A Dynamic Model of Firm Activities: Evidence from Danish Manufacturing

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Abstract

In this paper, we do two things. First, using a panel of firms in the Danish manufacturing for the period 2000-2007, we document stylized facts on the behavior of firms with respect to exporting and importing activities. It is shown that there exists considerable degree of firm heterogeneity in terms of size, wage payment and productivity; frequent incidence of simultaneous exporting and importing activities; significant export and import activity premia, and high persistence in the status of firm activities overtime. Second, we specify and structurally estimate a dynamic discrete choice model of export and import. This model provides a framework to analyze the determinants of firms' decisions to export and import while allowing for previous export and import decisions to affect future productivity trajectory. The estimation results show significant difference in demand elasticities in domestic and export markets. More firms and product varieties in export markets lead to tougher competition, more elastic demand and lower markups. We also find that firms with larger capital stock and paying higher wages to their workers are cost efficient even after controlling for their productivity. In line with the self-selection argument, we find significant sunk and fixed costs of exporting and importing, and positive correlation between the sizes of these costs and scale of firm operation. Distinguishing between trade activities, we show that these costs are on average greater in the case of exporting. Relatedly, exporting and more importantly importing positively affect future productivity trajectory, and thereby further drive the self-selection of firms into export and import markets.

JEL Codes: F14, L11, L60

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1. Introduction

Inspired by the pioneering work of Bernard and Jensen (1995), several studies on firms and export documented strong evidence on firm heterogeneity even in narrowly defined industries. These studies showed that only a fraction of firms are active in the global market and are systematically different from domestic firms in terms of productivity, factor intensity and factor payment. That is, they are larger, more productive, more skill and capital intensive, and pay higher wages. Furthermore, increased availability of detailed production and trade statistics enabled investigation of other dimensions of the export activity such as the number of products exported and markets served, and other firm activities such as importing, intrafirm trade, and R&D investment decisions of firms. These investigations documented firm characteristics very similar to exporting firms.¹

Despite significant theoretical and empirical contributions on firm heterogeneity and exporting and importing activities, studies on the relationship between exporting and importing activities within the framework of firm heterogeneity are relatively rare. To mention some of these studies: Bernard et al. (2007) for the US, Wagner (2007) for Germany, Andersson et al. (2008) for Sweden, Eriksson et al. (2009) and Smeets and Warzynski (2013) for Denmark, Muuls and Pisu (2009) for Belgium, Castellani et al. (2010) for Italy, Bas and Strauss-Kahn (2011) for France, Kasahara and Lapham (2013) for Chile, Aristei et al. (2013) for Eastern European and Central Asian countries. Although there are differences in terms of scope, methodology and sometimes findings, these studies showed that firms active in the world market are more productive and perform better than their domestic counterparts. Further, even among firms active globally, two-way traders—firms exporting and importing—are even more productive and primary drivers of the trade flow. These studies also made it clear that export and import decisions of firms are highly complementary.

However, as pointed out by Hayakawa et al. (2012), results on export and import market productivity cutoffs and productivity gain from exporting and importing have been less clear-cut. In this respect, they stated that “the next step will be to further examine both qualitative and quantitative differences of sunk costs for exporting in comparison with those for importing or among the destinations.” To this end, the main objective of this paper is to provide an empirical framework to structurally estimate a model that captures some of these empirical regularities.

¹ Redding (2010), Bernard et al. (2012) and Hayakawa et al. (2012) provide a survey of recent notable theoretical and empirical contributions.
In this paper, we use a rich dataset on firms in the Danish manufacturing sector for the period 2000-2007 with the objective of analyzing export and import behavior of firms where firms are heterogeneous in terms of capital usage, factor price payment and productivity. To this end, we structurally estimate a dynamic model of export and import activities of firms. In so doing, it is possible to characterize the intensity of competition (in terms of demand elasticity) and the reaction of firms (in terms of markups) to different degrees market competition in domestic and export markets; provide additional evidence on self—selection and learning—by—doing hypotheses, and the mechanisms such as market entry costs and fixed costs of operation in an attempt to explain the export and import premia. First, we find that the majority of firms are globally active via exporting, importing or both. Interestingly, their global market participation is mainly through exporting. Second, we confirm previous findings that firms active in the global market are systematically better in terms of different performance indicators. It is also shown that two-way traders are better performing group followed by those that only import and export. Firms restricting their activities to the domestic market constitute the least performing group. Third, we find high state dependence in the status of firm activities, and this is highly suggestive of considerable sunk and fixed costs of undertaking these activities. Fourth, we find that the exporting and importing involve significant sunk and fixed costs, and these costs are on average greater for exporting. Relatedly, the magnitude of these costs is positively correlated with the scale of firm operation mainly reflected in terms of its capital stock. Interestingly, exporting sunk costs of larger firms and fixed costs of small firms are lower compared to their importing counterparts. This explains the fact that exporting is the most common activity among firms in the Danish manufacturing sector. Very high sunk and fixed costs of importing deter large and small firms from starting or continuing to import goods respectively. This also explains the performance (specifically, productivity) ranking of firms with different forms of involvement in the international trade. Lastly, we find that there is in fact a productivity gain from exporting and even more from importing. This effect further reinforces the self-selection of firms into the global market.

This paper is related to several recent contributions that aimed at investigating the relationship between firm heterogeneity and export and import activities of firms. The closest study to this paper is Kasahara and Lapham (2013) who investigated the export and import decisions of Chilean firms in Melitz setting. Unlike their study, this paper allows for endogenous firm productivity heterogeneity. Additionally, we allow for heterogeneity of firms not only in terms of productivity
but also in terms of their capital usage and factor price payments. Methodologically, this study closely follows a recent contribution by Aw et al. (2011) who considered the joint export and R&D decisions of firms. Unlike their modelling approach to the dynamic aspect of the firm optimization problem, which assumes firms make sequential decisions of one after another, this paper considers these decisions as simultaneous choice problems. This paper is also related to Das et al. (2007) in its estimation of sunk and fixed costs using a Bayesian approach. Furthermore, the availability of long panel on firms allows the introduction of more structure in modeling market entry and exit decisions and transition of the state variables such as capital. Unlike most of previously done studies which showed the significance (and sometimes the complementarity) between sunk and fixed costs of export and import, this study first shows the importance of these costs in export and import decisions of firms and proceeds to estimate the magnitude of these costs.

