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ABSTRACT

Are capital intensive firms the biggest exporters?*

This paper starts out from the observation that the export shares of firms (export to sales ratio) vary greatly among firms, and tend to be systematically related to the firms' capital labour ratios. This observation cannot be explained by the standard heterogeneous firms and trade model by Melitz (2003), which predicts that all exporting firms have identical export shares. In our model, we relate the difference in export shares to firm level differences in transport costs. Two factors influence a firm's transport cost in our model. First, firm scale can affect transportation costs, making freight rates lower for large firms. Second, we allow for an association between the capital intensity of a firm and its transportation costs. In accordance with data, we assume this relationship to be sector specific. This implies that our model can generate the result that more productive and capital intensive firms have higher export shares due to scale economies in transportation, but the model can also generate the opposite pattern that more capital intensive firms have lower export shares due to a strong positive association between capital labour ratio and transportation costs. We use Japanese manufacturing firm level data to calibrate our model by matching firm level export shares to data sector by sector. Regressing the calibrated transportation costs on actual data then shows that the calibrated (calculated) numbers can explain about half of the variation in the data.

JEL Classification: F12 and F15
Keywords: calibration, capital labour ratio, export shares and heterogeneous firms

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1 Introduction

Current studies using firm or plant level data have documented that export firms tend to be larger, more productive and have a higher capital labour ratio than purely domestic firms (see e.g. Bernard et al. 2007a,b). This also holds in the Japanese firm-level data set that we use here.[1] The theoretical explanations for this are related to trade costs and market entry costs that make it more difficult to sell in foreign markets (Melitz 2003, Melitz and Ottaviano 2007, Eaton and Kortum 2002 and Yeaple 2005). For instance, in Melitz (2003), productivity and thus firm size are probabilistically distributed. Only the most productive firms will find it worthwhile to pay the beachhead costs necessary to export to foreign markets.[2]

Heterogeneity is important not only across firms but also across sectors. E.g. factor intensities have a strong sectorial component along with the firm-level variation. This paper focuses on firm- and sector-level heterogeneities in capital labour ratios, and the effect of this on firm-level export shares (export to total sales ratio). Bernard et al. (2007b) find that exporters are on average 12 percent more capital intensive than non-exporters. Similarly for Japanese data, Kimura and Kiyota (2006) find that the export probability increases by 2 percent in the capital-labour ratio. However, we point out that when comparing among exporters, it is not necessarily the most capital intensive firms that are the most intensive exporters (have the highest export share). Indeed, in several sectors, there is an opposite pattern: Capital intensity is negatively correlated with the export share of firms. E.g. in the iron and steel sector, in our dataset, the largest and most capital intensive firms produce crude steel products that are heavy to transport, and that are exported to a lower degree. Smaller firms, having a lower capital intensity, produce more specialised iron and steel products that are easier to transport and that are also exported to a much higher degree. The export share of firms therefore tends to be negatively related to the capital labour ratio in this sector. On the other hand, e.g. in the electrical equipment sector, the large capital intensive firms produce more advanced machinery that is exported to a higher degree than e.g. electric heaters produced by smaller firms with a lower capital labour ratio. This produces a positive relationship between firms' export shares and their capital labour ratio in the electrical equipment sector.

While firms' export shares systematically vary in the data, this is not the case in the workhorse trade model by Melitz (2003). Instead all exporting firms, irrespective of their productivity level, have constant export shares in the existing varieties of this model. To overcome this, we allow for firm-level variation in transportation costs. Empirical evidence indicates substantial differences in transportation costs at the sector level as well as at the firm level (see e.g. Anderson and van Wincoop 2004), and sector level differences in trade costs has a substantial effect

[1] See Wakasugi et al. (2008) and Kimura and Kiyota (2006).

[2] The fact that exporters are more productive than non-exporters is documented by e.g. Bernard and Jensen (2004); Clerides, Lach and Tybout (1998) for Colombia, Mexico, and Morocco; Bernard and Wagner (2001) for Germany; Baldwin and Gu (2003) for Canada.

on firm level exports as shown by e.g. Bernard et al.(2003, 2006). In this paper, we allow for scale economies in transportation, e.g. because larger firms get lower freight rates.[3] Inspired by the data, we also allow for the possibility that the firm level per unit transport cost is related to the capital intensity of the firm. These relationships are assumed to be sector specific, which implies that our model can account for sectors with increasing as well as decreasing firm export shares in firm capital intensities.

Several papers have introduced varying capital labour ratios in heterogenous firms models. Bernard et al. (2007a) analyse a Melitz model with two manufacturing sectors with different capital shares in production. This introduces an element of comparative advantage along with firm heterogeneity. However, all exporting firms have identical export shares (export to total sales ratio) in their model, since transport costs are exogenous and independent of firms' characteristics. Therefore, their model is not applicable to the analysis of firm and sector variations in the export shares of firms. Moreover, Burnstein and Vogel (2010) analyse a model with sector-specific capital labour ratios, but once more all firms have identical export shares. Finally, Crozet and Trionfetti (2010) analyse comparative advantage in a model with firm-level differences in capital labour ratio. This affects firm-level marginal costs and firm sales, but all firms have identical export shares also in their model. In contrast, our model generates firm specific export shares that depend on firms' capital labour ratios and scale economies in transportation.

We calibrate our model on Japanese manufacturing census firm-level data. This dataset provides information on a representative selection of more than 13,000 Japanese manufacturing firms for the year 2005. Japan is one of the largest exporters in the world, and 30 percent of all manufacturing firms are exporters, e.g. compared to 18 percent for the United States. As in other OECD countries, export is dominated by the largest firms, and 90 percent of total exports come from the top 10 percent exporters. The export industries with the largest export sales ratios are the precision instruments industry (19.1 percent), electrical machinery and apparatus (18.7 percent), machinery and equipment (17.3 percent), and motor vehicles (14.8 percent), (Wakasugi et al. 2008).

Before the model section, we document some stylized facts. Thereafter, we present the model. Finally, we calibrate our model to the data.

2 Stylised facts

2.1 Data

We utilise a Japanese firm-level dataset entitled *Kigyou Katsudou Kihon Chousa Houkokusho* (*The Results of the Basic Survey of Japanese Business Structure and Activities*) from the Research and Statistics Department, Minister's Secretariat, Ministry of International Trade and Industry (MITI). This dataset provides information on a representative selection of more than

[3] See e.g. Hummels and Skiba (2004).

28,000 Japanese firms for the year 2005 (including manufacturing as well as service sectors). The total number of manufacturing firms is 13,203, of which 4,189 are exporters. To be eligible for inclusion in the survey, firms must have more than 50 employees and a capital of more than 30 million Yen. The dataset provides detailed information on the activities of each firm.[4] We use data on capital measured as tangible capital assets, and employment measured as the number of regular workers. The capital-labour ratio is the ratio of these (million yen per worker). Export data is available as total exports and export by destination (9 regions in the world) at the firm level. Transport costs are defined as all costs related to transport of final products, such as costs for packaging and costs paid to transportation companies. There is no distinction between whether transport costs are for exports or domestic sales. We also use data for total sales and profits per firm.

2.2 Examples of sectors

Before turning to estimation and calibration of the full sample, we show some data on export shares, transport costs per sales and capital labour ratios for two representative sectors; the iron and steel and the electrical equipment sectors. In each sector, we single out exporting firms and then sort them according to their capital labour ratio. Thereafter, we split the sample at the average capital labour ratio into one group with high and one group with low capital labour ratio. We calculate the average export to sales ratio, average transportation costs and the average capital labour ratio for each group. A difficulty is that our transport cost data refers to total costs of transportation. These are highly endogenous to a firm's export status, since transportation to foreign destinations is more costly generally. Therefore, we calculate average transport costs for high and low capital intensity firms of non exporters only. Table 1 contains data for the two sectors, it also contains some typical products produced by firms in the high and low capital intensity groups.[5]

[4] See the Appendix for more details.

