847
2002	0.29	0.08	0.18	0.46	3889
2003	0.30	0.08	0.18	0.44	4447
2004	0.32	0.09	0.16	0.43	4675
2005	0.35	0.08	0.16	0.41	5151
2006	0.34	0.08	0.16	0.42	5344
2007	0.35	0.08	0.16	0.42	5456
2008	0.34	0.08	0.16	0.42	5638
2009	0.35	0.08	0.15	0.42	5903
2010	0.36	0.08	0.16	0.40	5917
2011	0.37	0.08	0.15	0.41	5330
2012	0.35	0.07	0.14	0.44	4737
2013	0.33	0.08	0.14	0.45	4320
2014	0.31	0.08	0.14	0.47	4050
2015	0.24	0.08	0.14	0.54	3087
2016	0.20	0.07	0.14	0.58	2477

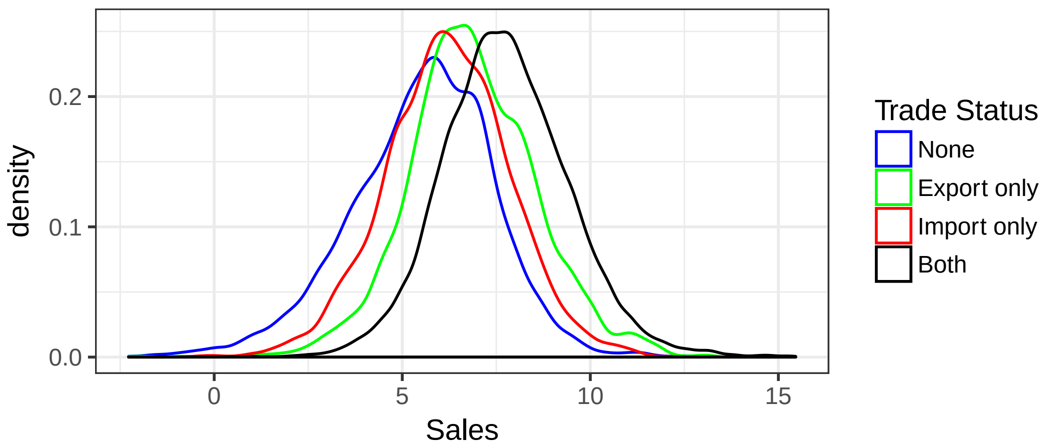
high proportion of firms that participate in the both the trade market activities relative to the firms that participate only in one trade market activity.

4 Descriptive Statistics

4.1 Exporter and Importer Performance

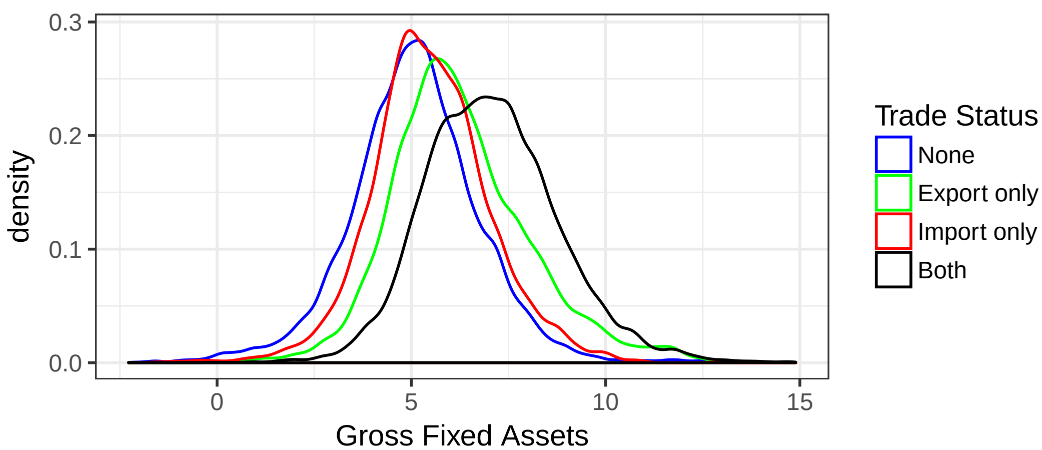
To see the difference in performance of firms that participate in the trade market versus those that don't, I show the density plots for log of sales, gross fixed assets, salaries and for the four categories of firms trade behavior defined above, in Tables 3, 4 and 5, respectively.

Table 3 Summary Statistics of Sales (log)



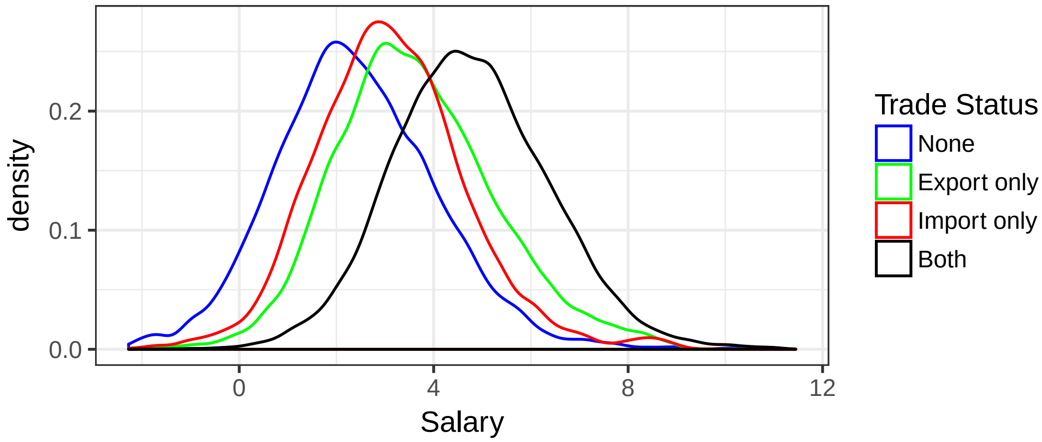
Status	Mean	Sd
None	5.52	1.91
Import only	6.86	1.72
Export Only	6.2	1.66
Both	7.74	1.69

Table 4 Summary Statistics of Gross Fixed Assets (log)



Status	Mean	Sd
None	5.09	1.68
Import only	6.26	1.8
Export Only	5.49	1.53
Both	7.06	1.73

Table 5 Summary Statistics of Salary (log)



Status	Mean	Sd
None	2.41	1.67
Import only	3.63	1.66
Export Only	3.11	1.56
Both	4.76	1.63

The distribution of firms that participate in the trade market is more skewed towards the right for all the variables mentioned above. In the case of sales, firms in category 'None' have an average of 5.52 whereas firms in category 'Export Only'; and 'Import Only' have and average of 6.86 and 6.82 respectively. Moreover, firms in category 'Both' have an average of 7.74. On the other hand, the standard deviation in the 4 cases is very similar, which suggests that the increase in average is not due to the presence of outliers. The same pattern is observed for gross fixed assets and salary.

This suggests that firms that participate in the both export and import market have higher sales, mean gross fixed assets and salaries than firms that participate in only export and only import. And firms that participate in either the export or import market have higher values than firms that do not participate in the trade market. This indicates that firms participating in the trade market has an positive effect on the observable characteristics of the firm.

The same pattern in observed for expenditure on raw material (Table 21) and expenditure on power and fuel (Table 22) in the Appendix section 7.1

4.2 Trade Premia

Trade premia is defined as the difference in attributes of firms based on their trade participation status. I estimate the trade premia using the following Fixed Effect (FE) regression:

$$X_{it} = \alpha_i + \gamma_t + \beta_1 d_{it}^X + \beta_2 d_{it}^M + \beta_3 d_{it}^X * d_{it}^M + \beta_4 age_{it} + \epsilon_{it} \tag{1}$$

where X_{it} is firm level characteristics such as Sales, Gross Fixed Assets, Expenditure on Raw Material and Salary, d_{it}^X is the export dummy, d_{it}^M is the import dummy, the interaction term between these two variables and age_{it} is the age of the firm. I estimate this equation using time and firm fixed effects to account for time invariant firm characteristics, and any time-specific effects.

Table 6 Export and Import Premia

	Dependent variable:			
	Sales	Gross Fixed Assets	Raw Materials	Salary
	(1)	(2)	(3)	(4)
d_{it}^X	0.422***	0.209***	0.422***	0.311***
	(0.014)	(0.011)	(0.016)	(0.012)
d_{it}^M	0.430***	0.188***	0.451***	0.287***
	(0.012)	(0.009)	(0.013)	(0.010)
$d_{it}^X * d_{it}^M$	−0.060***	0.023*	−0.037**	−0.004
	(0.016)	(0.012)	(0.019)	(0.014)
Age_{it}	0.039***	0.048***	0.041***	0.062***
	(0.001)	(0.001)	(0.001)	(0.001)
Fixed Effects	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Observations	73,882	73,882	73,882	73,882
R^2	0.142	0.171	0.137	0.255
Adjusted R^2	0.026	0.059	0.021	0.154
Note:		Robust standard errors shown in parenthesis		
				*p<0.1; **p<0.05; ***p<0.01

Table 6 displays the results for the above regression. The coefficients for both export and import dummy are positive and significant at 1% significance level. Column 1 of this table shows the trade premia for the variable sales. Firms in category ‘Export Only’ 52 % $(exp(0.422) - 1) * 100 =$ more sales than firms ‘None’. Similarly firm in category ‘Import Only’ on average 54% higher sales than firms in category ‘None’.