The rest of the paper is organized as follows. Section 2 presents the data source and description. Section 3 provides relevant descriptive statistics on export and import behavior of firms. Section 4 develops the structural model of firm export and import decisions. Section 5 presents the empirical strategy. Section 6 discusses estimation results of the model. Section 7 concludes.

2. Data description
The data used in this paper are all provided by Statistics Denmark. We focus our analysis on the time period 2000-2007, and industries in the manufacturing sector. We constructed our data from three datasets. The first dataset contains detailed information about the product portfolio of firms at 8–digits CN, and describes which products firms make domestically. It is based on a survey of all firms in the manufacturing sector with at least 10 employees. After constructing firm-level production data, there are 39,515 firm-year observations in this dataset. The second dataset contains VAT statistics and firm-level accounting information for more than 160,000 firms annually, comprising 1,322,736 firm–year observations. The third dataset provides information on export and import activities on the universe of Danish firms engaged in international trade. It contains the value, weight and quantity of export and import transactions for each firm and destination/source.

2 Classification of economic activities as manufacturing is based on NACE Rev.2 classification and covers industries 10-33 at 2-digits.
3 Combined Nomenclature (CN) is a Harmonized system of product classification with further subdivisions used in EU member countries.
market at 8–digits CN. We constructed firm-level exports and imports, and there are about 120,761 and 164,106 firm-year observations for export and import respectively.

Merging these datasets is easily done as firms are identified by a unique code. In order to make sure that firms with real economic activity are considered, we include only those with a reported level of physical production in Denmark. We restrict the time period to 2000-2007 due to the fact that there were a series of revisions of industry classification that pose a serious challenge on tracing firms and their core economic activities overtime.4 We also abstract from modelling entry and exit decisions in the domestic market. To this end, we consider a balanced panel of firms that are active at least in the domestic market for the time period 2000-2007. The dataset constitute 2,106 firms and 16,848 firm-year observations.

3. Some facts in the Danish manufacturing sector

This section documents salient features of export and import activities of firms in the Danish manufacturing sector. These features confirm previous findings on firm performance and international trade, and provide additional evidence on the importance of modeling export and import activities of firms jointly.

**Fact 1 Firms are heterogeneous in terms of size, wage payment and productivity.**

In most international trade models heterogeneity of firms is measure by productivity dispersion. Table 1 shows that firms are considerably different not only in terms of productivity but also in their capital usages and factor payments. It is also demonstrated that greater fraction of the firms are large, and these firms have become more prevalent overtime. It also shows that firms have become more productive, increased their use of capital input, and raised their payment to workers overtime. These features of input mix and productivity pattern provide a motivation to allow firms to be heterogeneous in terms of capital and wage payment besides the commonly known productivity.

**Fact 2 There is high incidence of simultaneous exporting and importing.**

Dividing firms into mutually exclusive categories based on their respective activities, Table 2 shows that among firms in the manufacturing sector exporting is the most common activity; more than

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4 Bernard et al. (2013) raise the issue of industry classification as it pertains to Danish data, and point out that the revisions in 1993 and 2007 were major whereas the 2003 one was minor.
70% of the firms export. Despite the relative rarity of importing, it is shown that greater fraction of firms engaged in exporting also import. Further, firms in the manufacturing sector have become more globally engaged as evident from declining share of firms active only in the domestic market, albeit constituting the smallest group, and rising share of firms that export, import or both. These patterns are suggestive of highly complementary exporting and importing activities.⁵

**Fact 3 There is a significant export and import activity premia.**

Insightful characterization of firm performance can be achieved by estimating export and import activity premia. Table 3 presents the export and import premia estimates. In the regression, year and industry effects, and employment size (except in the last performance indicator) are controlled for. All the estimates measure percentage differences relative to firms neither exporting nor importing but domestically active. It is shown that there is positive and highly significant productivity, input factor intensity and payment, and size premia associated with exporting and importing activities. Also, the estimated premia are systematically higher for firms engaged in both activities. Besides, there is higher import activity premium than export premium for firms partially engaged in the global trade via exporting or importing only.

Furthermore, we run the Kolmogorov-Smirnov test for first order stochastic dominance of distributions for firms with different economic activities.⁶ As shown in Table 4, the two-tailed tests reject the null hypothesis that the productivity (TFP) distributions of firms exporting, importing or both are the same.⁷ On the other hand, the one-tailed test shows that productivity distribution of firms both exporting and importing stochastically dominates that of firms either exporting or importing only, and hence they are more productive. Simultaneously, the productivity distribution of firms that only import stochastically dominates that of firms only export. These test results give rise to a clear productivity ranking of firms: exporting and importing firms followed by importing only and exporting only while the domestic firms constitute the least productive group.

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⁵ The fact that very high fraction of firms export, import or both demonstrates open small economy, and even more open manufacturing sector. Eriksson et al. (2009) compared Denmark vis-à-vis the US and showed that participation rate is, in fact, greater for Denmark for different groups of firms. In another note Bernard et al. (2007) showed that importing is less common compared to exporting in the US manufacturing sector.

⁶ As pointed out by Arnold and Hussinger (2010), the use of panel data may violate the independence assumption necessary for the test. Consequently, Kolmogorov-Smirnov test is run for separate years.

⁷ See section 5 for detailed discussion on TFP estimation.
**Fact 4 There is high persistence in the status of firm activities.**

Table 5 presents transition probabilities highlighting the dynamics of firm activities in terms of scope. There is high state dependence of firms engaged in the domestic market (80.85%), exporting only (57.76%), importing only (55.03%) and exporting and importing (93.82%). It is also demonstrated firms engaged in either exporting or importing are more likely to add importing (26.66%) or exporting (23.46%) as additional activity compared to firms engaged in neither of the activities (11.37% and 10.47% to start exporting and importing respectively). Furthermore, firms doing both are less likely to abandon one of these activities compared to firms engaged in only one of them. These firms abandon exporting, importing or both with a probability of 2.82%, 3.82%, and 0.46% respectively. In contrast, firms only exporting (importing) abandon exporting (importing) with a probability of 15.58% (21.51%). Finally, from the last row summarizing the average of the cross-sectional distribution of firms, it can be seen that there is very high incidence of firm involvement in international trade. Among firms at least active in domestic market during the period under consideration around 80% of them are active globally via exporting, importing or both.

The aforementioned facts on the nature of trade and firm performance provide strong rationale for modeling firm export and import decisions jointly. The next section develops the model and lays the foundation for empirical estimation.