[5] The product types are found by searching firm webpages. Thus, that information comes from outside our microdataset.

Electrical equipment (301)	Low K/L ratio	High K/L ratio
Type of product	electric heaters, industrial sawing machines, electronic devices and parts	marine generators and motors, turbines, weld machinery
Average K/L ratio	3.39	11.19
Average transport cost per sales (non-exporters)	0.0125	0.0118
Average export share	0.089	0.17
Iron and Steel (261)	Low K/L ratio	High K/L ratio
Type of product	speciality steel products, stainless steel products	crude steel, steel bars, tubes
Average K/L ratio	13.02	59.20
Average transport cost per sales (non exporters)	0.034	0.039
Average export share	0.099	0.073

Table 1: Two example sectors

The table shows how the two sectors differ. Exporting firms with high capital labour ratios in the electrical equipment sector (301) produce more advanced products. They are, on average, larger exporters (have higher export shares) and have lower transport costs. The pattern is the opposite in the iron and steel sector (261). High capital labour ratio firms produce more basic products like crude steel that have higher transport cost per sales and they export less.

In our model below, we relate the difference in export shares to firm-level differences in transport costs. Two factors are assumed to influence a firm's transport cost. First, firm scale affects transportation costs, and we allow for large firms to have lower transport costs e.g. because they get lower freight rates. Second, we allow for a sector-specific association between the capital intensity of a firm and its transportation costs. For instance, in the iron and steel industry, transport costs (per sales) tend to increase in firm capital labour ratios, whereas the opposite tends to hold in the electrical equipment industry. Our model can generate the result that more productive and capital intensive firms have higher export shares due to scale economies in transportation, but the model can also generate the opposite pattern that more capital intensive firms have lower export shares due to a strong positive association between capital labour ratio and transport costs.

2.3 Patterns of firm exports

We start by showing that our dataset has the usual properties when comparing exporters to non-exporters. Table 2 shows that exporters, as customary, are larger, more productive and have a higher capital-labour ratio.[6]

	Capital-labour ratio	Profit per sales	Profit per employee	Profit	Size	Sales
Non-Exporters	10.4	0.025	1.26	479	237	10441
Exporters	11.8	0.052	2.39	2659	708	44908

Table 2: Basic statistics for exporters and non-exporters

However, within the group of exporting firms, there are systematic differences when it comes to their export ratio (the ratio of export sales to total sales). In the aggregate, there tends to be a negative relationship between a exporting firm's capital labour ratio and its export ratio (ratio of export to total sales) as illustrated in Figure 1. The negative relationship is confirmed by the quantile regressions in the Appendix. Note that the Melitz model predicts that all firms have identical export shares.

The relationship between export share and capital labour ratio is very similar when looking at exports to different destinations. An example is given by Figure 2 that plots firm export shares against the capital labour ratio for Japanese exports to North America.[7] The horizontal line in Figure 2 illustrates the firm-level North American export share (ratio of exports to North America and total sales) predicted by the standard Melitz model. The line is calibrated using sector-level trade costs data as in Venables and Limao (2001).[8]

However, once we analyse the data sector by sector, the pattern changes. Some sectors display a negative relationship between the export to sales ratio and the capital labour ratio, as illustrated by Figure 3a, other sectors show more of a positive relationship. Such a case is displayed in Figure 3b.

[6] We measure capital as tangible assets (unit: million yen) and labour as the number of regular workers (unit: person).

[7] The picture is similar for Japanese exports to other parts of the world (e.g. Europe and Asia).

[8] Trade cost, τ, is calculated as follows: τ=CIF/FOB=b*ln(distance). b is significantly estimated to 0.25 in Table 2 in Limao and Venables (2001). We employ the CEPII distance data set to calculate the geographical distance from Japan (http://www.cepii.fr/anglaisgraph/bdd/distances.htm). The distance is measured from Tokyo to the biggest population city in each region. Export data in our firm level data set is divided into 9 regions in the world. The trade costs from Japan to North America, Europe, and Asia are 0.079, 0.083 and 0.143, respectively. The export share, $\frac{\phi}{1+\phi}$, is calculated for each destination, where $\phi \equiv \tau^{1-\sigma}$. Using $\sigma = 4$, we get 0.074, 0.078 and 0.063 as export shares to North America, Europe and Asia, respectively.