The interaction term value of -0.060 is not higher than the coefficient value of the export and import dummy. Therefore, the cumulative effect of participating in both activities is higher than the effect of participating in just one trade activity. Therefore, firms that lie in category ‘Both’ have on average 120% higher sales than firms that lie in category ‘None’.

The same trend is also observed for gross fixed assets, salary and expenditure on raw materials. The age variable also has a positive coefficient and is significant at 1% significance level. Therefore, on average the older a firm becomes the higher its capital, assets etc. become.

This section verifies the presence of trade premia in our dataset. It further substantiates the point that firms that participate in one trade market activity (export or import) have better sales, gross fixed assets etc than firms that do not participate in the trade market. Furthermore, firms that participate in the both of the trade market activities have a higher trade premia than the firms that participate in one of the trade activities.

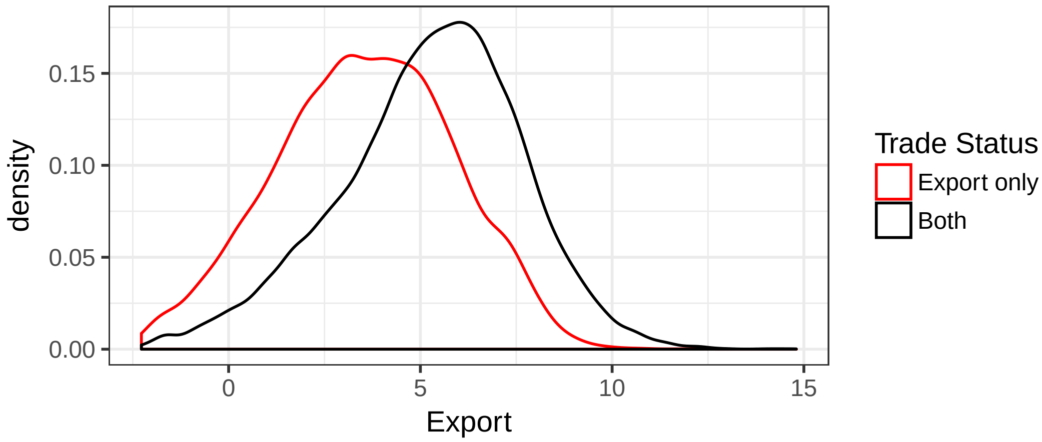
In the next section, I descriptively investigate whether exports have an effect on imports and vice-versa.

4.3 Complementarity between Exporting and Importing

The difference between density plots for export value of firms that lie under category ‘Both’ versus those that lie in ‘Export Only’ will give a better understanding of whether there is an effect of one activity on the other. Table 7 displays the the density plot of the log values of export for firms in the category ‘Export only’ and ‘Both’ defined above. The table shows that firms in category ’Both’ have a higher mean of exports (5.24) than firms in category ’Export Only’ (3.56). This suggests that importing may have a positive association with exporting such that firms export more if they also import.

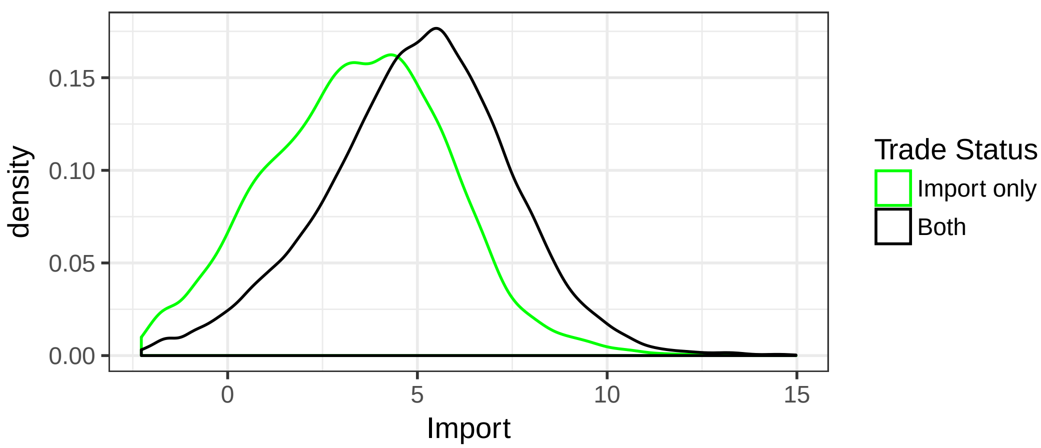
Table 8 displays the density plot of the log value of import for firms in category ’Both’ and ‘Import Only’. Firms that participate in both the export and import market have higher imports (4.95) than firms that only participate in the import market (3.41). Again, this shows that firms import more if they are also exporters.

Table 7 Summary statistics of Export (log)



Status	Mean	Sd
Export Only	3.56	2.3
Both	5.24	2.39

Table 8 Summary statistics of Import (log)



Status	Mean	Sd
Import only	3.44	2.38
Both	4.99	2.45

Tables 7 and 8 suggest that both these activities have a positive effect on the other and this might be because importing complements exporting and vice-versa. This complementarity needs further research, and is the focus of my paper.

I estimate the trade premia similar to the regression in equation 1 to see the effect decision to import on exporting value. This is done by estimating the following fixed-effects (FE) regression:

$$log(Export)_{it} = \alpha_i + \gamma_t + \beta_1 d^M_{it} + +\beta_2 age_{it} + \epsilon_{it}$$

$$log(Import)_{it} = \alpha_i + \gamma_t + \beta_1 d^X_{it} + \beta_2 age_{it} + \epsilon_{it}$$

Table 9 Export and Import Premia

	Dependent variable:			
	Export	Import	Capital Productivity	Profit to Sales
	(1)	(2)	(3)	(4)
d^M_{it}	0.506***		0.159***	0.061***
	(0.026)		(0.009)	(0.004)
d^X_{it}		0.458***	0.097***	0.021***
		(0.024)	(0.011)	(0.005)
$d^X_{it} * d^M_{it}$			−0.027**	−0.005
			(0.013)	(0.006)
Age_{it}	0.068***	0.051***	−0.005***	−0.001**
	(0.003)	(0.002)	(0.001)	(0.0004)
Fixed Effects	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes
Observations	38,359	44,174	69,374	72,401

Note: Robust standard errors shown in parenthesis
*p<0.1; **p<0.05; ***p<0.01

The first two columns of table 9 display these results. Firms that import have on average a higher value of exports. The opposite is also true, exporting firms have a higher value of imports. This further suggests the presence of complementarity between exporting and importing.

In the next section, I investigate the effect of exporting and importing on simple measures of productivity.

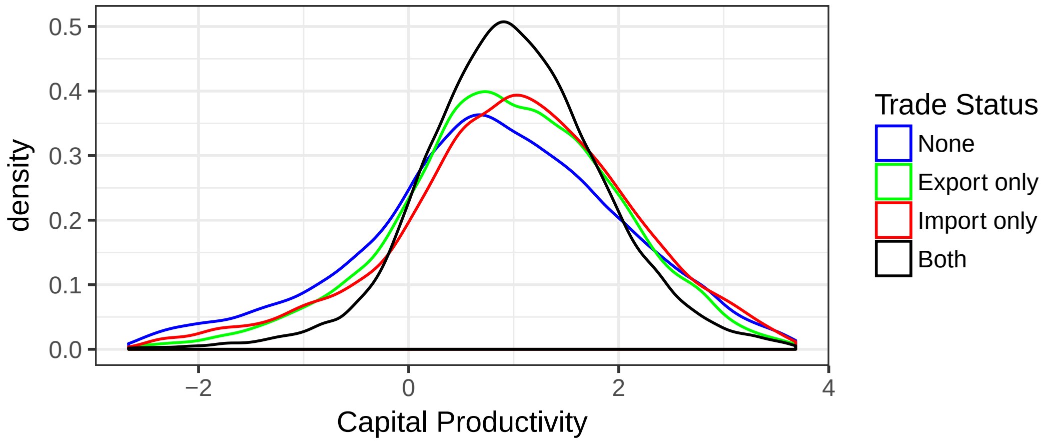
4.4 Productivity and Export/Import

Gupta et al. (2018) define a simple measure of productivity known as *capital productivity*. It is defined as the log of value added per unit of capital used by a firm:

$$log(VA_{it}) - log(k_{it}) \tag{2}$$

where VA_{it} is firm-level value added, computed as total industrial sales plus change in stock minus power and fuel expenditures, and raw material expenses. Table 10 displays the summary statistics for this variable based on the trade activity status. The mean of capital productivity increases as activity status moves from *None* to *Export only or Import only* to *Both*, whereas the standard deviation decreases.