### 4. Model

Consider an infinite horizon stationary dynamic stochastic model of firms. In the model there are \( i = 1, 2, ..., n \) number of firms each choosing alternative \( j \) from a set of possible alternatives \( J \) in each time period \( t \). The maximum expected discounted reward for firm \( i \) in time period \( t \) is given by the value function:

\[
V(S_t, \epsilon_t) = \max_{d_{jt}} E \left[ \sum_{t=s}^{\infty} \beta^{t-s} \sum_{j=1}^{J} R_j(S_t, d_{jt}, \epsilon_{jt}) d_{jt} \mid S_s, \epsilon_s \right]
\]

Where \( S_t \) refers to the vector of observed state variables, \( \epsilon_t = (\epsilon_{1t}, \epsilon_{2t}, ..., \epsilon_{jt}) \) vector of unobserved shocks associated with each alternative, \( R_j(S_t, d_{jt}, \epsilon_{jt}) \) the reward function, profit net of sunk/fixed costs, \( \beta \) the discount factor, and
More specific functional representation of the reward function is given by:

\[ R_j(S_t, d_{jt}, e_t) = \begin{cases} 
\pi(.) & ; \text{if } d_{1t} = 1 \\
\pi(.) - \gamma_{it}^{X,F} - \gamma_{it}^{X,S}(1 - \chi_t^X) & ; \text{if } d_{2t} = 1 \\
\pi(.) - \gamma_{it}^{M,F} - \gamma_{it}^{M,S}(1 - \chi_t^M) & ; \text{if } d_{3t} = 1 \\
\pi(.) - \gamma_{it}^{X,F} - \gamma_{it}^{X,S}(1 - \chi_t^X) - \gamma_{it}^{M,F} - \gamma_{it}^{M,S}(1 - \chi_t^M) & ; \text{if } d_{4t} = 1 
\end{cases} \]

Where

\[ \chi_t^X = \mathbb{I}(d_{2,t-1} = 1 \text{ or } d_{4,t-1} = 1) \]

\[ \chi_t^M = \mathbb{I}(d_{3,t-1} = 1 \text{ or } d_{4,t-1} = 1) \]

\[ \pi(.) = \begin{cases} 
\pi^D(S_t, d_{jt}, e_{jt}) & ; \text{if } d_{kt} = 1 \text{ for } k = 1, 3 \\
\pi^D(S_t, d_{jt}, e_{jt}) + \pi^X(S_t, d_{jt}, e_{jt}) & ; \text{if } d_{kt} = 1 \text{ for } k = 2, 4 
\end{cases} \]

Where \( \chi_t^X \) and \( \chi_t^M \) are indicator functions showing whether a firm pays sunk or fixed cost, \( \pi^D(.) \) and \( \pi^X(.) \) profit functions in the domestic and export markets; \( \gamma^{X,S}, \gamma^{M,S}, \gamma^{X,F} \) and \( \gamma^{M,F} \) are sunk and fixed costs in the export and import markets respectively. The policy functions are \( d_{1t} = 1 \) (firm serves domestic market); \( d_{2t} = 1 \) (firm serves both domestic and export markets); \( d_{3t} = 1 \) (firm serves domestic and uses import markets), and \( d_{4t} = 1 \) (firm serves domestic and export, and uses import markets).

Under standard regulatory conditions, after dropping firm index \( i \) for simplicity, we can write the Bellman equation and the alternative-specific value functions as follows:

\[ V(S_t, e_t) = \max_{d_{jt}} \left\{ R_j(S_t, d_{jt}, e_{jt}) + \beta \int V(S_{t+1}, e_{t+1})dF(S_{t+1}, e_{t+1}|S_t, e_t, d_{jt} = 1) \right\} \]

\[ V_j(S_t, e_t) = R_j(S_t, d_{jt}, e_{jt}) + \beta \int V(S_{t+1}, e_{t+1})dF(S_{t+1}, e_{t+1}|S_t, e_t, d_{jt} = 1) \]

Given the alternative specific value functions, firms choose the alternative that yields the highest expected discounted flow of profit, and the optimal decision rule is given by:

\[ d^*(S_t, e_t) = \arg\max_{j \in J} \left\{ V_j(S_t, e_t) \right\} \]
Given the dynamic nature of the firm decision problem, it is important to be more explicit about the timing assumptions of the model. We assume that at time period  

i. Firm observes the state vector \((S_t, \varepsilon_t)\)

ii. Firm maximizes static profit \(\pi(S_t, d_{jt}, \varepsilon_{jt})\)

iii. Firm observes the sunk and fixed costs \((\gamma^{X,S}, \gamma^{X,F}, \gamma^{M,S}, \gamma^{M,F})\)

iv. Firm decides to produce, export or import

Having outlined the firm decision problem, and the timing assumption necessary for estimation, in the next section we present the empirical procedure to estimate parameters of the static and dynamic components of the model.

5. Empirical Procedure

Structural estimation of the firm decision problem specified in the previous section requires combining the production (and cost) side with demand side. This involves introducing specific functional forms that define consumer preference, cost, revenue and profit functions, and distributional assumptions that determine evolution of state vector. We divide the estimation procedure into two steps. In the first step we estimate demand, cost and productivity parameters, and then sunk and fixed costs of exporting and importing.

In estimating demand, cost and productivity parameters, we closely follow Aw et al (2011) in that the short-run marginal cost function is given by:

\[ c_{it} = \beta_0 + \beta_k k_{it} + \beta_w w_{it} + \beta_m m_{it} - \omega_{it} + \varepsilon_{it} \]

Where \( k_{it} \) refers to capital stock of firms; \( w_{it} \) firm and time specific wages; \( m_{it} \) vector of variable input prices common to all firms, and \( \omega_{it} \) firm productivity. With this specification, the observable capital stock and wage, and the unobservable productivity become a source of firm heterogeneity.\(^8\)

In this specification marginal cost does not depend on output level implying that shocks affecting output decisions in one market will not output affect decisions in other markets.

Assumption I: Consumers both in domestic and export markets have CES preferences.