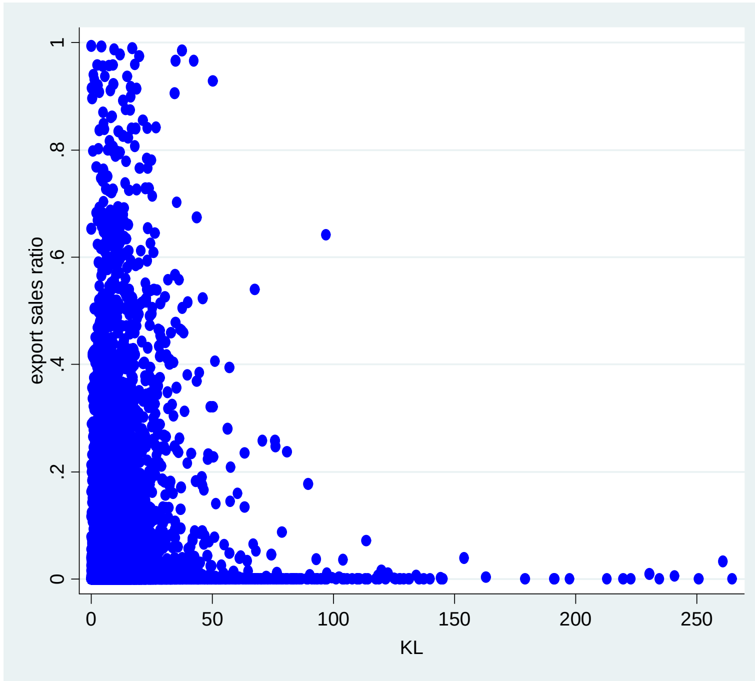


Figure 1: Export shares and capital labour ratio for the entire sample

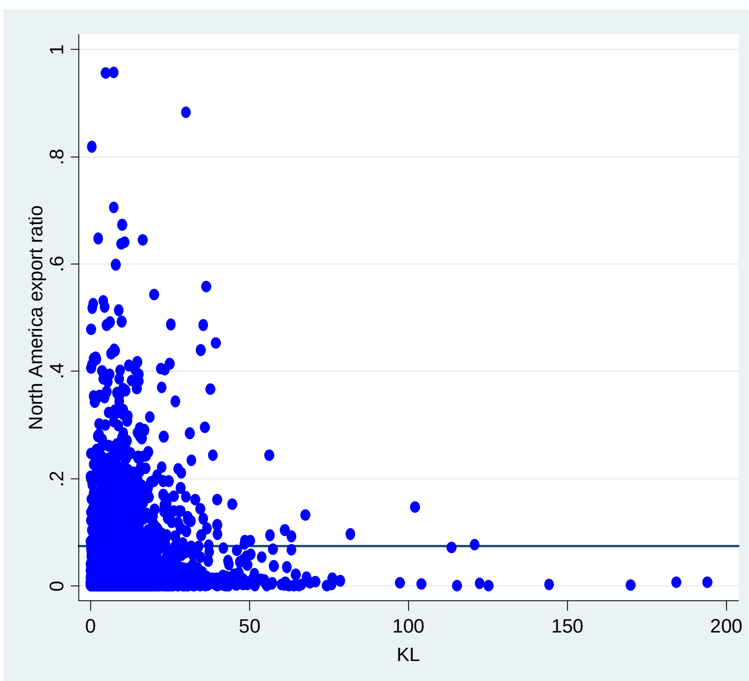


Figure 2: Export shares and capital labour ratio for export to North America

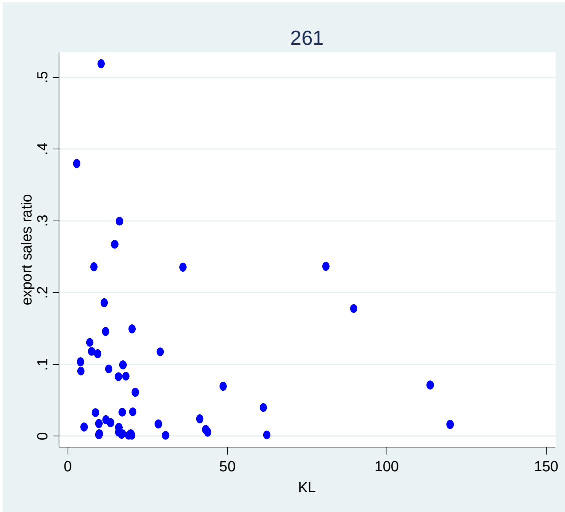


Figure 3a: Export shares and capital labour ratio for firms in sector 261 (Iron and steel)

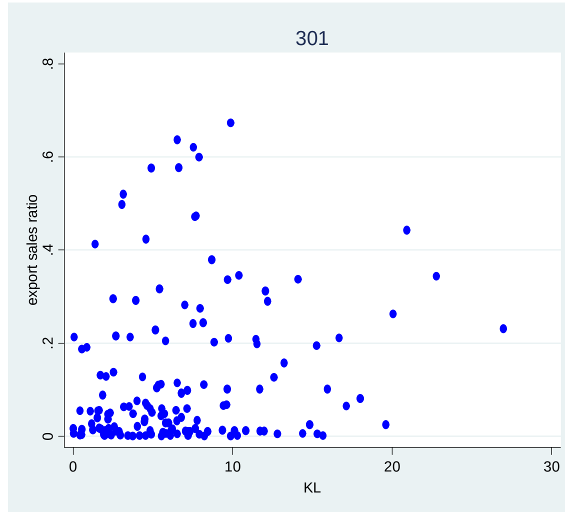


Figure 3b: Export shares and capital labour ratio in sector 301 (Electric machinery)

2.4 Transport costs and exports

We will here relate firms' varying export shares to firm differences in transportation costs. First, there is likely to be scale economies in transportation; e.g. Hummels and Skiba (2004) find that a 10 percent increase in product weight/value leads to a 4-6 percent increase in shipping costs using U.S. data. Therefore, we will allow for scale economies in transportation. Second, as suggested by the data, we also allow for a systematic but sector-specific relationship between the capital intensity of production and the transportation cost of the produced good. That is, the capital labour ratio in production is used as a proxy for some characteristics of the final good that affect transportation costs.[9] For instance, in basic sectors such as steel or paper, a high capital labour ratio may imply that firms are producing heavy bulk items with relatively high transport costs. On the other hand, e.g. in machinery sectors, it may be that a high capital labour ratio implies a more advanced product that has a lower transportation cost. Figure 4 shows an aggregate picture of how firms' transportation costs per sales (unit: million yen) depend on their capital labour ratio. Quantile regressions show a positive relation between firm capital labour ratios and firm transportation costs when regressing all export firms (see Appendix section 6.1). However, the pattern varies by sector, and Figures 5a,b show the relationship for the two example sectors: iron and steel (261) and electrical equipment (301). The figures show that there is a stronger positive association between a firm's capital labour ratio and its transport costs in the iron and steel sector than in the electrical machinery sector. As shown in the calibration section below, export shares decrease in the capital labour ratio for firms in the iron and steel sector whereas they increase in the electrical equipment sector.

[9] Hummels (1999) shows how sector level capital labour ratios are related to sector level trade costs.

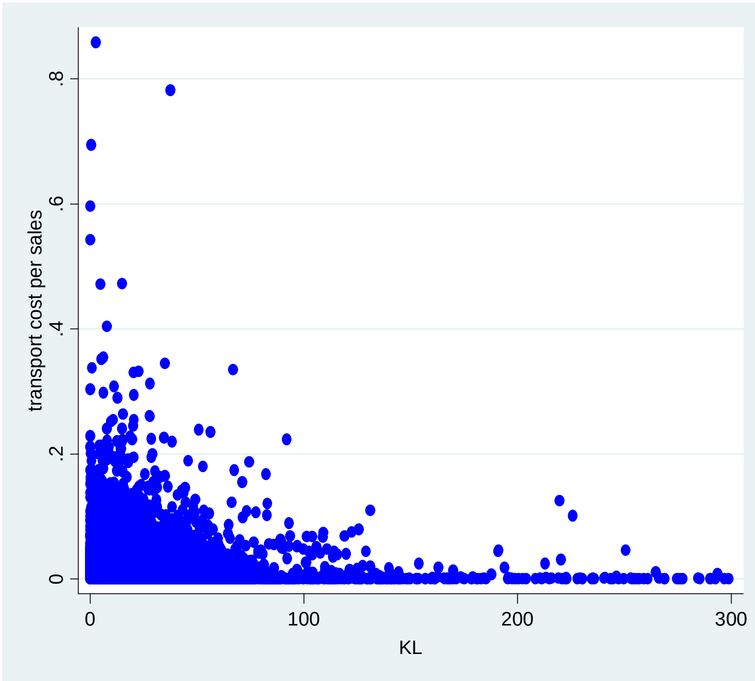


Figure 4: Transport cost per sales and capital labour ratio for the entire sample of firms

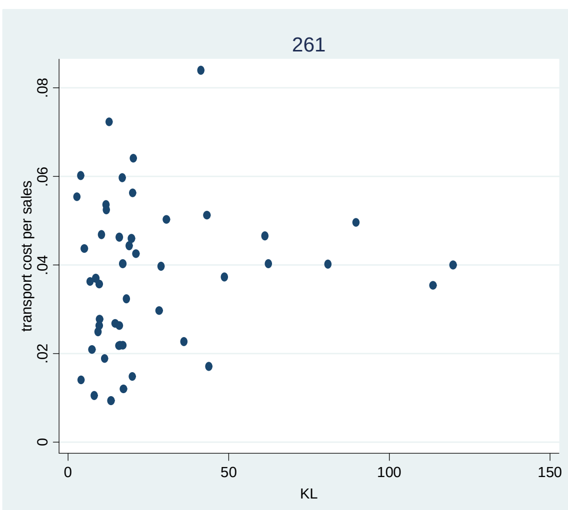


Figure 5a K/L ratio and transportation cost in Iron and Steel

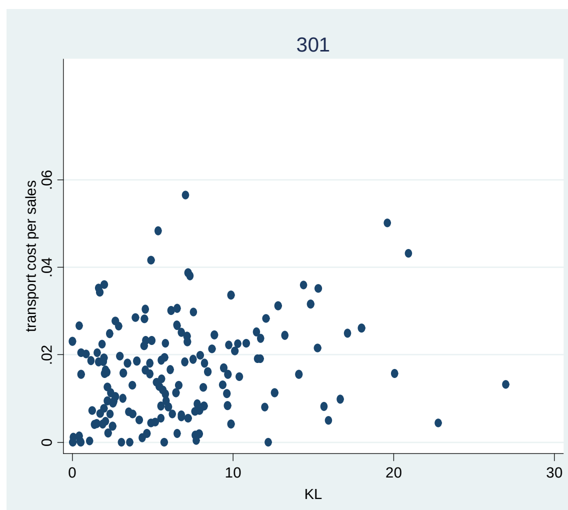


Figure 5b K/L ratio and transportation cost in Electric Equipment

3 Model

Here, we introduce two factors of production, capital and labour, in the Helpman Melitz and Yeaple (2004) version of the Melitz (2003) model. Capital is a firm specific fixed cost to start up production. It is assumed that higher productivity is associated with a higher capital labour ratio, as documented by numerous empirical studies on micro data (see Bernard et al. 2007). We also allow the per unit transportation cost of a firm to depend on its capital labour ratio as well as on the total quantity shipped. This implies that the firms' export shares vary with the capital labour ratios in production.