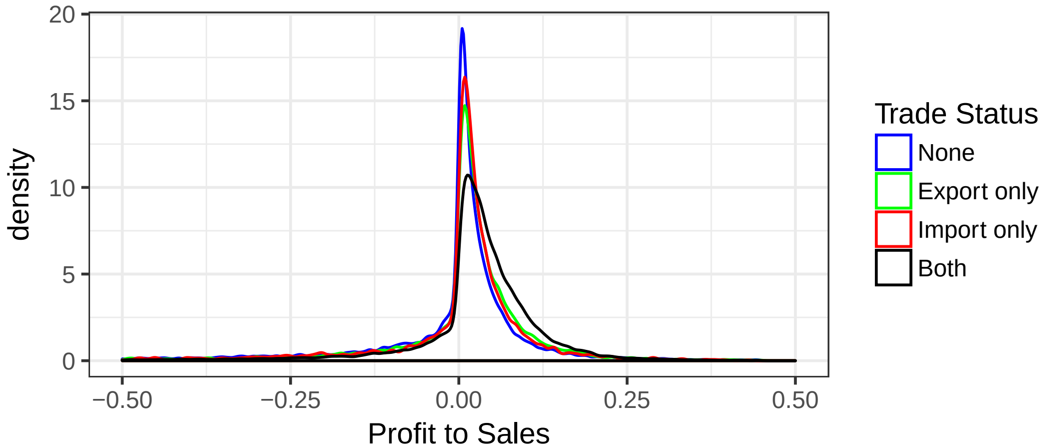
Table 10 Summary statistics of Capital Productivity (log)



Status	Mean	Sd
None	0.8	1.2
Import only	0.94	1.03
Export Only	1	1.1
Both	0.99	0.86

Table 10 displays that firms which participate in the trade market have a higher capital productivity as firms participating in the trade market have a higher mean than those firms that do not particii.epate in the trade.

Table 11 Summary statistics of Profit to Sales



Status	Mean	Sd
None	-0.1	0.43
Import only	-0.03	0.29
Export Only	-0.06	0.34
Both	0.01	0.21

I also use a measure of firm profitability, calculated by dividing the profit after tax of a firm with its sales. Table 11 shows the summary statistics for this variable. The same pattern is observed for this variable as well. The mean increases from -0.1 when a firm is not participating in the trade market to -0.03 and -0.06 when a firm is participating in import and export respectively to 0.01 when a firm is participating in both of the trade market activities.

The last two columns of table 9 estimate the trade premia for the simple measures of the productivity defined above i.e capital productivity and profit-to-sales ratio. Both of the crude measures of productivity are positively correlated to the discrete decisions of importing and exporting. Firms under category ‘Export Only’ have on average a higher capital productivity and profit-to-sales ratio than firms under category ‘None’. The same is also observed for firms under category ‘Import Only’.

The interaction term is lower than the coefficient of export and import column 3 and is not significant in column 4. This suggests firms under category ‘Both’ have on average a higher capital productivity and profit-to-sales ratio than firms under category ‘Export Only’ and ‘Import Only’.

4.5 Transition Probability

Table 12 displays the transition probabilities observed in the data and the values in the brackets represent the number of firms. There are very high levels of persistence from *None* in t-1 to *None* in t. Moreover, high levels of persistence are also observed in *Both* (91.5%). This means that there must be high sunk costs to enter in the export and import market since only 12% of the firms that do not participate in the trade market in t-1 start participating in the trade market in t.

Interestingly, the levels of persistence in *Import Only* and *Export Only* is not as high. A large portion of firms switch to participating in both the trade market activities in period t. This suggests that participating in export in time period in t-1 increases the probability of participating in import markets in time period t and vice-versa. Also, the number of firms that flip-flop (switch trade market status) is low, which provides further evidence of sunk costs to participating in the trade market as well.

Table 12 Empirical Transition Probability

Status Year t	Status Year $t+1$			
	None	Import Only	Export Only	Both
None	0.877	0.068	0.033	0.022
	(16431)	(1275)	(623)	(416)
Import Only	0.131	0.732	0.011	0.127
	(1304)	(7278)	(107)	(1259)
Export Only	0.134	0.023	0.664	0.179
	(650)	(113)	(3215)	(865)
Both	0.016	0.036	0.033	0.915
	(467)	(1030)	(963)	(26491)

This section provides descriptive evidence that firms that participate in the trade market are bigger, and have higher productivity than firms that do not participate in the trade market. It provides evidence that exporting firms export more if they participate in the import market as well and vice-versa. It also provides evidence that there is persistence in trade status (especially when the firms are not participating in the trade market and when they are participating in the export and import market).

In the next section, I proceed to calculate productivity using more sophisticated techniques used in the literature and investigate the endogenous effect of the decision to export and import on productivity. Then, I investigate if the sunk cost hypothesis and self-selection hypothesis is observed using a dynamic random effects probit model. I end the next section by estimating a dynamic bivariate probit model to examine the complementary nature of these two activities.

5 Empirical Analysis

The empirical analysis in this section is divided into the following three parts:

- Learning-by-Doing: How does lagged choice of export and import impact productivity?
- Self-Selection and Sunk Cost Hypothesis:
  - Do more productive firms self-select into exporting and importing and does the behavior of exporting and importing suggest the presence of a sunk cost?
  - Lagged Cost Complementarity between Exporting and Importing: Does engaging in one activity at time $t-1$ increase the probability of engaging at time t in the other?
- Contemporaneous Cost Complementarity between Exporting and Importing : Does engaging in one activity at time t complement participation in the other at time t?

5.1 Learning-by-Doing

I assume that the firms have a Cobb-Douglas production function:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \eta_{it} \tag{3}$$

where l_{it} is the labor, k_{it} is capital, ω_{it} is the total factor productivity or unobserved productivity and η_{it} is a unknown shock affecting the firms output. However, the OLS estimation provides biased results as it does not account for simultaneity problem i.e the productivity of a firm should be correlated with the inputs of production.

There is a vast literature on the estimation of productivity starting with the seminal paper in productivity estimation: Olley and Pakes (1992) and subsequent modifications of their method: Levinsohn and Petrin (2003), Ackerberg et al. (2006) and Wooldridge (2009). The estimation strategy of Olley and Pakes (1992) is highlighted in section 7.2.

Olley and Pakes (1992) **OP** uses investment as function of productivity and capital to invert out productivity. There are many zeroes for this variable in data. Therefore, I use the methods shown in Levinsohn and Petrin (2003) and Ackerberg et al. (2006) to estimate Cobb-Douglas parameters as they use intermediate input demand instead.

Levinsohn and Petrin (2003) **LP** uses a strategy similar to Olley and Pakes (1992) but use intermediate input demand as the function to invert out ω_{it}. Here, the intermediated material demand function is given by:

$$m_{it} = m_{it}(\omega_{it}, k_{it})$$

This function is assumed to be montonically increasing and therefore productivity can be found by inverting the function above. Therefore, we can write the Cobb-Douglas equation as:

$$y_{it} = \beta_l l_{it} + \phi_{it}(m_{it}, k_{it})$$

where $\phi_{it}(m_{it}, k_{it}) = \beta_k k_{it} + \omega_{it}(m_{it}, k_{it})$. They suggest the use of a third degree polynomial to approximate ϕ_{it} and substitute it into the equation above to give the following result:

$$y_{it} = \beta_l l_{it} + \sum_{i=0}^{3}\sum_{j=0}^{3} \delta_{ij} k_{it}^i m_{it}^j + \eta_{it}$$

The coefficient is β_l is estimated by OLS using the equation above as they assume that the labor is a flexible input i.e there are no labor adjustment costs and $\hat{\phi}_{it}$ is estimated by subtracting the effect of labor from the fitted value of the previous equation:

$$\hat{\phi}_{it} = \hat{y}_{it} - \hat{\beta}_l l_{it} = \sum_{i=0}^{3}\sum_{j=0}^{3} \hat{\delta_{ij}} k_{it}^i m_{it}^j$$

Therefore, for any value of β_k:

$$\hat{\omega}_{it} = \hat{\phi}_{it} - \beta_k k_{it}$$

It is also assumed that ω_{it} follows a first order Markov process :

$$\omega_{it} = E[\omega_{it} | \omega_{it-1}] + \epsilon_{it}$$

They assume a polynomial expansion of the expectation above to give:

$$\omega_{it} = \gamma_o + \gamma_1 \omega_{it-1} + \gamma_2 \omega_{it-1}^2 + \gamma_3 \omega_{it-1}^3 + \epsilon_{it}$$

Therefore, the value of β_k, for which the expression below is minimised is chosen to be the coefficient of capital.

$$\beta_k^* = arg\min_{\beta_k} \sum_{i=1}^{N} \sum_{t=2}^{T} (y_{it} - \hat{\beta}_l l_{it} - \beta_k k_{it} - E[\omega_{it} \hat{|} \omega_{it-1}])^2 \tag{4}$$

On the other hand, Ackerberg et al. (2006) **ACF** use a similar strategy but, suggest that labour might also be correlated with productivity. Therefore, they write the firms input material demand as a function of productivity, capital as well as labor :

$$m_{it} = f_{it}(\omega_{it}, k_{it}, l_{it})$$

Inverting this function for ω_{it} and substituting into the production function results in the following equation of the form:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + f_{it}^{-1}(m_{it}, k_{it}, l_{it}) + \epsilon_{it} \tag{5}$$

They suggest that the labor coefficient along with capital since it is correlated with productivity.