The assumption of CES consumer preference implies that demand takes the standard Dixit-Stiglitz form in both markets. That is, the demand firm \( i \) faces at time period \( t \) becomes

\[ Q_{it}^D = \frac{i^D}{p^D} \left( \frac{p^{D}_t}{p^D} \right) \]

\(^8\) Notation wise, lower case letters refer to variables in logarithmic scale.
\[
\Phi_t^D (p_t^D)^{\xi_D} \quad \text{and} \quad Q_t^X = \frac{r_t^X (P_t^X)}{P_t^X} = \Phi_t^X (P_t^X)^{\xi_X} \text{ in domestic and export markets respectively.}^9
\]

In both demand functions, \( I_t \) refers to the market size; \( P_t \) industry price index; \( P_t \) firm price index, and \( \xi < 0 \) demand elasticity for the respective domestic and export markets. It can be shown that the respective domestic and export market revenues and profit functions are given by:

\[
\begin{align*}
\pi_t^D (\Phi_t^D, k_{it}, w_{it}, \omega_{it}) &= (\xi_D + 1) \ln \left( \frac{\xi_D}{\xi_D + 1} \right) + \ln \Phi_t^D + (\xi_D + 1) (\beta_0 + \beta_k k_{it} + \beta_w w_{it} + \beta_m m_t - \omega_{it}), \\
\pi_t^X (\Phi_t^X, k_{it}, w_{it}, \omega_{it}) &= (\xi_X + 1) \ln \left( \frac{\xi_X}{\xi_X + 1} \right) + \ln \Phi_t^X + (\xi_X + 1) (\beta_0 + \beta_k k_{it} + \beta_w w_{it} + \beta_m m_t - \omega_{it}).
\end{align*}
\]

At this point it is useful to be explicit about the state vector \((S_t, \varepsilon_t) = (k_t, \omega_t, d_{j,t-1}, \Phi_t^D, \Phi_t^X, \varepsilon_t)\) and it comprises firm capital \(k_t\) and productivity \(\omega_t\), firm activity status in previous time period \(d_{j,t-1}\), market level aggregates in domestic and export markets \(\Phi_t^D\) and \(\Phi_t^X\), and unobserved state vector \(\varepsilon_t\). Now, we introduce simplifying assumptions on the evolution of state vector overtime and relationship between the observed and unobserved elements of the state vector.\(^{10}\) These assumptions greatly reduce the computational burden of estimating the parameter vector, and especially that of sunk and fixed cost parameters.

**Assumption II:** The one-time period reward function is additively separable in the observable and unobservable components. That is, the reward function can be written as:

\[
R_f (S_t, d_{jt}, \varepsilon_{jt}) = \bar{R}_f (S_t, d_{jt}) + \varepsilon_{jt}
\]

**Assumption III:** The unobserved state variables are identically and independently distributed across firms and overtime. That is,

\[
dF_c (\varepsilon_{t+1} | \varepsilon_t) = dF_c (\varepsilon_{t+1}).
\]

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\(^9\)The specification of the export demand function is slightly different from Aw et al. (2011). However, it has no effect on the estimation of demand, cost and productivity parameters.

\(^{10}\)For rigorous exposition of these simplifying assumptions, see Aguirregabiria and Mira (2010).
**Assumption IV:** After controlling for current values of the observable state variables and current decisions of the firms, future values of the observable state variables are independent of the current unobserved state variables. More specifically,

\[ dF_S(S_{t+1}|S_t, \epsilon_t, d_{jt} = 1) = dF_S(S_{t+1}|S_t, d_{jt} = 1) \]

To be more precise about the transition of the observed state variables, capital is assumed to be evolving deterministically over time.\(^{11}\) Similarly, the market level indicators \( \Phi^P_t \) and \( \Phi^X_t \) are assumed to follow exogenous first-order Markov processes whereas firm productivity is assumed to follow a controlled first order Markov process:

\[ \omega_t = E[\omega_{t-1} | \omega_{t-1}, X_{t-1}, M_{t-1}] + \xi_t = \omega(\omega_{t-1}, X_{t-1}, M_{t-1}) + \xi_t \]

Where \( \xi_t \sim N(0, \sigma^2_{\xi}) \) and \( X_{t-1} \) and \( M_{t-1} \) refer to previous export and import statuses of firms.\(^{12}\)

More specifically, we assume that firm productivity takes the following functional form:

\[ \omega_t = \alpha_0 + \alpha_1 \omega_{t-1} + \alpha_2 (\omega_{t-1})^2 + \alpha_3 (\omega_{t-1})^3 + \alpha_4 X_{t-1} + \alpha_5 M_{t-1} + \alpha_6 X_{t-1} M_{t-1} + \xi_t \]

This productivity transition specification allows for possible non-linear relationship between current and previous period levels of productivity, and expected productivity gain from previous history of exporting and importing.

**Assumption V:** Conditioning on the observed state variables and decision variable of the firm, the reward function \( \bar{R}_f(S_t,d_{jt}) \) is independent of \( \epsilon_{jt} \).

**Assumption VI:** The unobserved state variables are independent across alternatives and have Type I Extreme Value distribution.

It can easily be seen that from assumptions III and IV, the transition density of the state vector becomes

\[ dF_S(S_{t+1}, \epsilon_{t+1}|S_t, \epsilon_t, d_{jt} = 1) = dF_S(S_{t+1}|S_t, d_{jt} = 1) dF_\epsilon(\epsilon_{t+1}). \]

In addition, combining the definitions of the value and the alternative-specific value functions along with assumptions II—V, we have the following relationships:

\(^{11}\) Capital is not fixed rather it evolves deterministically. For the moment, we abstract from modelling the evolution of capital. Given the availability of long panel, this assumption could be restrictive, and will be relaxed as: \( k_t = \delta_0 + \delta_1 k_{t-1} + \delta_2 X_t + u_t \) where \( u_t \sim N(0, \sigma^2_u) \) and \( X_t \) includes observable firm-specific characteristics such as investment.