3.1 Basics

There are two countries – home and foreign (denoted by *) – and two factors, physical capital and labour, amounting to L^W and K^W worldwide. Workers and capital can move freely between sectors but are immobile between countries. The home country is endowed with the share λ of the world endowment of labour L^W and capital K^W, that is, countries may be of different size, but they have identical capital labour ratios. A homogeneous good is produced, using labour only, in a constant-returns sector with perfect competition. Differentiated manufactures are produced with increasing-returns technologies using both capital and labour. There are m sectors of differentiated goods.

All individuals in a country have the utility function:

$$U = C_M^{\mu} C_A^{1-\mu}, \quad where \quad C_M = \prod_m C_m^{\theta_m}. \tag{1}$$

where C_A is consumption of the homogeneous good and C_M is consumption of an aggregate of differentiated goods, m is a sector index, $\mu \in (0, 1)$ and $\theta_m > 0$ are constants, and sector shares in consumption sum to one, $\sum \theta_m = 1$. Differentiated goods from each manufacturing sector enter the utility function through a sector-specific index C_m, defined by

$$C_m = \left[\int_{k \in \Psi} c_{km}^{(\sigma-1)/\sigma} dk \right]^{\sigma/(\sigma-1)}, \tag{2}$$

Ψ being the set of varieties consumed, c_{km} the amount of consumed variety k from sector m, and $\sigma > 1$ the elasticity of substitution.

Each consumer spends a share μ of his income on manufactures, and constant fractions θ_m of this are spent on varieties from each sector. Thus, it is possible to separately analyse the equilibrium for each sector. Total demand for a domestically produced variety i in a sector m is

$$x_{im} = \frac{p_i^{-\sigma}}{P^{1-\sigma}} \cdot \theta_m \mu Y, \tag{3}$$

where $P^{1-\sigma} = \int_{k \in \Psi} p_k^{1-\sigma} dk$ is the CES price index, p_k is the price of variety k, and Y is income in the country.

The unit factor requirement of the homogeneous good is one unit of labour. This good is freely traded, and since it is also chosen as the numeraire, we have

$$p_A = w = 1, \tag{4}$$

w being the wage of workers in all countries.

Ownership of capital is assumed to be fully internationally diversified; that is, if one country owns X-percent of the world capital stock, it will own X-percent of the capital in each country. The income of each country is

$$Y = \lambda(L^W + \pi K^W), \tag{5}$$

where π is average return to capital and λ the home country's share of world endowments. For simplicity, we will assume that π is given by an outside sector, which implies that income is given.[10]

Firms are differentiated, and their firm-specific marginal production costs a_i are distributed according to the cumulative distribution function $G(a)$. Here, it is also, in accordance with the data, assumed that firms with a lower labour input coefficient a also have a higher capital requirement.[11] There is a fixed entry cost f_E to find out the firm-specific marginal cost a. Thereafter, firms need to make a fixed capital investment $h(a)$ to start production. Finally, a fixed cost f_X is required if the firm chooses to export. The capital requirement for a firm in sector m with the labour input coefficient a is given by $h_m(a)$, which is a decreasing concave function in a. The cost function for firm i in sector m is

$$f_E + h_m(a_i)\pi + f_X + a_i x_i, \tag{6}$$

where π is the rental rate of capital, which is exogenously given by an outside sector.

Manufacturing goods (differentiated goods) are costly to transport. Transport costs, τ, depend on distance, t, but also on goods properties. E.g. parts and components may be easy to transport, whereas steel is not. We will allow transportation costs to be a function of the capital labour ratio of a firm, $h(a)$. However, this relationship is sector specific and we do not put any restrictions on it. It could be positive as well as negative. We also allow for scale economies in transportation so that the unit transportation cost may fall with the quantity exported, $\widetilde{x}$. That is, the transportation costs $\tau_{im} = \tau(h_m(a_i), t, \widetilde{x}_i)$, where $\frac{\partial \tau}{\partial h} \lesseqgtr 0$, $\frac{\partial \tau}{\partial d} > 0$, and $\frac{\partial \tau}{\partial \widetilde{x}} \leq 0$. These costs are of a frictional "iceberg" nature: for one unit of good from the home country to arrive in the foreign country, $\tau > 1$ units must be shipped. Transport costs between countries are also assumed to be equal in both directions.

Profit maximisation by manufacturing firms leads to a constant mark-up over the marginal cost, and the price in the domestic and foreign market is

$$p_i = \frac{\sigma}{\sigma - 1} a_i \text{ and } \quad p_{im} = \frac{\sigma}{\sigma - 1} \tau_{im} a_i, \tag{7}$$

respectively. Note that the export price will depend on the firm- and sector-specific transportation cost.

[10] We could, for instance, have a constant returns to scale sector with free trade that only uses capital as input.

[11] This is a standard finding among micro data studies. See e.g. Bernard et al. (2007).

3.2 Equilibrium

Firms in each sector draw labour input coefficients, a, from a cumulative density function, $G(a)$, after paying the entry cost f_E. The firm then decides whether to make a fixed investment in production capital $h(a)\pi$ to sell domestically and whether to invest another f_X in labour to sell abroad. For ease of notation we continue to suppress sector indices. The cutoff level of productivity at which a firm just breaks even from starting production for the domestic market is a_D and the cut-off productivity for an exporter is a_X : $a_i > a_D$ implies that firm i does not produce, $a_X < a_i < a_D$ that it produces for the domestic market only, and $a_i < a_X$ that firm i is an exporter. The conditions determining these cut-off productivities are

$$a_D^{1-\sigma} B = h(a_D)\pi, \tag{8}$$

$$\left(a_X \cdot \tau(h(a_X), t, \widetilde{x})\right)^{1-\sigma} B^* = f_X, \tag{9}$$

where $B \equiv \frac{\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\theta\mu Y}{\sigma P^{1-\sigma}}$ and $B^* \equiv \frac{\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\theta\mu Y^*}{\sigma P^{*1-\sigma}}$. Because firms in the two economies have identical technology and identical factor prices it must be that $B = B^*$ in equilibrium.[12] Note that the cut-off conditions are sector specific, since h and τ are sector- and firm-specific functions.

The model is closed by assuming free entry of firms. This implies the following equilibrium condition:

$$F_E = \lambda \int_0^{a_D} (a^{1-\sigma} B - h(a_i)\pi) dG(a) + \lambda \int_0^{a_X} \left((\tau a)^{1-\sigma} B^* - f_X\right) dG(a), \tag{10}$$

where $F_E = \delta f_E$, and δ is the constant Poisson probability of exit facing each firm.

Because $B = B^*$, we have identical cut-off productivity levels, a_D and a_X, in both countries. The three above equations determine a_D, a_X, and n. We make the assumption that $\pi > \frac{f_x}{\phi h}$, which ensures that exporters are more productive than non-exporters, $a_X < a_D$.

3.3 Parametrisation

To solve the model analytically, we here parametrise $h(a), G(a)$ and $\tau(a, t, \widetilde{x})$. We follow Helpman, Melitz and Yeaple (2004) and assume a Pareto probability density function:

$$G(a) = \left(\frac{a}{a_0}\right)^{\rho}, \tag{11}$$

where $\rho > 1$ is a shape parameter and a_0 is a scaling parameter. Without loss of generality we assume that $a_0 = 1$.