They suggest the following steps:

1. Obtain $\phi_{it}(m_{it}, k_{it}, l_{it}) = \beta_l l_{it} + \beta_k k_{it} + f_{it}^{-1}(m_{it}, k_{it}, l_{it})$ by regressing y_{it} on polynomial approximation of $\phi_{it}(m_{it}, k_{it}, l_{it})$

2. Use the Markovian nature of $\omega_{it} = E(\omega_{it}|\omega_{it-1}) + e_{it}$ and use the following moment equations to estimate β_k and β_l:

$$E[e_{it}(\beta_k, \beta_l)| \begin{pmatrix} k_{it} \\ l_{it-1} \end{pmatrix}] = 0 \tag{6}$$

However, exogenously regressing lagged export and import variables on productivity (residuals of the Cobb-Douglas function) suggests that past export and import performance does not impact future revenue and the capital coefficient will be biased if capital is correlated with the export or import status. This has been highlighted by De Loecker (2013), and they suggest that the trade activities should be accommodated endogenously in the productivity evolution process. This is done by accommodating the the lagged export and import variable into the Markovian productivity evolution procedure:

$\omega_{it} = E(\omega_{it}|\omega_{it-1}, d_{it-1}^X, d_{it-1}^M) + e_{it}$

I use the log values of the following variables for the estimation procedure: gross fixed assets as a measure of capital, salary as a measure of labor and a expenditure on raw materials as a measure of intermediated input. Since productivity evolution is assumed to have a Markovian nature, I assume the following form of productivity evolution where it depends upon the discrete decision to export and import:

$$\omega_{it} = \alpha_o + \alpha_1\omega_{it-1} + \alpha_2\omega_{it-1}^2 + \alpha_3\omega_{it-1}^3 + \alpha_4 d_{it-1}^X + \alpha_5 d_{it-1}^M + \alpha_6 d_{it-1}^X d_{it-1}^M + \nu_{it} \qquad (7)$$

where d_{it-1}^X and d_{it-1}^M is the discrete decision to export and import respectively.

I report the estimates for the effect of discrete decision to export and import on productivity in the main section whereas I report the effect of the log values of export and import on productivity the appendix section 7.3.

The estimates of the Cobb-Douglas and the productivity evolution coefficients using the Levinsohn-Petrin method are shown in Table 13 and 14 respectively.

Table 13 Cobb-Douglus coefficients LP (Discrete)

	Value	Bootstrap Standard Errors
l_{it}	0.299	0.006
k_{it}	0.437	0.020

Note: Standard erros are calculated using 200 block bootstrapped samples

Table 14 Productivity Evolution LP (Discrete)

	Dependent variable:
	ω_{it}
ω_{it-1}	0.701^{***}
	(0.005)
ω^2_{it-1}	0.082^{***}
	(0.002)
ω^3_{it-1}	-0.008^{***}
	(0.0003)
d^X_{it-1}	0.002
	(0.007)
d^M_{it-1}	0.035^{***}
	(0.005)
$d^X_{it-1} * d^M_{it-1}$	-0.006
	(0.009)
Constant	0.341^{***}
	(0.007)
Observations	62,487
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 14 shows that coefficients of $\omega_{it-1}, \omega^2_{it-1}$ and ω^3_{it-1} are significant at 1%. Therefore, productivity evolutions depends strongly on the past productivity and the coefficients suggest that there is a non linear relationship with past productivity. The coefficient of d^X_{it-1} is positive but it is not significantly different than zero and coefficient of d^M_{it-1} is positive and significant at 1% level. The interaction term between exporting and importing also does not have a significant effect on productivity. The results suggest lagged decision to export does not a have a significant effect on productivity (firms do not experience learning-by-exporting). However, lagged decision to import causes the productivity to increase by 3.5

per cent (firms experience learning-by-importing).

Table 23 and 24 in the Appendix 7.3 display the Cobb-Douglas and productivity evolution coefficients when the productivity evolution is dependent on the lagged continuous log value of export and import rather than the lagged decision to export and import. The effect of export and import has the same sign in this case as well. It shows that lagged continuous value of export does not have a significant effect on productivity and increase in lagged continuous log value of import by 1 unit increases the productivity by 3.6 %.

As written before, De Loecker (2013) say that exogenously accommodating the decision to export and import implies that past export and import experience has no impact on direct technological improvements. Therefore, the coefficient of capital will be biased upwards if the decision to participate in the trade market correlated with capital. Table 15 displays the coefficients when the export and import decision is not endogenously accommodated in productivity evolution. In this case, the coefficient of capital is biases upwards (0.452 (Table 24) compared to 0.437 (Table 14) the endogenous case) since the variation in output is attributed more towards capital rather than productivity.

Table 15 Cobb-Douglus coefficients LP (Exogenous Productivity Evolution)

	Value	Bootstrap Standard Errors
l_{it}	0.295	0.005
k_{it}	0.452	0.021

Note: Standard erros are calculated using 200 block bootstrapped samples

The results from the estimation method mentioned in Ackerberg et al. (2006) **ACF** are shown in 16 and 17. The coefficient of labor is similar in this estimation method which further suggests that labor is a flexible input as assumed in the **LP** estimation procedure. The results also show strong dependence on past productivity. In terms of the endogenous effect of export and import on productivity is roughly the same. The export decision does not have a significant effect on productivity and the import decision has a 2.6% increase to the productivity. These results are similar to the results from the Levinsohn-Petrin estimation.

Table 16 Cobb-Douglus coefficients ACF (Discrete)

	Value	Bootstrap Standard Errors
l_{it}	0.374	0.107
k_{it}	0.474	0.073

Note: Standard erros are calculated using 200 block bootstrapped samples

Table 17 Productivity Evolution ACF (Discrete)

	Dependent variable:
	ω_{it}
ω_{it-1}	0.755^{***}
	(0.004)
ω^2_{it-1}	0.073^{***}
	(0.002)
ω^3_{it-1}	-0.008^{***}
	(0.0003)
d^X_{it-1}	0.00003
	(0.007)
d^M_{it-1}	0.026^{***}
	(0.005)
$d^X_{it-1} * d^M_{it-1}$	-0.005
	(0.009)
Constant	0.250^{***}
	(0.006)
Observations	62,487
Note:	*p<0.1; **p<0.05; ***p<0.01

Tables 25 and 26 in Appendix 7.3 display the Cobb-Douglas and productivity evolution coefficients, when the productivity evolution is dependent on the lagged continuous lag value of export and importing. The results also show a similar effect of export and import on productivity as the discrete choice results.

A drawback of this estimation procedure is that the Cobb-Douglas production function used in the estimation procedure does not account for immediate impact (effect at time t) of importing behavior to the productivity of a firm. It is assumed that participating in the import market has an effect only in increasing the productivity of the firm in the next period (at time t+1).

Based on the results above, I conclude that manufacturing firms experience learning-by-importing and do not experience learning-by-exporting. In the next section, I investigate if more productive firms self-select into exporting and importing and if the sunk cost hypothesis is observed for the discrete decision to export and import with the help of a dynamic probit random effects model.

5.2 Sunk Cost and Self-Selection Hypothesis

The sunk cost and self-selection hypothesis states that entry into the trade market involves costs that are sunk in nature and only the most productive firms can overcome these trade costs. To investigate this hypothesis, I estimate a dynamic random effects probit model similar to the model used in Roberts and Tybout (1997). I define d_{it}^X as the discrete decision to export, where Bellman equation for a profit maximising firm deciding to enter the export market is:

$$V_{it}(S_{it}) = \max_{d_{it}^X} \mathbb{E}_t(\sum_{i=0}^{\infty} \delta^{t+i} R_{i,t+i} | S_{it}) \tag{8}$$

where δ is the one-period discount factor, S_{it} is the relevant state variables affecting the firms decision, R_{it} is the revenue. Expanding the profit for time t, the equation above can also be written as:

$$V_{it}(S_{it}) = \max_{d_{it}^X}(\pi^D(S_{it}) + d_{it}^X(\pi^X(S_{it}) - f^X - c^X(1 - d_{it-1}^X)) + \sum_{t=t11}^{\infty} \delta^{t-j} R_{ij} | S_{it}) \tag{9}$$

where $\pi^D(S_{it})$ is the domestic profit, $\pi^X(S_{it})$ is the export profit, f^X is the fixed cost of exporting and c^X is the sunk cost of exporting. This equation can also be written as:

$$V_{it}(S_{it}) = \max_{d_{it}^X} \mathbb{E}\Big(\pi^D(S_{it}) + d_{it}^X(\pi^X(S_{it}) - f^X - c^X(1 - d_{it-1}^X)) + \delta \mathbb{E}(V_{it}(S_{it+1})|S_{it}, d_{it}^X)\Big) \quad (10)$$

Thus, a firm will participate in the export market if:

$$\begin{aligned} \pi_{it}^* = \pi^X(S_{it}) + \delta \mathbb{E}_t(V_{i,t+1}(S_{it+1}|S_{it}, d_{it}^X = 1) - V_{i,t+1}(S_{it+1}|S_{it}, d_{it}^X = 0)) \\ -(f^X + c^X(1 - d_{it-1}^X)) \geq 0 \end{aligned} \quad (11)$$

It is assumed that the state variables entering the Bellman equation are the following: $S_{it} = (k_{it}, l_{it}, \omega_{it}, d_{it-1}^X)$ i.e capital, labor, productivity and lagged decision to participate in the export market. In the model above, it is assumed that a firm pays a sunk cost if it did not participate in the export market in the previous period ($d_{it-1}^X = 0$). If there are no sunk costs, then according to the Bellman equation above, a firm will export as long as the current profits plus the discounted expected profit is greater than the fixed costs of exporting. The reduced form expression of the equation above is:

$$d_{it}^X = \begin{cases} 1, & \text{if } \pi_{it}^* \geq 0. \\ 0, & \text{if } \pi_{it}^* < 0. \end{cases} \quad (12)$$

To do the reduced form estimation of the model, I write the above equation as a linear function of the relevant state variables mentioned in the previous paragraph, along with dummy variables to adjust for industry and time effects as follows:

$$\pi_{it}^* = \gamma_1^X d_{it-1}^X + \gamma_3^X \hat{\omega}_{it} + \beta_1^X k_{it} + \beta_2^X l_{it} + s_i^X + \mu_t^X + \alpha_i + \epsilon_{it}^X \quad (13)$$

A positive and significant coefficient for d_{it-1}^X shows that there is persistence in exporting behavior, and thus provides evidence for the presence of sunk cost in export market participation. If the sunk cost hypothesis did not hold then the probability of exporting should not depend on the lagged decision to export. Moreover, a positive and significant coefficient for ω_{it} provides evidence for the self-selection hypothesis as firms with high productivity have a higher probability of participating in the export market. Finally, a positive and significant coefficient for k_{it} and l_{it} provides evidence indicating that bigger firms have a higher chance of participating in the export market.