\(^{12}\) With a slight abuse of notation, \( X_{t-1} \) and \( M_{t-1} \) here refers to previous export and import statuses as opposed to, \( d_{jt} \) notation which we follow in the rest of the paper. Also, such a specification could be economically more intuitive.
\[ V(S_t, \varepsilon_t) = \max_{j \in J} \{ V_j(S_t, \varepsilon_t) \} \]

\[ V_j(S_t, \varepsilon_t) = \sum_j \left[ \max_{j \in J} \{ W_j(S_{t+1}, d_{jt+1}) + \varepsilon_{jt} \} \right] + \varepsilon_t \]

Using the mathematical properties implied by assumption V, we have

\[ E_{\varepsilon_{t+1}}[V(S_{t+1}, \varepsilon_{t+1})] = E_{\varepsilon_{t+1}}[\max_j \{ W_j(S_{t+1}, d_{jt+1}) + \varepsilon_{jt+1} \}] \]

\[ = \ln \left( \sum_j \exp \left( W_j(S_{t+1}, d_{jt+1}) \right) \right) \]

It also follows that

\[ W_j(S_t, d_{jt}) = \sum_j \left( \ln \left( \sum_{j=1}^J \exp \left( W_j(S_{t+1}, d_{jt+1}) \right) \right) \right) \left( S_t, d_{jt} = 1 \right) \]

We further simplify estimation by discretizing the observable state variables into finite sets, and this gives rise to:

\[ W_j(S_t, d_{jt}) = \sum_j \left( \ln \left( \sum_{j=1}^J \exp \left( W_j(S_{t+1}, d_{jt+1}) \right) \right) \right) dF_S \left( S_{t+1}, S_t, d_{jt} = 1 \right) \]

As we shall see below, this formulation of the alternative-specific value function, in closed form and after integrating out the unobserved state variable, is of considerable importance in reducing the computational burden of estimating the parameter vector, especially the sunk and fixed costs.

To summarize, the parameter vector \( \theta = (\theta_{\xi}, \theta_{\beta}, \theta_{\alpha}, \theta_{\gamma}) \) comprises demand parameters characterizing consumer behavior in domestic and export markets \( \theta_{\xi} = (\xi_D, \xi_X) \); marginal cost parameters \( \theta_{\beta} = (\beta_K, \beta_W) \); productivity transition parameters \( \theta_{\alpha} = (\alpha_0, \alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6, \sigma_\xi) \), and sunk and fixed costs parameters constituting the dynamic component of the decision problem of the firm \( \theta_{\gamma} = (\gamma^X, \gamma^F, \gamma^M, \gamma^M, \gamma^F) \).

**Demand, cost and productivity parameters**

In order to estimate demand function parameters, we use the relationship between total variable cost and revenue functions in the domestic and export markets. Following CES demand preferences and the resulting domestic and export revenue functions, total variable cost can be calculated as
elasticity weighted sum of the revenues in domestic and export markets. After appending an error term, the total variable cost function is estimated using ordinary least squares, and domestic and export market demand elasticities are recovered.

\[ TVC_{it} = R^D_{it} \left( 1 + \frac{1}{\xi_D} \right) + R^X_{it} \left( 1 + \frac{1}{\xi_X} \right) + \eta_{it} \]

We follow the procedure used by Aw et al. (2011) to jointly estimate the cost and productivity parameters. To this end, we use the domestic revenue function, which is available for all firms in the sample. We append an error term, to allow for measurement errors, to the domestic revenue function:

\[ r^D_{it} = (\xi_D + 1) \ln \left( \frac{\xi_D}{\xi_D + 1} \right) + \ln \Phi^D_t + (\xi_D + 1)(\beta_0 + \beta_k k_{it} + \beta_w w_{it} + \beta_m m_t - \omega_{it}) + \nu_{it} \]

As \(-(\xi_D + 1)\omega_{it} + \nu_{it}\) is unknown, we use a semi-parametric approach by Levinsohn and Petrin (2003). Given that electricity usage is almost costless to adjust and dependent on observed firm capital and unobserved productivity \(e_{it} = f(k_{it}, \omega_{it})\), we can express productivity as \(\omega_{it} = f^{-1}(k_{it}, e_{it}) = g(k_{it}, e_{it})\), and the estimating equation becomes:

\[ r^D_{it} = \delta_0 + \sum_{t=1}^{T} \delta_t D_t + (\xi_D + 1) \beta_w w_{it} + g(k_{it}, e_{it}) + \psi_{it} \]

Where \(\delta_0\) captures \((\xi_D + 1) \left( \ln \left( \frac{\xi_D}{\xi_D + 1} \right) + \beta_0 \right)\); \(D_t\) time-varying domestic market aggregate variable \(\ln \Phi^D_t\) and common market-level factor prices \((\xi_D + 1)\beta_m m_t\), and \(g(.)\) captures the non-linear relationship between capital, productivity and domestic revenue and \(\psi_{it}\) an error term which includes \(\nu_{it}\).

Assuming \(g(.)\) is a cubic function in \(k_{it}\) and \(e_{it}\), we estimate the equation using ordinary least squares. The main results of this estimation are the marginal cost parameter \(\beta_w\), and the fitted values \(g(\cdot)\) denoted by \(\hat{\phi}_{it} = (\xi_D + 1)(\beta_k k_{it} - \omega_{it})\) used in the construction of firm productivity
series $\omega_{it} = -1/((\xi_D + 1)\hat{\phi}_{it} + \beta_k k_{it})$. Substituting the productivity transition function into $\hat{\phi}_{it}$, and rearranging the terms, we have the following estimating equation\textsuperscript{13}

$$\hat{\phi}_{it} = \beta_k k_{it} - \alpha_0^* + \alpha_1(\hat{\phi}_{it-1} - \beta_k k_{it}) - \alpha_2^*(\hat{\phi}_{it-1} - \beta_k k_{it})^2$$

$$+ \alpha_3^*(\hat{\phi}_{it-1} - \beta_k k_{it})^3 - \alpha_4^*X_{it-1} - \alpha_5^*M_{it-1} - \alpha_6^*X_{it-1}M_{it-1} - u_{it}^*$$

Applying nonlinear least squares to the above equation, and transforming the estimates using estimated domestic and export demand elasticities, marginal cost parameter $\beta_k$ and productivity transition parameter vector $\theta_\alpha$ can jointly be obtained.