The functional form for the capital requirement, $h(a)$, is

$$h(a) = \frac{h_0}{a^{\varepsilon}}, \tag{12}$$

[12] This holds also if countries are of different size, see Helpman, Melitz and Yeaple (2004).

where h_0 and ε are sector-specific parameters. A higher ε implies that the capital intensity of a firm increases more in its productivity. Sector subscript are omitted.

Finally, firm-level transport costs are specified according to:

$$\tau(h(a), t, \widetilde{x}) = t \cdot h(a)^{\kappa} \cdot \widetilde{x}^{-\eta}. \tag{13}$$

Parameters κ and η are sector specific. They determinee the strength of the relation between transport costs and capital intensity and between transport costs and scale economy, respectively. Thus, transport costs depend on sector-specific parameters, but may also depend on the export volume and the capital intensity of the firm. The latter depends on the productivity of the firm according to (12). Note that we do not place any restriction on κ. However, we do assume that $\eta \geqslant 0$, which rules out negative scale economies in transportation. When $\kappa = \eta = 0$, transport costs are constant and identical for all firms, as in the standard Melitz model.

The firm-level transport cost can be rewritten using (3):

$$\tau = \Phi a^{\frac{\sigma\eta - \kappa\varepsilon}{1-\eta(\sigma-1)}}, \tag{14}$$

where $\Phi \equiv \left(t h_0^{\kappa} \left(\frac{\sigma}{\sigma-1} B \right)^{-\eta} \right)^{\frac{1}{1-\eta(\sigma-1)}}$.

3.4 Trade liberalisation

Even though trade liberalisation is not the central concern of this paper, we here first show that our model, under certain conditions, has many of the standard properties when trade is liberalised. Trade liberalisation can come either in the form of regulatory liberalisation (lower f_X) or lower trade/transport costs, t.[13] We analyse in this section for simplicity a small country case, where B is independent of f_X and t. Using the parametrisation (12) and (13) together with the cut-off conditions (8) and (9) give the relative cut-offs for non-exporters and exporters:

$$\frac{a_D^{\sigma-(1+\varepsilon)}}{a_X^{(\sigma-1)\left(1-\frac{\eta\sigma-\kappa\varepsilon}{1-\eta(\sigma-1)}\right)}} = \frac{\Phi^{\sigma-1} f_X}{h_0 \pi}. \tag{15}$$

Starting with regulatory liberalisation, lower market entry costs f_X, we can see from (15) that a sufficient condition for cut-offs to converge, is that $\left(1 - \frac{\eta\sigma-\kappa\varepsilon}{1-\eta(\sigma-1)}\right) > 0$ and that $\sigma - (1+\varepsilon) > 0$. Note that the standard result of converging cut-offs does not apply hold when η is very large, in which case transport costs have a strong tendency to fall in the productivity (size) of a firm. In this case, the advantage of the largest and most productive firms on the export market is strongly magnified by scale economies in transportation. Lower market entry costs (lower f_X) will affect the export of these firms so much that it crowds out some marginal exporters. A similar story holds for a very high σ that magnifies the advantages of the most productive firms.

[13] See Baldwin and Forslid (2010).

Next, a sufficient condition for convergence of the cut-offs, in the case of lower trade costs, t, is that $\left(1-\frac{\eta\sigma-\kappa\varepsilon}{1-\eta(\sigma-1)}\right)>0$, $\sigma-(1+\varepsilon)>0$ and $\frac{1}{1-\frac{1}{(\sigma-1)\eta}}>0$. Similar to the case of regulatory liberalisation, these conditions do not hold if scale economies in transportation η are very large, or when σ is very large. We do not require these conditions to hold in our calibration below.

3.5 Export shares

In this paper, we focus on firms' export shares. Using the demand equation (3), and that $B=B^*$, the export share of of firm i, s_i, is given by

$$s_i=\frac{\left(\tau\left(h(a),\widetilde{x}\right)\right)^{1-\sigma}}{1+\left(\tau\left(h(a),\widetilde{x}\right)\right)^{1-\sigma}}. \tag{16}$$

Note that when τ is identical for all firms, as in standard versions of the Melitz model, the export share $s_i=\frac{\tau^{1-\sigma}}{\frac{B}{B^*}+\tau^{1-\sigma}}$ is identical for all exporting firms in a country irrespective of their productivity. More productive firms export more, but their export sales increase in exact proportion to their domestic sales, keeping the export share constant.

After substituting for the transport cost in the parametrised function, we get

$$s_i=\frac{\left(\Phi h_i^{\frac{\sigma\eta-\kappa\varepsilon}{\varepsilon(\eta(\sigma-1)-1)}}\right)^{1-\sigma}}{1+\left(\Phi h_i^{\frac{\sigma\eta-\kappa\varepsilon}{\varepsilon(\eta(\sigma-1)-1)}}\right)^{1-\sigma}}, \tag{17}$$

where $\Phi=\left(th_0^{\frac{\sigma\eta}{\varepsilon}}\left(\sigma B\right)^{-\eta}\right)^{\frac{1}{1-\eta(\sigma-1)}}$. Note that substituting $\eta=\kappa=0$ gives the Melitz outcome, $s_i=\frac{t^{1-\sigma}}{1+t^{1-\sigma}}$.

The relationship between a firm's export share and its capital labour ratio is determined by the sign of $\frac{\partial s_i}{\partial h_i}$, which in turn is determined by the sign of $\frac{\sigma\eta-\kappa\varepsilon}{\varepsilon(\eta(\sigma-1)-1)}$ as seen from (17):

$$\frac{\partial s_i}{\partial h_i}\gtrless 0 \quad \text{when} \quad \frac{\sigma\eta-\kappa\varepsilon}{\varepsilon(\eta(\sigma-1)-1)}\lesseqgtr 0. \tag{18}$$

Higher κ or ε implies that a high capital labour ratio is associated with higher transport costs and a high capital labour ratio therefore tends to decrease the export share, $\frac{\partial s_i}{\partial h_i}<0$. When scale economies in transportation are very low (η close to zero), the effect of κ and ε dominates. However, for large enough η, scale economies in transportation dominates, which implies that high-productivity firms and firms with a high capital labour ratio have lower transportation costs and higher export shares.[14]

[14] For very high scale economies in transportation we actually get $\frac{\partial s_i}{\partial h_i}<0$ again. To rule out this case, we assume that $\eta<\max\left[\frac{\kappa\varepsilon}{\sigma},\frac{1}{\sigma-1}\right]$.

4 Calibration

4.1 Method

We calibrate the model to match the data on firm-level export shares in each sector. Using data for the firm-level capital labour ratio, we calibrate parameters $\kappa, \eta, \varepsilon$ and Φ to minimise the sum of squared deviations between s_i as defined by (17) and firm-level data on export sales to total sales.[15] We report calibrations for $\sigma = 4$ and $\sigma = 7$, which are common estimates of σ by studies using product level data (see e.g. Romalis 2007).[16]

The final step is to use the calibrated parameters to construct firm-level transportation costs using (14) and firm-level data on the capital labour ratio. The constructed transport costs are then compared to actual data on transport costs.

4.2 Results

We first calibrate the model to match firm-level export shares with data sector by sector. Sectors with less than five observations (firms) are omitted, as the standard deviation explodes. Four sectors produce nonsensical results, which leaves us with 48 calibrated sectors. Overall, 20 sectors display a clear positive relationship and 16 a clear negative relationship between a firm's capital intensity and its export share. The remaining sectors have a relatively flat calibrated relationship. There is a clear tendency for machinery sectors to display a positive relationship, whereas e.g. foodstuff, raw materials and metal industries have more sectors with a negative relationship, which is intuitive. Figure 6 shows the result of the calibration for the iron and steel sector (261) and the electrical equipment sector (301). The iron and steel sector, which has transport costs that increase in firm capital labour ratios, displays a negative relationship. The electrical equipment sector, where the association between transport costs and the firm level capital labour ratio is weaker, displays a positive relationship. Plots of the calibration results for all sectors are found in appendix 6.2.