A similar model can be estimated for the discrete decision to import, since importing also involves additional fixed and sunk costs. A firm would be able to participate in the import market if the productivity benefits are enough to overcome the costs. Learning-from-importing has already been demonstrated in the previous section. The Bellman equation of a firm deciding to enter the import market is the following:

$$V_{it}(S_{it}) = \max_{d_{it}^M}\Big(\pi(S_{it}) - d_{it}^M(f^M + c^M(1 - d_{it-1}^M)) + \delta\mathbb{E}(V_{it}(S_{it+1})|S_{it}, d_{it}^M)\Big) \tag{14}$$

where π is total profit of a firm, f^M is the fixed cost of importing and c^M is the sunk cost of importing and $S_{it} = (k_{it}, l_{it}, \omega_{it}, d_{it-1}^M)$.

Since S_{it} contains productivity and the previous section suggests that firms exhibit productivity improvements, therefore, this Bellman equation assumes that importing in time t provides benefits in t+1 as the decision to import increases the expected value productivity in the next period. Here, a firm will participate in the import market if:

$$\begin{aligned}\pi^* = \delta\mathbb{E}_t\Big(V_{i,t+1}(S_{it+1}|S_{it}, d_{it}^M = 1) - V_{i,t+1}(S_{it+1}|S_{it}, d_{it}^X = 0)\Big) \\ -(f^M + c^M(1 - d_{it-1}^M)) \geq 0\end{aligned} \tag{15}$$

Therefore, a firm will participate in the import market if the discounted productivity benefits of participating in the import market outweigh the costs of participating in it.

$$d_{it}^M = \begin{cases} 1, & \text{if } \pi^* \geq 0. \\ 0, & \text{otherwise.} \end{cases} \tag{16}$$

This can be tested with a reduced form dynamic probit model similar to the discrete decision to export in equation 13 Therefore, the reduced form equations of the discrete choices to export and import are the following:

$$d_{it}^{X*} = \gamma_1^X d_{it-1}^X + \gamma_3^X \hat{\omega}_{it} + \beta_1^X k_{it} + \beta_2^X l_{it} + s_i^X + \mu_t^X + \alpha_i + \epsilon_{it}^X \tag{17}$$

$$d_{it}^{M*} = \gamma_1^M d_{it-1}^M + \gamma_3^M \hat{\omega}_{it} + \beta_1^M k_{it} + \beta_2^M l_{it} + s_i^M + \mu_t^M + \alpha_i + \epsilon_{it}^M \tag{18}$$

Here s_i is a vector of industry dummies and μ_t is a vector of time dummies. Equation 17 and 18 are referred to as the *Base Model.*

The *Lagged cost complementarity* hypothesis states that the decision to export at time $t-1$ could decrease the cost of importing at time t and vice-versa. To investigate the presence of lagged cost complementarity between exporting and importing, I add another variable to the state space of the bellman equation: lagged export decision into the import decision equation and lagged import decision to export decision equation. Therefore, the corresponding Bellman equation that accounts for lagged complementarity for the export decision is:

$$V_{it}(S_{it}) = \max_{d_{it}^X}\Big(\pi^D(S_{it}) + d_{it}^X(\pi^X(S_{it})) - F(d_{it}^X, d_{it-1}^X, d_{it-1}^M) + \delta\mathbb{E}(V_{it}(S_{it+1})|S_{it}, d_{it}^X)\Big) \quad (19)$$

where

$$F(d_{it}^X, d_{it-1}^X, d_{it-1}^M) = \begin{cases} \lambda^X * d_{it}^X(f^X + c^X(1 - d_{it-1}^X)), & \text{if } d_{it-1}^M = 1. \\ d_{it}^X(f^X + c^X(1 - d_{it-1}^X)), & \text{if } d_{it-1}^M = 0. \end{cases} \quad (20)$$

Here, λ^X is the degree of cost complementarity that the lagged decision to import has on the decision to export. If the value of $\lambda^X > 1$, then participating in the import market in period $t-1$ increases the cost to export in period t. If $\lambda^X = 1$, then participating in the import market in period $t-1$ does not have an effect on the cost to export in period t. If $0 < \lambda^X < 1$, then participating in the import market in period $t-1$ decreases the cost to export in period t.

Similarly, the Bellman equation for the import decision is:

$$V_{it}(S_{it}) = \max_{d_{it}^M}\Big(\pi(S_{it}) - F(d_{it}^M, d_{it-1}^M, d_{it-1}^X) + \delta\mathbb{E}(V_{it}(S_{it+1})|S_{it}, d_{it}^M)\Big) \quad (21)$$

where

$$F(d_{it}^M, d_{it-1}^M, d_{it-1}^X) = \begin{cases} \lambda^M * d_{it}^M(f^M + c^M(1 - d_{it-1}^M)), & \text{if } d_{it-1}^X = 1. \\ d_{it}^M(f^M + c^M(1 - d_{it-1}^M)), & \text{if } d_{it-1}^X = 0. \end{cases} \quad (22)$$

Here, λ^M represents the degree of complementarity on the cost to import if a firm participated in the export market in the previous period. The reduced form equation of the two Bellman equations that account for lagged complementarity are the following:

$$d_{it}^{X*} = \gamma_1^X d_{it-1}^X + \gamma_2^X d_{it-1}^M + \gamma_3^X \hat{\omega}_{it} + \beta_1^X k_{it} + \beta_2^X l_{it} + s_i^X + \mu_t^X + \alpha_i^M + \epsilon_{it}^X \quad (23)$$

$$d_{it}^{M*} = \gamma_1^M d_{it-1}^M + \gamma_2^M d_{it-1}^M + \gamma_3^M \hat{\omega}_{it} + \beta_1^M k_{it} + \beta_2^M l_{it} + s_i^M + \mu_t^M + \alpha_i^M + \epsilon_{it}^M \quad (24)$$

Here, it is important to notice that γ_2^X measures the cost complementarity effect of lagged importing on exporting, since the productivity benefit of lagged importing (learning-from-importing) is already accounted for in $\hat{\omega}_{it}$. Therefore, if $\gamma_2^X > 0$, then this means that importing in time $t-1$ leads to decrease in cost of exporting at time t. Similarly, if

$\gamma_2^M > 0$, then this means that exporting in time $t-1$ leads to decrease in cost of importing at time t. The interpretation of the other coefficients is the same as in equations 17 and 18 respectively.

I use a dynamic random effects probit specification with Wooldridge method (Wooldridge (2005)) which treats the initial conditions problem by accounting for the correlation of the initial value of d_{i1} with α:

$$\alpha_i = \gamma d_{i1} + \tilde{\alpha}_i$$

where $\tilde{\alpha}_i \sim N(0, \sigma_\alpha^2)$

A random effects model is used because it accounts for the unobserved individual heterogeneity and the methodology of Wooldridge (2005) helps to account for the correlation between the initial value and the unobserved heterogeneity.[4]

I use the log value of gross fixed assets as a measure of capital, log value of wages as a measure of labor and use productivity estimates of the Levinsohn-Petrin method in the previous section along with industry and time dummies.

Table 18 and 19 shows the results of the estimation and the average marginal effects of the dynamic random effects probit model, respectively. Columns 1 and 3 in both the tables show the result for the base reduced model of importing and exporting whereas columns 2 and 4 display the estimates when accounting for the lagged complementarity between exporting and importing.

[4] A brief description of the dynamic random effects probit model is provided in Appendix section 7.4.