**Sunk and fixed cost parameters**

We know that the alternative-specific value function is given by $V_j(S, e_j; \theta) = W_j(S, d_j; \theta) + e_j$. Consequently, we can easily define choice probabilities of the alternatives as:

$$\Pr(d_{jt} = 1|S_t) = \Pr(V_j(S_t, e_j) \geq V_k(S_t, e_j), \forall k \neq j)$$

And this choice probability of alternative $j$ boils down to a multinomial logit form and can be expressed as:

$$\Pr(d_{jt} = 1|S_t) = \frac{\exp \left( W_j(S_t, d_{jt}) \right)}{\sum_{j=1}^J \exp \left( W_j(S_t, d_{jt}) \right)}$$

After introducing the sunk and fixed costs parameter vector $\theta_\gamma = (\gamma^{XS}, \gamma^{XF}, \gamma^{MS}, \gamma^{MF})$, the likelihood increment for firm $i$ at time period $t$ is given by:

$$L_{it}(d_{ijt}|S_{it}; \theta_\gamma) = \Pr(d_{ijt} = 1|S_{it}; \theta_\gamma),$$

and the likelihood of the data becomes:

$$L(d|\theta_\gamma) = \prod_i \prod_t \prod_j \left( L_{it}(d_{ijt}|S_{it}; \theta_\gamma) \right)^{d_{ijt}}$$

\textsuperscript{13}$$\hat{\phi}_{it} = (\xi_D + 1)\beta_k k_{it} - (\xi_D + 1)\alpha_0 + \alpha_1(\hat{\phi}_{it-1} - (\xi_D + 1)\beta_k k_{it}) - \frac{\alpha_2}{(\xi_D + 1)}(\hat{\phi}_{it-1} - (\xi_D + 1)\beta_k k_{it})^2 +$$

$$- \frac{\alpha_3}{(\xi_D + 1)^2}(\hat{\phi}_{it-1} - (\xi_D + 1)\beta_k k_{it})^3 - (\xi_D + 1)\alpha_4 X_{it-1} - (\xi_D + 1)\alpha_5 M_{it-1} - (\xi_D + 1)\alpha_6 X_{it-1}M_{it-1} - (\xi_D + 1)v_{it}$$
As clearly pointed out by Das et al. (2007), the likelihood function may not necessarily be globally concave in the parameter vector, and thereby it is computationally difficult to find likelihood function optimizing parameter vector. As a result, instead of trying to maximize the likelihood function we proceed to estimate the posterior distribution of the parameter vector using Bayesian Markov Chain Monte Carlo (MCMC) method. Implementation of this method requires specification of a prior distribution $\pi(\theta_{r})$, and a likelihood function $L(d|S;\theta_{r})$. Following the standard Bayesian inference approach, the posterior distribution can be obtained as:

$$
\Pr(\theta_{r}|d,S) = \frac{\pi(\theta_{r})L(d|S;\theta_{r})}{\int \pi(\theta_{r})L(d|S;\theta_{r})d\theta_{r}} = \frac{\pi(\theta_{r})L(d|S;\theta_{r})}{L(d|S)} \propto \pi(\theta_{r})L(d|S;\theta_{r})
$$

We use Metropolis-Hastings algorithm to draw parameter values from the posterior distribution $\Pr(\theta_{r}|d,S)$ to obtain sunk and fixed cost parameter estimates. Details of the Metropolis-Hastings algorithm will be available as an appendix.

6. Estimation results

This section presents estimation results of the static and dynamic parameters of the model of firm export and import decisions of firms.

Demand, cost and productivity parameter estimates

Table 6 presents estimates of the demand, marginal cost and productivity parameters of the model. From demand parameter estimation, it is shown that there is a significant difference in the implied values of elasticity in domestic and export markets. Demand in domestic market is less elastic than in export markets. This elasticity differential leads to a mark-up rate of 55% and 16% in domestic and export markets respectively. Lower markup rate in the export market is in line with the fact that several firms participate and greater varieties of good are supplied in export markets. A negative and highly significant coefficient for capital shows that firms with large capital stock have relatively lower marginal cost of production, and hence they are more productive. A negative and significant relationship between marginal cost and wages of workers strongly suggests that firm attract highly skilled workers by paying higher wages.

Coming to the productivity parameters of the model, the estimated parameters indicate that current and lagged productivities of firms are significantly and nonlinearly correlated. It is also shown that previous exporting and importing activities have a positive and significant impact on current
productivity levels. Further, it can be seen that the productivity gain from importing is even higher compared to that of exporting. The same effect is also found when considering export and import intensities, fraction of exports and imports in total sales.

In Table 7 we present bivariate probit estimation results on the correlations between firm productivity, capital stock, current and previous export and import activity statuses of firms. The first two columns show that productivity and capital stock of firms are important determinants in the export and import export decisions of firms. That is, firms which are more productive, large in terms of capital size, and with previous history of either exporting or importing are more likely to export or import.

From results shown in the last four columns, it is indicated that export revenue is positively and significantly determined by firm capital stock and current productivity levels conditional on firm export participation. However, it turns out that significant portion of the variation in the level of export sales remained unexplained, as shown by very high $\rho \approx 0.89$ in the fixed effect regressions. This, in turn, provides a rationale to do the modelling at even disaggregated level.

**Sunk and fixed cost parameter estimates**

The results from estimating the sunk and fixed costs of exporting and importing are summarized in Table 8. Two important results are found. First, there are substantial sunk and fixed costs of exporting and importing activities, strongly implying self-selection effect. Additionally, it is shown that exporting activities require relatively higher sunk and fixed costs compared to importing activities. Second, we find that the scale of operation and the magnitude of sunk and fixed costs are positively correlated. That is, larger firms incur greater sunk and fixed costs of exporting and importing. It is also shown that for larger firms sunk costs, and for small firms fixed costs of exporting is lower compared to their importing counterparts. This explains the fact that exporting is the most common activity among firms in the Danish manufacturing sector. Very high sunk and fixed costs of importing deter large and small firms from starting or continuing to import goods respectively.\(^{14}\) This could also explain the productivity ranking of firms with different forms of involvement in the international trade where importing firms are generally more productive.

\(^{14}\) High sunk cost for large importing firms may be due to the fact that there is high incidence of intra firm trade.
7. **Conclusion**

Using a panel of firms in the Danish manufacturing sector, we documented a few stylized facts on the behavior of firms with respect to exporting and importing activities. We found considerable degree of firm heterogeneity in terms of size, wage payment and productivity; frequent incidence of simultaneous exporting and importing activities; significant export and import activity premia, and high persistence in the status of firm activities overtime. Motivated by these empirical regularities, we specify and structurally estimate a dynamic discrete choice model of export and import decisions of firms. The model provides a framework to analyze the determinants of firms’ decisions to export and import while allowing for previous export and import decisions to affect future productivity trajectory. The estimation results showed significant difference in demand elasticity in domestic and export markets. In line with the expectation that more firms and more product varieties in export markets lead to tougher competition, more elastic demand and lower markup compared to domestic markets. From cost parameter estimates, we found that firms with larger capital stock and paying higher wages to their workers are cost efficient. That is, these firms have lower marginal cost even after controlling for their productivity. Furthermore, in agreement with self-selection hypothesis, we found significant sunk and fixed costs of exporting and importing. We also found greater sunk and fixed costs for exporting compared to that of importing activities, and when allowing for firm size difference, a positive correlation between the sizes of these costs and the scale of firm operation. On the other hand, previous history of exporting and importing improves current productivity levels of firms. This provides evidence of learning—by—exporting and learning—by—importing in the Danish manufacturing sector. Therefore, in addition to size significance of sunk and fixed costs, productivity gain from exporting and importing further magnifies self-section of firms into export and import markets.