[15] We use the genetic algorithm in matlab for the calibration.

[16] We have calibrated the model for other values of σ with very similar results.

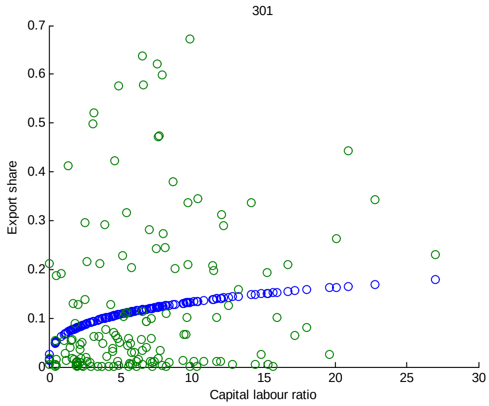


Figure 6a: Calibrated export shares, sector 301: Industrial electric apparatus

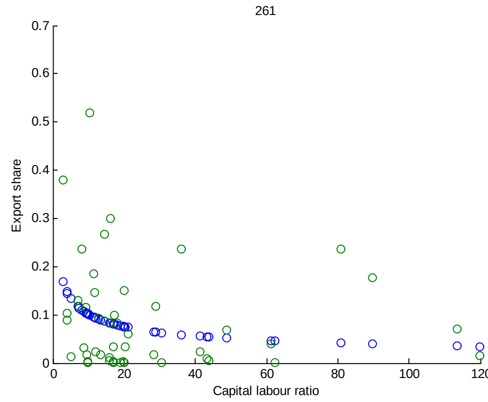


Figure 6b: Calibrated export shares, sector 261: Iron and steel

Tables A3 and A4 in Appendix display the calibrated values for parameters $\kappa, \eta, \varepsilon$, and Φ, for all sectors, the constructed sector-level average values for τ, and the standard deviations per sector for the estimated export shares. Transport costs constructed from the calibrated parameter values are large in some sectors, as shown in the tables. However, as suggested by the survey by Anderson and van Wincoop (2004), trade costs could be quite large.[17]

4.3 Comparing constructed and actual transport costs

As a final step, we feed the calibrated parameters into (14) and use data on the firm-level capital labour ratio to calculate firm-level transport costs. Thereafter, we compare actual firm-level transport costs to the constructed values. Table 3 shows an OLS-regression where constructed values are used to explain the variation in actual transport costs.[18] We also aggregate transport costs per sector and perform the same regression.[19] The correlations are positive and significant. The R-squared values in the table shows that the constructed transport costs explain about 40-50 percent of the variation in firm-level transport costs and some 45-60 percent when aggregated by sector.[20] Constructed transport costs increase in σ, and the fit of the model is somewhat better for the lower σ.

[17] They find that total trade costs in rich countries are about 170% when pushing the data very hard.

[18] We have data on firm-level transportation cost, but the data does not distinguish between domestic and international transports.

[19] The reported regression is on an unweighted sector mean, but weighing firms by e.g. export sales produces almost identical results.

[20] Two sectors with calibrated trade costs of several thousand percent are dropped in the case of σ.

Dependentvariable: Transport costs per sold unit	**Firm level**		**Sector level**	
	σ=4	**σ =7**	**σ =4**	**σ =7**
Calibrated transport cost	.015***	.029***	.0077***	.036***
t-value	(64.06)	(49.3)	(6.17)	(8.58)
R2	0.51	0.38	0.45	0.61
#obs	3976	3996	48	48

t-values are shown in parenthesis: *** indicate significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table 3: Comparing calibrated/constructed transport costs to actual transport costs

5 Conclusion

This paper starts out from the observation that the export shares of firms (export to sales ratio) vary greatly among firms, and tend to be systematically related to the firms' capital labour ratios. This observation cannot be explained by the Melitz model, which is one of the work horse models of trade with heterogeneous firms, since it predicts that all firms have identical trade shares. More productive firms export more, but the share of export to total production is constant.

In our model, we relate the difference in export shares to firm-level differences in transport costs. Two factors influence a firm's transport cost in our model. First, firm scale affect transportation costs, and we allow large firms to have lower transport costs e.g. because they get lower freight rates. Second, we allow for an association between the capital intensity of a firm and its transportation costs. We assume that this relationship is sector specific. Our model can generate the result that more productive and capital intensive firms have higher export shares due to scale economies in transportation, but also the opposite pattern that more capital intensive firms have lower export shares due to a strong positive association between capital labour ratio and transport costs.

We use Japanese manufacturing firm-level data on the firm-level capital labour ratio to calibrate our model by matching firm-level export shares to the data sector by sector. This results in sectors where firm export shares increase in the capital labour ratio and sectors where export shares decrease in firm capital ratios. Then, we use the calibrated parameters for each sector to compute the implied firm-level transport costs. This computed transport cost is then compared to actual data. Sector averages are also computed. Regressing the computed transport costs on actual data shows that the calibrated (calculated) numbers can explain some 40-50 percent of the variation in the data and some 50-60 percent in the case of transport costs aggregated at the sectoral level.

It has been well established in the previous empirical literature that exporters are more capital intensive than non-exporters, and the same is true in our dataset. This seems to suggest that promoting investment in capital is a way of strengthening a nation's exports. However, it is not generally the case that the capital share is positively related to the firm's export share when comparing among exporters in our data. The pattern instead varies strongly by sector, and subsidies to capital investments are therefore not necessarily a route to promoting export.

6 Appendix

6.1 The overall relationship between firms' capital labour ratio and their export share using quantile regressions

We here investigate the relationship between capital-labour ratio and export ratio for exporting firms using simultaneous quantile regressions. Table A1 shows the results for different quantiles when controlling for firm size (employment). There is a significant negative relationship in the lower 25 percent quantile as well as in the mean quantile. The upper 75 percent quantile is insignificant.[21] Table A2 shows quantile regressions of the data in Figure 4. The regressions confirm the impression that there is a positive relationship between the capital labour ratio of exporters and their total transport costs per sales.

Dependent variable: Exportshare	Q25	Q50	Q75
Capital labour ratio	-0.00010***	-0.00021**	0.00023
	(-3.90)	(-2.22)	(0.43)
Employment	5.61e-06***	0.000013***	0.0000175***
	(7.36)	(3.9)	(4.47)
nobs	4189	4189	4189

t-values are shown in parenthesis: *** indicate significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A1: Quantile regressions of the firm capital labour ratio on the export share

Dependent variable: Transport cost per sales	Q25	Q50	Q75
Capital labour ratio	0.00071*	0.00026***	0.00041***
	(1.86)	(6.25)	(5.16)
Nobs	4189	4189	4189