Table 18 Dynamic Random Effects Probit (Estimates)

	Export Decision		Import Decision	
	(1)	(2)	(3)	(4)
	Base	Lagged Complementarity	Base	Lagged Complementarity
d^X_{it-1}	1.834***	1.786***		0.380***
	(0.025)	(0.026)		(0.023)
d^M_{it-1}		0.370***	1.600***	1.554***
		(0.025)	(0.024)	(0.024)
$\hat{\omega}_{it}$	0.216***	0.198***	0.277***	0.266***
	(0.013)	(0.013)	(0.012)	(0.012)
k_{it}	0.0669***	0.0467***	0.109***	0.100***
	(0.013)	(0.012)	(0.012)	(0.011)
l_{it}	0.210***	0.186***	0.213***	0.186***
	(0.013)	(0.013)	(0.012)	(0.012)
d^X_{i1}	1.333***	1.264***		
	(0.045)	(0.044)		
d^M_{i1}			1.081***	0.986***
			(0.038)	(0.037)
Constant	-3.264***	-3.122***	-3.655***	-3.617***
	(0.130)	(0.128)	(0.128)	(0.124)
σ^2_α	0.804	0.771	0.731	0.687
	(0.024)	(0.024)	(0.022)	(0.021)
Log-Likelihood	-14513.0	-14406.6	-15879.7	-15749.5
LR Test	$\chi^2(1) = 106.4$	p=0.000	$\chi^2(1) = 130.19$	p=0.000
Industry Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 19 Dynamic Random Effects Probit (Average Marginal Effects)

	Export Decision		Import Decision	
	(1)	(2)	(3)	(4)
	Base	Lagged Complementarity	Base	Lagged Complementarity
d^X_{it-1}	0.218***	0.212***		0.0495***
	(0.00410)	(0.00393)		(0.0039)
d^M_{it-1}		0.0439***	0.209***	0.202***
		(0.00299)	(0.00389)	(0.00375)
$\hat{\omega}_{it}$	0.0257***	0.0235***	0.0362***	0.0347***
	(0.00161)	(0.00159)	(0.00165)	(0.00161)
k_{it}	0.00797***	0.00553***	0.0142***	0.0130***
	(0.00154)	(0.00151)	(0.00158)	(0.00153)
l_{it}	0.0250***	0.0220***	0.0279***	0.0243***
	(0.00164)	(0.00162)	(0.00161)	(0.00158)
N	62485	62485	62485	62485

Standard error in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Columns 1 and 2 of tables 18 and 19 displays the coefficients and the average margial effects for equations 17 and 23 respectively. The state dependence parameter (coefficient of d^X_{it-1}) is positive significant at 1% level with the highest magnitude amongst all of the coefficients. This provides evidence in favor of persistence in exporting behavior which confirms the sunk-cost hypothesis. The average marginal effect of the lagged decision to export is the higest at 0.218. This means that there is a 20% increase in probability of exporting if a firm has exported in the previous period. Productivity (ω_{it}) also has a significant and and positive effect on exporting which provides evidence of self-selection of high productivity firms into exporting. Moreover Capital and Labor (k_{it} and l_{it}) also have a positive and significant effect, which tells us that a bigger firm has a higher chance of participating in the export market.

The likelihood ratio test rejects the base model (column 1)in favor of the model that accounts for the lagged complementarity (column 2) in the case of the export decision. And the lagged import coefficient in column 2 of table 18 is significant at 1% level and positive and shows that that importing at time t increases the probability of exporting at time $t + 1$. Hence, this provides evidence of lagged cost complementarity between lagged importing decision and exporting decision.

Moreover, the coefficient of the initial export decision (d_{i1}^X) has the second highest magnitude of all the coefficients and is significant at 1% level suggesting that it it corrects for bias introduced by the 'initial condtions' problem. The value of σ_α^2 in the table does not account for the contribution of the initial export decision. Therefore, the estimated variance of unobserved heterogeneity $\sigma_\alpha^2 = \lambda^2 * \hat{Var}(d_{i1}^X) + \hat{\sigma^2}_{\tilde{\alpha}} = 1.16$. This means that individual effects capture about 54% of the unexplained variance. This suggests there are firm specific variables other than the ones used in the estimation that contribute towards the export market participation decision.

Columns 3 and 4 of table 18 and 19 displays the coefficients and the average margial effects for equations 18 and 24 respectively. The results for the import decision are quite similar to the results for the export decision. The state dependence parameter is the largest amongst all variables and significant at 1% level. This suggests that there is persistence in importing behavior as well and confirms the sunk cost hypothesis for importing decision. Productivity, capital and labor coefficients are also significant at 1% and has a positive effect on importing which provides evidence in favor of self-selection of high productivity firms into importing and bigger firms having a higher probability of import participation.

The lagged export coefficient (d_{it-1}^X in column 4) is significant and positive and this provides evidence that exporting at time t increases the probability of importing at time $t+1$. It has the third highest value of the average marginal effects. This provides evidence in favor of lagged cost complementarity hypothesis for import decision.

The coefficient of initial import variable (d_{i1}^M) has the second highest magnitude and is significant at 1% level. This suggests the variable corrects for bias introduced by 'initial conditions' problem. The unobserved heterogeneity explains only about 48% of the unexplained variation in the data.

Table 27 in Appendix 7.4 displays the estimation results for the same equation with ACF productivity estimates. The coefficients in this table are quite similar to the results above.

These results provide evidence in favor of the sunk-cost hypothesis, self-selection of higher productivity firms and bigger firms into exporting and importing as well as evidence in favor of lagged cost complementarity.

However, this estimation equation cannot estimate if there is contemporaneous cost complementarity between exporting and importing . The contemporaneous cost complementarity hypothesis states that there might be reduction in costs to export and import if a firm decides to participate in both the activities at the same time. The next section shows the results of a dynamic bivariate probit model which accounts for contemporaneous cost complementarity as well.

5.3 Contemporaneous Complementarity between Exporting and Importing

The Bellman equation of a profit maximising firm deciding to export and import simultaneously is the following:

$$V_{it}(S_{it}) = \max_{d_{it}}\big(\pi^d_{it}(S_{it}) + d^X_{it} * (\pi^X_{it}(S_{it})) + F(d_{it}, d_{it-1}) + \beta\mathbb{E}(V_{it}(s_{it+1})|s_{it}, d_{it})\big) \tag{25}$$

where $d_{it} = (d^X_{it}, d^M_{it})$ and $S_{it} = (k_{it}, l_{it}, \omega_{it}, d^X_{it-1}, d^M_{it-1})$. $F(d_{it}, d_{it-1})$ is the fixed and sunk costs the firms must pay to export and import and it takes the following form:

$F(d^X_{it}, d^M_{it}, d^X_{it-1}, d^X_{it-1}) =$

$$F(d^M_{it}, d^X_{it-1}, d^X_{it-1}) = \begin{cases} \lambda^M * d^M_{it}(f^M + c^M(1 - d^M_{it-1})), & \text{if } d^X_{it-1} = 1. \\ d^M_{it}(f^M + c^M(1 - d^M_{it-1})), & \text{if } d^X_{it-1} = 0. \end{cases} \tag{26}$$

$$F(d^X_{it}, d^X_{it-1}, d^M_{it-1}) = \begin{cases} \lambda^X * d^X_{it}(f^X + c^X(1 - d^X_{it-1})), & \text{if } d^M_{it} = 1. \\ d^X_{it}(f^X + c^X(1 - d^X_{it-1})), & \text{if } d^M_{it-1} = 0. \end{cases} \tag{27}$$

$$F(d^X_{it}, d^M_{it}, d^X_{it-1}, d^X_{it-1}) = \begin{cases} \lambda^B[f^X + f^M + c^X(1 - d^X_{it-1}) + c^M(1 - d^M_{it-1})], & \text{if } (d^X_{it}, d^m_{it}) = (1, 1). \\ 0, & \text{if } (d^X_{it}, d^m_{it}) = (1, 1). \end{cases} \tag{28}$$

Here f^X is the fixed cost of exporting, c^X is the sunk cost of exporting, f^M is the fixed cost of importing and f^M is the fixed cost of importing.

The costs to participate in the export or import market only are similar to the costs in the Bellman equations in the previous section. The cost to participate in both the export and import market introduces a new term: λ^B that captures the degrees of contemporaneous cost complementarity between exporting and importing.

The reduced form model of the bellman equation is a dynamic bivariate probit model. Then, the bivariate dynamic probit model takes the following form:

$$d_{it}^X = \begin{cases} 1, & \text{if } d_{it}^{X*} \geq 0. \\ 0, & \text{if } d_{it}^{X*} < 0. \end{cases} \tag{29}$$

$$d_{it}^M = \begin{cases} 1, & \text{if } d_{it}^{M*} \geq 0. \\ 0, & \text{if } d_{it}^{M*} < 0. \end{cases} \tag{30}$$

The discrete decision of exporting and importing is modelled as a function of previous import and export status controlling for lagged firm characteristics and industry and time fixed effects.

Therefore, the reduced form equation for the decision to export and import are the following:

$$d_{it}^{X*} = \gamma_1^X d_{it-1}^X + \gamma_2^X d_{it-1}^M + \gamma_3^X \hat{\omega}_{it} + \beta_1^X l_{it} + \beta_2^X l_{it} + s_i^X + \mu_t^X + \epsilon_{it}^X \tag{31}$$

$$d_{it}^{M*} = \gamma_1^M d_{it-1}^M + \gamma_2^M d_{it-1}^X + \gamma_3^M \hat{\omega}_{it} + \beta_1^M k_{it} + \beta_2^M l_{it} s_i^M + \mu_t^M + \epsilon_{it}^M \tag{32}$$

Here γ_1 identifies the state dependence coefficient, γ_2 accounts for the fact that participating in one activity in time t-1 improves the odds of participating in the other at time t (lagged complementarity),γ_3 accounts for the self-selection mechanism, β_1 and β_2 account for capital and labor of a firm. s_i^M μ_t^M are industrial and time dummies respectively.