There are three main ongoing extensions. First, there is a need to account for multi-product nature of production given increasing prevalence and importance of multi-product firms in production, export and import activities. Second, owing to non-negligible difference in the core activities of firms, estimation of the parameters for individual industries is necessary. Lastly, the assumption of identically and independently distributed unobserved state variables is somehow restrictive; the correlation coefficient between error terms from the bivariate probit estimation is 0.28. This necessitates allowing for serial correlation overtime and across alternatives.
References


Kasahara, H., & Lapham, B. (2013). Productivity and the decision to import and export:


Table 1: Summary statistics on firm capital size, wage payment and productivity

<table>
<thead>
<tr>
<th>Year</th>
<th>Firm size</th>
<th>Capital</th>
<th>Wage payment</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small</td>
<td>Large</td>
<td>Mean</td>
<td>Median</td>
</tr>
<tr>
<td>2000</td>
<td>47.25 %</td>
<td>52.75 %</td>
<td>27.53</td>
<td>6.84</td>
</tr>
<tr>
<td>2001</td>
<td>46.44 %</td>
<td>53.56 %</td>
<td>28.52</td>
<td>7.07</td>
</tr>
<tr>
<td>2002</td>
<td>45.44 %</td>
<td>54.56 %</td>
<td>29.89</td>
<td>7.29</td>
</tr>
<tr>
<td>2003</td>
<td>44.59 %</td>
<td>55.41 %</td>
<td>30.55</td>
<td>7.67</td>
</tr>
<tr>
<td>2004</td>
<td>43.80 %</td>
<td>56.70 %</td>
<td>31.41</td>
<td>7.84</td>
</tr>
<tr>
<td>2005</td>
<td>43.68 %</td>
<td>56.32 %</td>
<td>31.14</td>
<td>7.84</td>
</tr>
<tr>
<td>2006</td>
<td>42.69 %</td>
<td>57.31 %</td>
<td>31.79</td>
<td>8.22</td>
</tr>
<tr>
<td>2007</td>
<td>42.17 %</td>
<td>57.83 %</td>
<td>32.86</td>
<td>8.26</td>
</tr>
</tbody>
</table>

Note: Small (large) firms are those with capital size below (above) the median value, which is calculated for all years combined. Capital is in millions and wages in thousands of DKK. Productivity is estimated TFP.

Table 2: Sample summary on firm export and import activities

<table>
<thead>
<tr>
<th>Year</th>
<th>Domestic</th>
<th>Import Only</th>
<th>Export Only</th>
<th>Both</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># Firms</td>
<td>% Firms</td>
<td># Firms</td>
<td>% Firms</td>
</tr>
<tr>
<td>2000</td>
<td>501</td>
<td>23.79</td>
<td>144</td>
<td>6.84</td>
</tr>
<tr>
<td>2001</td>
<td>476</td>
<td>22.60</td>
<td>134</td>
<td>6.36</td>
</tr>
<tr>
<td>2002</td>
<td>411</td>
<td>19.52</td>
<td>139</td>
<td>6.60</td>
</tr>
<tr>
<td>2003</td>
<td>370</td>
<td>17.57</td>
<td>148</td>
<td>7.03</td>
</tr>
<tr>
<td>2004</td>
<td>385</td>
<td>18.28</td>
<td>155</td>
<td>7.36</td>
</tr>
<tr>
<td>2005</td>
<td>390</td>
<td>18.52</td>
<td>153</td>
<td>7.26</td>
</tr>
<tr>
<td>2006</td>
<td>371</td>
<td>17.62</td>
<td>150</td>
<td>7.12</td>
</tr>
<tr>
<td>2007</td>
<td>369</td>
<td>17.52</td>
<td>168</td>
<td>7.98</td>
</tr>
<tr>
<td></td>
<td>Import Only</td>
<td>Export Only</td>
<td>Both</td>
<td></td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------</td>
<td>-------------</td>
<td>---------</td>
<td></td>
</tr>
<tr>
<td>Value added per worker</td>
<td>7.736*</td>
<td>2.662*</td>
<td>11.13***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(6.44)</td>
<td>(2.55)</td>
<td>(13.36)</td>
<td></td>
</tr>
<tr>
<td>Sales per worker</td>
<td>14.81***</td>
<td>8.132***</td>
<td>29.02***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(10.97)</td>
<td>(6.47)</td>
<td>(27.49)</td>
<td></td>
</tr>
<tr>
<td>Capital per worker</td>
<td>3.637</td>
<td>14.15***</td>
<td>22.76***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.00)</td>
<td>(4.19)</td>
<td>(8.47)</td>
<td></td>
</tr>
<tr>
<td>Material per worker</td>
<td>35.13***</td>
<td>25.86***</td>
<td>65.42***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(11.49)</td>
<td>(9.91)</td>
<td>(28.25)</td>
<td></td>
</tr>
<tr>
<td>Energy per worker</td>
<td>11.48***</td>
<td>5.867*</td>
<td>29.70***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(4.01)</td>
<td>(2.36)</td>
<td>(14.03)</td>
<td></td>
</tr>
<tr>
<td>Wage</td>
<td>1.552**</td>
<td>1.429**</td>
<td>3.601***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.65)</td>
<td>(2.74)</td>
<td>(8.92)</td>
<td></td>
</tr>
<tr>
<td>Employment size</td>
<td>41.63***</td>
<td>15.26***</td>
<td>170.8***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(11.45)</td>
<td>(5.23)</td>
<td>(51.41)</td>
<td></td>
</tr>
</tbody>
</table>

_t statistics in parentheses, * p < 0.05, ** p < 0.01, *** p < 0.001_
Table 4: Kolmogorov-Smirnov test for equality of productivity distributions