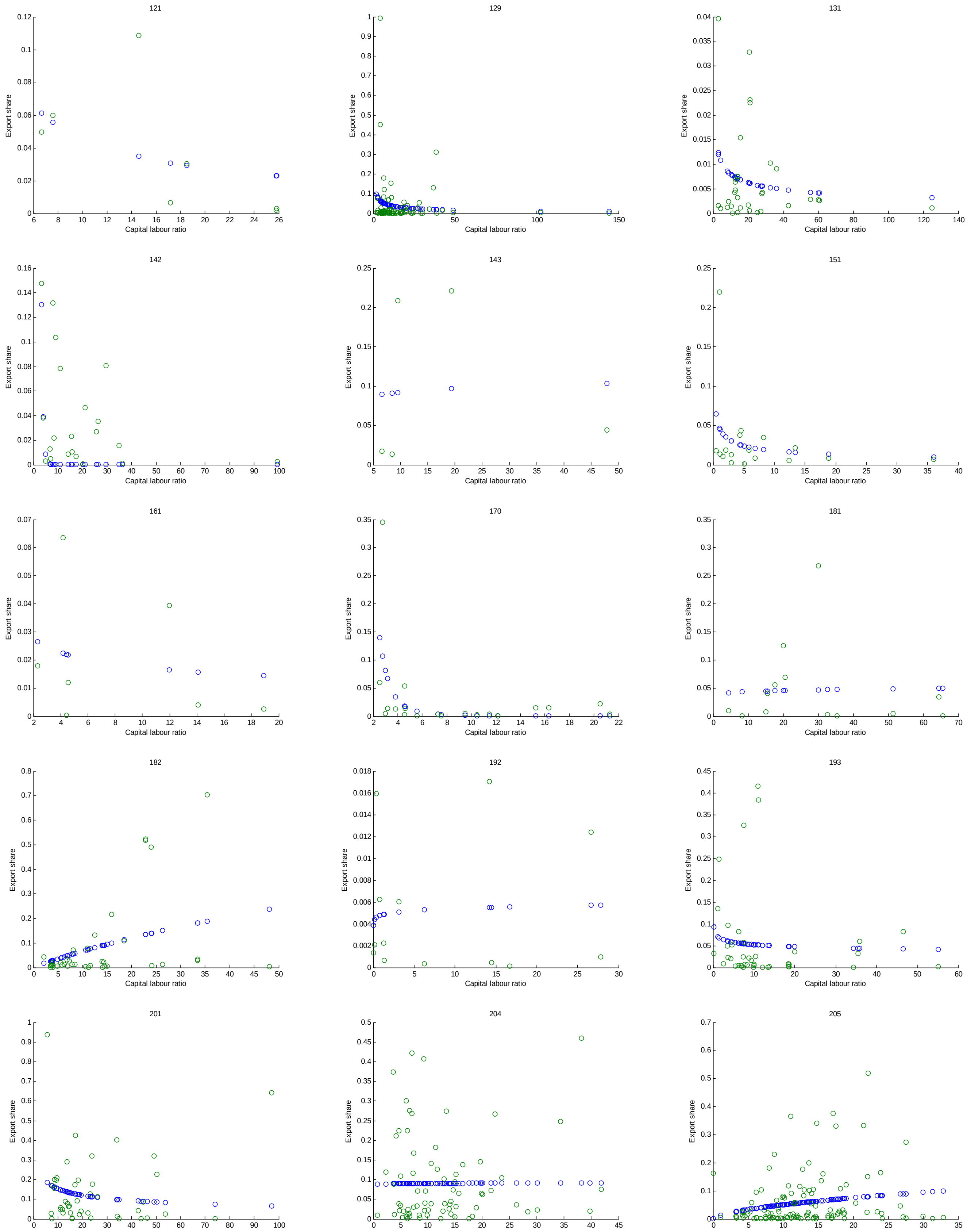
t-values are shown in parenthesis: *** indicate significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level.

Table A2: Quantile regressions of the firm capital labour ratio on the transport cost

6.2 Calibration plots

The figures below show the calibration results sector by sector.