The bivariate probit specification also allows for the estimation of contemporaneous cost complementarity as it allows the shocks to decision to export and import ϵ_{it}^X and ϵ_{it}^M be correlated. This gives gives the following form to the error structure:

$$\begin{pmatrix} \epsilon_{it}^X \\ \epsilon_{it}^M \end{pmatrix} \sim N\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix} \right)$$

The estimated ρ measures the correlation between the unobserved errors. Therefore, if the value of rho is significantly greater than zero, then this would suggest that the shocks of the two decisions are positively correlated. This would provides evidence in favor of contemporaneous complementarity. This model specification has been used to test the contemporaneous relationship by Aristei et al. (2013), Aw, M. J. Roberts, et al. (2007) and Manez et al. (2015).

This model has a few drawbacks: it does not account for individual heterogeneity (α_i) and it does not account for the initial conditions problems. Therefore, to interpret the coefficients of this specification it has to assumed that d_{i1} is endogenously given and industry and time dummy variables account for the individual firm heterogeneity.

Table 20 displays the results for the dynamic probit specification. All the coefficients for the export decision except the capital coefficient is significant at 1% level and have the same sign as the coefficients in the previous section. However, all of the coefficients for import decision are significant at 1% level. The state-dependence coefficient has the strongest effect among all the variables, suggesting that there is persistence in both the activities and high sunk cost. There is a positive effect of productivity on both activities, providing further evidence of self-selection of firms into exporting and importing. The coefficients of labor and productivity are positive and quite similar to previous section. Firms which were importing in the previous year are more likely to be exporters and firms which were exporting in the previous year are more likely to be importing this year.

The likelihood-ratio test with the null hypothesis that the correlation between the unobserved errors is 0 is rejected at 1% significance level. This means that there is a significant increase in the log likelihood of the model in a bivariate probit specification as compared to two independent probit models. The estimated value of ρ is 0.438 and is significant at 1% level. A positive estimate of ρ suggests that there is contemporaneous cost complementarity between exporting and importing as shocks that lead a firm to participate in one activity tend to lead it to participate in both.

Table 20 Dynamic Bivariate Probit (Estimates)

	(1) Export Decsion	(2) Import Decision
d^X_{it-1}	2.539***	0.397***
	(0.031)	(0.027)
d^M_{it-1}	0.360***	2.175***
	(0.027)	(0.033)
$\hat{\omega}_{it}$	0.103***	0.165***
	(0.015)	(0.015)
k_{it}	0.00873	0.0788***
	(0.015)	(0.012)
l_{it}	0.135***	0.134***
	(0.018)	(0.017)
Constant	-2.212***	-2.768***
	(0.111)	(0.080)
$corr(\epsilon^X_{it}, \epsilon^M_{it})$	0.439***	
	(0.017)	
LR test	$corr(\epsilon^X_{it}, \epsilon^M_{it})$, $\chi^2(1) = 641.056$	
	p=0.000	
Industry Dummies	Yes	
Time Dummies	Yes	

Note: Robbust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 28 in Appendix 7.5 displays the results for the ACF productivity estimates and the results are similar to the results in Table 20.

6 Conclusion

In this paper, I analyse the dynamic linkages between exports, imports and productivity. First, I estimate the effect of the decision to export and import on productivity. This is done by endogenously accommodating the decision to export and import in the productivity evolution process in the methods suggested by Levinsohn and Petrin (2003) and Ackerberg et al. (2006). I find that the decision to export does not have a significant effect on productivity whereas the decision to import has a significant and positive effect on productivity (3.6% and 2.7% according to LP and ACF method respectively)

Second, I estimate a dynamic random effects probit model on the decision to export and import. I use capital, labor, productivity estimates and lagged decision to import and export as covariates. The results suggest that there is high levels persistence in participation in exporting and importing, and capital, labor and productivity have a positive and significant impact on the decision to export and import. Moreover, the lagged decision to export has a positive effect on the probability to import and vice versa.

Third, I estimate a dynamic bivariate probit model on the decision to export and import and use the same covariates as in the dynamic random effects probit estimation procedure. The covariates have the same sign and therefore the same effect as in the dynamic random effects probit estimation procedure. The interesting result from this estimation is that the shocks to both of the decisions are correlated as the errors of the two decisions are significantly correlated with a value of 0.439.

The results lead to following conclusions for exporting behavior: i): Firms do not display learning-by-exporting, ii): Persistence in the exporting behavior suggesting the presence of sunk costs. There is self-selection of higher productivity firms into exporting iii): Presence of lagged cost complementarity: Lagged export decision increases the probability of importing.

The conclusions for importing behavior are as follows: i): Firms display learning-by-importing, ii): Persistence in importing behavior provides evidence for sunk costs in the decision to import. There is also self-selection of higher productivity firms into importing iii): Presence of lagged cost complementarity: Lagged import decision increases the probability of exporting after accounting for the productivity benefits of the lagged importing decision.

Moreover, there is evidence in favor of contemporaneous cost complementarity between the decision to export and import as the unobserved shocks for both the decisions are positively correlated after accounting for productivity and other firm-specific characteristics.

The dynamic bivariate probit model in this paper does not account for individual heterogeneity and the initial conditions problem. Therefore, estimating a dynamic bivariate model that accommodates individual heterogeneity by using random effects and the endogeneity of initial conditions problem with the help of Wooldridge (2005) will help provide more robust results for contemporaneous cost complementarity between exporting and importing.

This work can be extended by estimating the fixed and sunk costs of trading activities as well as their cost complementarity with the help of a dynamic model along the lines of Kasahara and Lapham (2013) and Aw, M. Roberts, et al. (2011). This can help us run counter-factual simulations to see the effect of increase in the costs to exporting on importing, and vice-versa.

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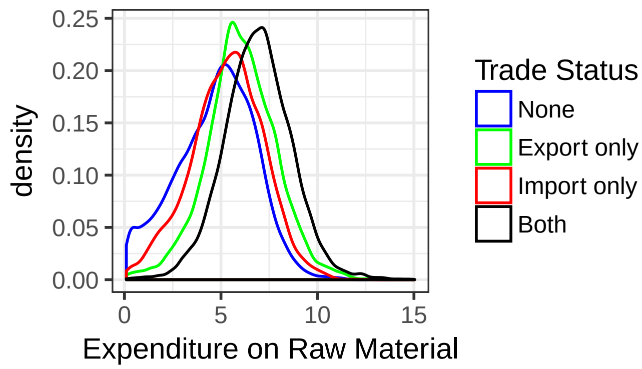
7 Appendix

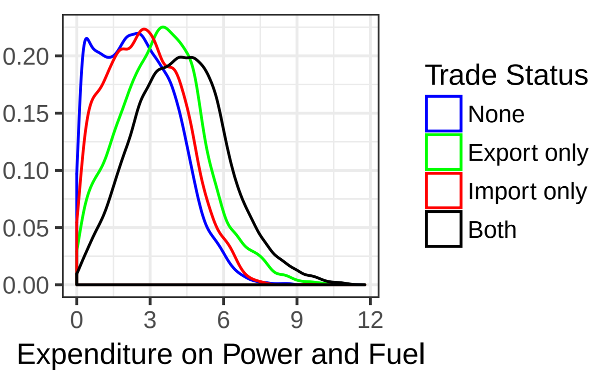
7.1 Appendix (Descriptive Statistics)

Table 21 Summary Statistics of Expenditure on Raw Material (log)



Status	Mean	Sd
None	4.73	2.03
Import only	6.04	1.82
Export Only	5.32	1.88
Both	6.9	1.77

Table 22 Summary Statistics of Expenditure on Power and Fuel (log)



Status	Mean	Sd
None	2.51	1.56
Import only	3.5	1.75
Export Only	2.81	1.57
Both	4.24	1.88

7.2 Appendix (Productivity Estimation OP)

Olley and Pakes (1992) (OP) use the following strategy to estimate the Cobb-Douglas function:

The log transformation of the production function is written as :

$$y_{it} = \beta_o + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \epsilon_{it} \tag{33}$$

where l_{it} is labour, k_{it} is capital, m_{it} is the demand for materials, ω_{it} is firm-level-productivity observable to the firm and ϵ_{it} are shocks to production.
The optimal investment decision of the firm is characterised by the following function:

$$i_{it} = f_k(l_{it-1}, k_{it}, \omega_{it}) \tag{34}$$

The optimal labor decision is characterised by the following function:

$$l_{it} = f_k(l_{it-1}, k_{it}, \omega_{it}) \tag{35}$$

These are the assumptions made by **OP**:

1. $f_k(l_{it-1}, k_{it}, \omega_{it})$ is invertible in ω_{it}
2. ω_{it} follows a first order markov process
3. Investment at period i is not active until period $t+1$: $k_{it+1} = (1-\delta)k_{it} + i_{it}$
4. Labor is a perfectly flexible input i.e there are no labor adjustment cost

The estimation procedure proceeds in two step:

1. Estimation of β_k: Since $\omega_{it} = f_k^{-1}(l_{it-1}, k_{it}, i_{it})$ and inserting this in the Cobb-Douglas equation to get:

   $$y_{it} = \beta_l l_{it} + \phi_{it}(l_{it-1}, i_{it}, k_{it})$$

   where $\phi_{it}(l_{it-1}, i_{it}, k_{it}) = \beta_k k_{it} + f_k^{-1}(l_{it-1}, k_{it}, i_{it})$ $\phi_{it}(l_{it-1}, i_{it}, k_{it})$ is approximated using a polynomial expression and $beta_l$ is estimated by OLS on the previous equation

2. Estimation of β_k: Since ω_{it} follows a first order markov process, it can be written as:

   $$\omega_{it} = h(\omega_{it-1}) + e_{it}$$

Then ϕ_{it} can be written as:

$$\phi_{it} = \beta_k k_{it} + h(\omega_{it-1}) + e_{it}$$

$$\phi_{it} = \beta_k k_{it} + h(\phi_{it-1} - \beta_k k_{it-1}) + e_{it}$$

The unknown form of function h is approximated by quadratic function and for any value of β_k to get:

$$\hat{\phi_{it}} = \beta_k k_{it} + \gamma_0 \gamma_1 \omega_{it-1}^{\hat{\beta_k}} + \gamma_2 (\omega_{it-1}^{\hat{\beta_k}})^2 + \gamma_3 (\omega_{it-1}^{\hat{\beta_k}})^3$$

This expression is minimised to get the estimate of β_k.