<table>
<thead>
<tr>
<th>Year</th>
<th>Export Only Vs. Import Only</th>
<th>Export Only Vs. Both</th>
<th>Both Vs. Import Only</th>
<th>Both Vs. Export Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.2091***</td>
<td>0.2262***</td>
<td>0.3657***</td>
<td>-0.2091***</td>
</tr>
<tr>
<td>2001</td>
<td>0.1802**</td>
<td>0.2320***</td>
<td>0.3757***</td>
<td>-0.1802**</td>
</tr>
<tr>
<td>2002</td>
<td>0.1662**</td>
<td>0.1598***</td>
<td>0.2854***</td>
<td>-0.1662**</td>
</tr>
<tr>
<td>2003</td>
<td>0.1066</td>
<td>0.2965***</td>
<td>0.3183***</td>
<td>-0.1066</td>
</tr>
<tr>
<td>2004</td>
<td>0.1024</td>
<td>0.2503***</td>
<td>0.3164***</td>
<td>-0.1024</td>
</tr>
<tr>
<td>2005</td>
<td>0.1543**</td>
<td>0.2870***</td>
<td>0.3710***</td>
<td>-0.1543**</td>
</tr>
<tr>
<td>2006</td>
<td>0.1303</td>
<td>0.2861***</td>
<td>0.3389***</td>
<td>-0.1303</td>
</tr>
<tr>
<td>2007</td>
<td>-0.1274</td>
<td>0.2003***</td>
<td>0.2908***</td>
<td>-0.1274</td>
</tr>
</tbody>
</table>

Table 5: Transition probabilities of firms

<table>
<thead>
<tr>
<th>Status t</th>
<th>Status t+1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domestic</td>
</tr>
<tr>
<td>Domestic</td>
<td>80.85</td>
</tr>
<tr>
<td>Import Only</td>
<td>18.28</td>
</tr>
<tr>
<td>Export Only</td>
<td>13.03</td>
</tr>
<tr>
<td>Both</td>
<td>0.46</td>
</tr>
<tr>
<td>All</td>
<td>18.80</td>
</tr>
</tbody>
</table>

*p < 0.05, **p < 0.01, ***p < 0.001
Table 6: Demand, cost and productivity estimation

<table>
<thead>
<tr>
<th></th>
<th>Demand</th>
<th>Cost</th>
<th>Productivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Domestic</td>
<td>Export</td>
<td>Discrete</td>
</tr>
<tr>
<td>1+1/ξ</td>
<td>0.6451***</td>
<td>0.8644***</td>
<td>-0.0946***</td>
</tr>
<tr>
<td>(9.60)</td>
<td>(35.15)</td>
<td></td>
<td>(-54.05)</td>
</tr>
<tr>
<td>σ</td>
<td>2.817</td>
<td>7.373</td>
<td>-0.5558***</td>
</tr>
<tr>
<td>P/MC</td>
<td>1.55</td>
<td>1.16</td>
<td></td>
</tr>
</tbody>
</table>

* t statistics in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001

---

Table 7: Bivariate probit estimation of export and import participation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Export status</th>
<th>Import status</th>
<th>Export revenue</th>
<th>Export revenue</th>
<th>Export revenue</th>
<th>Export revenue</th>
<th>Export revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>ωᵢ tà</td>
<td>0.475***</td>
<td>0.981***</td>
<td>3.263***</td>
<td>3.087***</td>
<td>0.609***</td>
<td>0.593***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(5.65)</td>
<td>(12.23)</td>
<td>(35.73)</td>
<td>(35.50)</td>
<td>(6.44)</td>
<td>(6.30)</td>
<td></td>
</tr>
<tr>
<td>kᵢ tà</td>
<td>0.100***</td>
<td>0.107***</td>
<td>0.429***</td>
<td>0.411***</td>
<td>0.150***</td>
<td>0.154***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(7.25)</td>
<td>(7.57)</td>
<td>(22.66)</td>
<td>(22.55)</td>
<td>(7.68)</td>
<td>(7.94)</td>
<td></td>
</tr>
<tr>
<td>Xᵢ tà−1</td>
<td>2.248***</td>
<td>0.701***</td>
<td>-</td>
<td>2.987***</td>
<td>-</td>
<td>0.606***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(59.89)</td>
<td>(18.60)</td>
<td>(30.78)</td>
<td>(10.92)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mᵢ tà−1</td>
<td>0.607***</td>
<td>1.999***</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<tr>
<td></td>
<td>(15.50)</td>
<td>(55.54)</td>
<td>(55.54)</td>
<td></td>
<td>(55.54)</td>
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<td></td>
</tr>
<tr>
<td>Year FE</td>
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<td>Yes</td>
<td></td>
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<tr>
<td>Industry FE</td>
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<td>Yes</td>
<td>Yes</td>
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<td></td>
</tr>
<tr>
<td>Firm FE</td>
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<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

|                | R²=0.4490 | R²=0.5058 | ρ =0.8966 | ρ =0.8899 |
|                |           |           |           |           |

* t statistics in parentheses * p < 0.05, ** p < 0.01, *** p < 0.001

23
Table 8: Sunk and fixed costs of exporting and importing (in 1,000 USD)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Small</th>
<th>Large</th>
<th>All</th>
<th>Priors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_{X,S}$</td>
<td>363.81</td>
<td>442.18</td>
<td>381.49</td>
<td>$\gamma_{X,S} \sim N(0, 1000)$</td>
</tr>
<tr>
<td>$\gamma_{X,F}$</td>
<td>184.20</td>
<td>276.24</td>
<td>189.88</td>
<td>$\gamma_{X,F} \sim N(0, 1000)$</td>
</tr>
<tr>
<td>$\gamma_{M,S}$</td>
<td>322.72</td>
<td>462.94</td>
<td>226.17</td>
<td>$\gamma_{M,S} \sim N(0, 1000)$</td>
</tr>
<tr>
<td>$\gamma_{M,F}$</td>
<td>198.98</td>
<td>260.07</td>
<td>171.03</td>
<td>$\gamma_{M,F} \sim N(0, 1000)$</td>
</tr>
</tbody>
</table>

Standard errors in parentheses.

Note: $\beta = 0.95$, # Capital grids=10, # Productivity grids=100, # Iterations=20,000, Burn-in=5,000, 1 USD=5.44 DKK
Figure 1: Trace plot of fixed and sunk costs of exporting and importing