7.3 Appendix (Learning-by-doing)

Table 23 Cobb-Douglus coefficients LP (Continuous)

	Value	Bootstrap Standard Errors
l_{it}	0.299	0.006
k_{it}	0.429	0.018

Note: Standard erros are calculated using 200 block bootstrapped samples

Table 24 Productivity Evolution LP (Continuous)

	Dependent variable:
	ω_{it}
ω_{it-1}	0.693^{***}
	(0.005)
ω_{it-1}^2	0.083^{***}
	(0.002)
ω_{it-1}^3	-0.008^{***}
	(0.0003)
d_{it-1}^X	0.003
	(0.007)
d_{it-1}^M	0.036^{***}
	(0.005)
$d_{it-1}^X * d_{it-1}^M$	-0.006
	(0.009)
Constant	0.354^{***}
	(0.007)
Observations	62,487
Note:	*p<0.1; **p<0.05; ***p<0.01

Table 25 Cobb-Douglus coefficients ACF (Continuous)

	Value	Bootstrap Standard Errors
l_{it}	0.062	0.206
k_{it}	0.603	0.101

Note: Standard erros are calculated using 200 block bootstrapped samples

Table 26 Productivity Evolution ACF (Continuous)

	Dependent variable:
	ω_{it}
ω_{it-1}	0.781^{***}
	(0.004)
ω_{it-1}^2	0.062^{***}
	(0.001)
ω_{it-1}^3	-0.006^{***}
	(0.0002)
d_{it-1}^X	0.004
	(0.008)
d_{it-1}^M	0.043^{***}
	(0.006)
$d_{it-1}^X * d_{it-1}^M$	-0.006
	(0.009)
Constant	0.237^{***}
	(0.007)
Observations	62,487
Note:	*p<0.1; **p<0.05; ***p<0.01

7.4 Appendix (Dynamic Random Effects Probit Model)

Let i be the unit and t be the time. A dynamic random effects probit is written as:

$$y_{it}^* = \gamma y_{i,t-1} + x_{it}'\beta + \alpha_i + \epsilon_{it}; y_{it} = 1[y_{it}^* > 0]$$

where γ is the state dependence parameter.

There are three ways to estimate the above equation:

1. Treat y_{i1} as exogenously given and do not explain it
2. Heckman Method
3. Wooldridge Method

I use the Wooldridge method which assumes that α_i:

$$\alpha_i = \lambda y_{i1} + \tilde{\alpha}_i$$

Assumptions:

1. The i-units are a random sample
2. $\epsilon_{it} \sim N(0, 1)$ is independent of x_i
3. $\tilde{\alpha_i} \sim N(0, \sigma_{alpha}^2)$ is independent of x_i and ϵ_{it}

The likelihood function is given by:

$$L_i(\beta, \gamma, \sigma_\alpha, \lambda) = \int_{-\infty}^{\infty} \prod_{t=2}^{T} \Phi(x_{it}^{'}\beta + \gamma y_{it-1} + \lambda y_{i1} + \tilde{\alpha}) \frac{\phi(\tilde{\alpha})}{\sigma_{\tilde{\alpha}}} d\tilde{\alpha}$$

$$L(\beta, \gamma, \sigma_\alpha, \lambda) = \prod_{i=1}^{N} L_i(\beta, \gamma, \sigma_\alpha, \lambda : y_i, x_i$$

The marginal effects are given by:

$$\frac{\delta E[y_{it}|x_{it}, \alpha_i]}{\delta x_{it,j}} = \beta_j \phi(x_{it}^{'}\beta + \alpha_i) \tag{36}$$

I report the average marginal effects which are given by:

$$\frac{1}{N} \sum_i \phi(x_{it}^{'}\beta + \alpha_i)\hat{\beta}_j$$

Table 27 Dynamic Random Effects Probit (ACF Estimates)

	Export Decision		Import Decision	
	(1)	(2)	(3)	(4)
	Base	Lagged Complementarity	Base	Lagged Complementarity
d^X_{it-1}	1.834***	1.786***		0.380***
	(0.025)	(0.026)		(0.023)
d^M_{it-1}		0.370***	1.600***	1.554***
		(0.025)	(0.024)	(0.024)
$\hat{\omega}_{it}$	0.216***	0.198***	0.277***	0.266***
	(0.013)	(0.013)	(0.012)	(0.012)
k_{it}	0.0748***	0.0539***	0.119***	0.110***
	(0.013)	(0.012)	(0.012)	(0.011)
l_{it}lsalary	0.226***	0.201***	0.234***	0.206***
	(0.013)	(0.013)	(0.012)	(0.012)
d^X_{i1}	1.333***	1.264***		
	(0.045)	(0.044)		
d^M_{i1}			1.081***	0.986***
			(0.038)	(0.037)
Constant	-3.264***	-3.122***	-3.655***	-3.617***
	(0.130)	(0.128)	(0.128)	(0.124)
σ^2_α	0.804	0.771	0.731	0.687
	(0.024)	(0.024)	(0.022)	(0.021)
Log-Likelihood	-14513.0	-14406.6	-15879.7	-15749.5
Industry Dummies	Yes	Yes	Yes	Yes
Time Dummies	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

7.5 Appendix (Dynamic Bivariate Probit Model)

Let the latent model be:

$$y_{it}^{1*} = x_{it}^T\beta_1 + y_{it-1}\gamma + \varepsilon_{it}^1$$
$$y_{it}^{2*} = x_{it}^T\beta_2 + y_{1t-1}\gamma + \varepsilon_{it}^2$$

we have the observed responses as,

$$y_{it}^1 = I(y_{it}^{1*} > 0)$$

$$y_{it}^2 = I(y_{it}^{2*} > 0)$$

The error distribution is given as follows,

$$(\varepsilon_{it}^1, \varepsilon_{it}^2) \sim N\left(0, \quad \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right)$$

The multivariate normal density of $f(y_{it}^{1*}, y_{it}^{2*})$ given the assumption above is given by:

$$\begin{aligned} f(y_{it}^1, y_{it}^2) = \frac{1}{2\pi\sigma_{y_{it}^1}\sigma_{y_{it}^2}\sqrt{1-\rho^2}} exp(\frac{-1}{2(1-\rho^2)}[\frac{(y_{it}^1 - \mu_{y_{it}^1})^2}{\sigma_{y_{it}^1}^2} + \\ \frac{(y_{it}^2 - \mu_{y_{it}^2})^2}{\sigma_{y_{it}^2}^2} - 2\rho\frac{(y_{it}^1 - \mu_{y_{it}^1})(y_{it}^2 - \mu_{y_{it}^2})}{\sigma_{y_{it}^1}\sigma_{y_{it}^2}}] \end{aligned} \tag{37}$$

Therefore the likelihood function is given by

$$\begin{aligned} L(\beta_1, \beta_2, \gamma_1, \gamma_2) = \Big(\prod P(Y_{it}^1 = 1, Y_{it}^2 = 1 \mid \beta_1, \beta_2, \gamma_1, \gamma_2)^{Y_{it}^1 Y_{it}^2} \\ P(Y_{it}^1 = 0, Y_{it}^2 = 1 \mid \beta_1, \beta_2, \gamma_1, \gamma_2)^{(1-Y_{it}^1)Y_{it}^2} \\ P(Y_{it}^1 = 1, Y_{it}^2 = 0 \mid \beta_1, \beta_2, \gamma_1, \gamma_2)^{Y_{it}^1(1-Y_{it}^2)} \\ P(Y_{it}^1 = 0, Y_{it}^2 = 0 \mid \beta_1, \beta_2, \gamma_1, \gamma_2)^{(1-Y_{it}^1)(1-Y_{it}^2)}\Big) \end{aligned} \tag{38}$$

Table 28 Dynamic Bivariate Probit (ACF Estimates)

	(1)
	exp
exp	
lagexp	2.539***
	(152.29)
lagimp	0.360***
	(19.05)
lpresacf	0.103***
	(11.84)
lgfa	0.0125
	(1.54)
lsalary	0.143***
	(17.41)
_cons	-2.212***
	(-28.56)
imp	
lagexp	0.397***
	(23.28)
lagimp	2.175***
	(129.84)
lpresacf	0.165***
	(19.66)
lgfa	0.0848***
	(11.01)
lsalary	0.146***
	(18.27)
_cons	-2.768***
	(-36.07)
athrho	
_cons	0.439***
	(29.48)
rho	0.413
chi2	61856.1

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$