[21] When dropping employment from this equation, the Q50 coefficient becomes insignificant. Regressions with more finely defined quantiles show the same pattern.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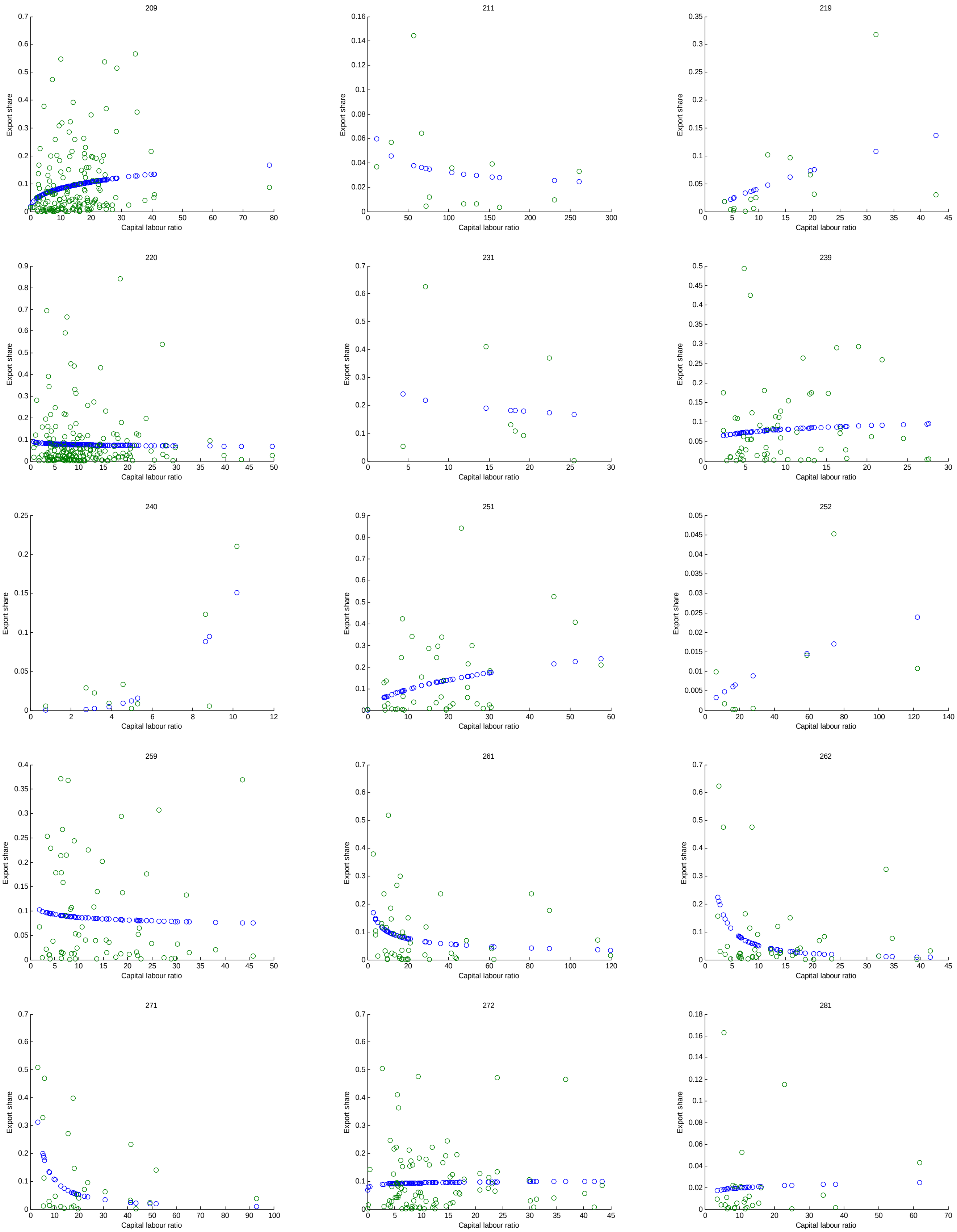
Export share
Capital labour ratio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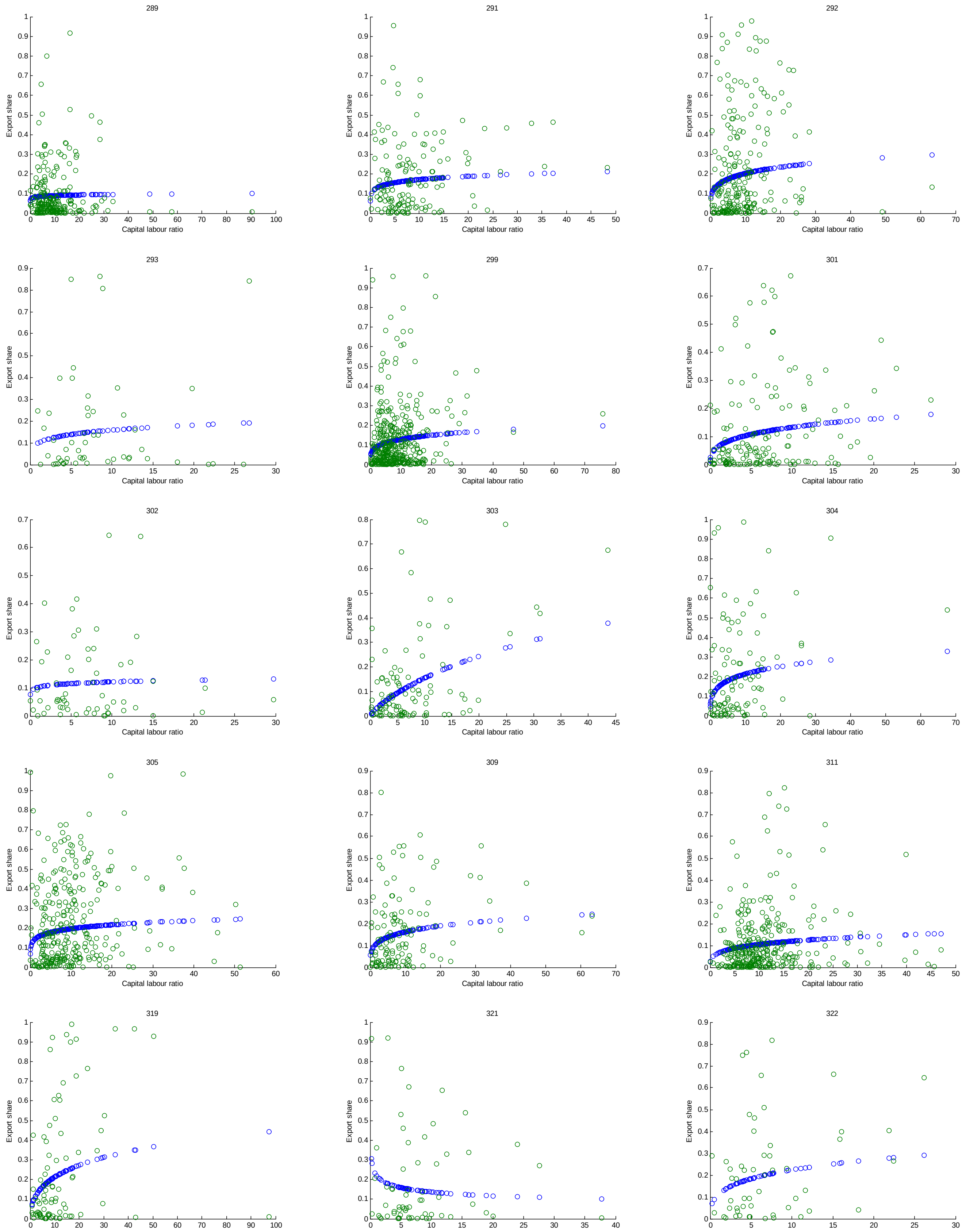
281
Export share
Capital labour ratio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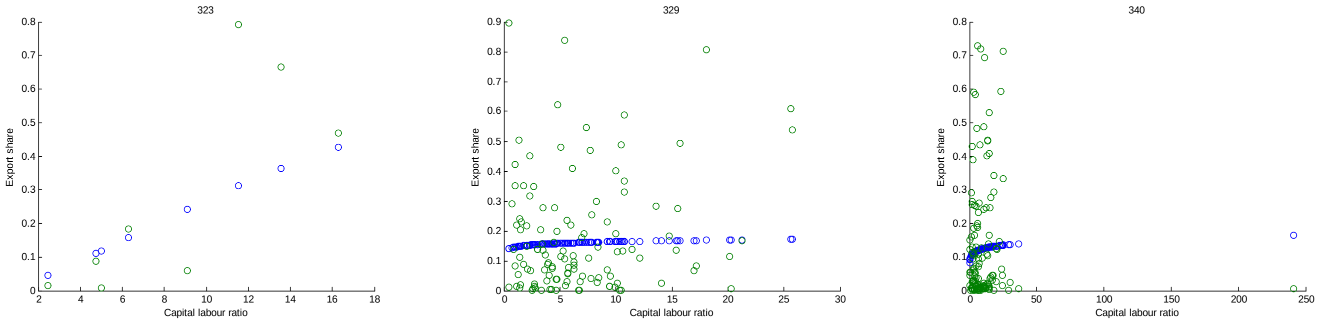
Export share
Capital labour ratio



6.3 Values of calibrated parameters

Tables A3 and A4 below displays calibrated parameter values by sector. It also displays the sector-level transport cost constructed from the calibrated values. The final two columns display standard deviation for the calibrations that could be compared to the calibrated export shares in the figures above.

sec	Obs	η	κ	ε	Φ	τ	st dev
121	7	1.077	1.489	2.098	1.535	2.057	2.374
129	76	0.007	0.220	0.728	1.866	1.959	2.235
131	33	1.599	1.479	3.309	3.789	4.378	5.007
142	21	3.248	1.598	3.839	1.794	2.123	2.252
143	5	1.336	2.452	2.257	2.288	1.126	1.151
151	17	0.063	0.559	0.572	2.706	2.407	2.712
152	8	1.033	0.454	1.025	2.202	37.737	63.174
161	7	2.609	3.178	2.709	3.060	2.704	2.676
170	19	1.003	1.015	1.133	0.566	8.247	12.465
181	13	2.114	2.571	3.456	2.954	1.747	1.694
182	39	0.801	2.817	1.348	4.978	1.473	0.955
192	13	0.023	0.141	0.587	5.918	4.832	4.738
193	41	0.199	0.765	1.065	2.349	1.605	1.763
201	44	1.662	- 0.222	1.100	0.067	11.766	15.271
204	73	0.902	1.517	2.389	2.179	1.161	1.156
205	114	0.148	0.497	0.970	4.206	1.639	1.544
209	166	1.344	3.074	2.002	2.988	1.208	1.123
211	13	0.877	1.896	1.706	1.977	2.077	2.196
219	14	2.875	4.554	5.000	5.616	1.842	1.812
220	195	0.062	0.084	3.803	2.190	1.304	1.330
231	8	0.187	1.036	0.749	1.292	0.623	0.650
239	61	0.326	0.938	1.389	2.336	1.241	1.232
240	10	0.109	0.212	0.630	9.720	3.014	3.642
251	42	0.048	0.037	0.888	3.418	1.122	0.718
252	8	0.252	0.602	1.579	7.350	3.525	3.031
259	65	2.341	2.972	2.940	2.019	1.199	1.193
261	48	2.976	2.187	3.502	1.456	1.287	1.479
262	44	0.711	0.955	2.007	1.037	1.843	1.999
271	28	1.850	1.733	2.145	0.849	1.552	2.402
272	91	0.113	0.250	1.728	2.199	1.122	1.113
281	27	2.525	3.577	3.061	4.059	2.665	2.700
289	228	0.033	0.523	0.244	2.254	1.164	1.143
291	146	0.136	0.440	1.149	1.906	0.725	0.682
292	223	1.453	1.992	3.450	1.950	0.634	0.568
293	53	0.992	1.905	2.264	2.083	0.808	0.725
299	383	1.124	2.629	1.854	2.306	0.969	0.887
301	153	0.185	0.567	1.193	2.427	1.059	0.877
302	60	0.119	0.541	0.850	2.061	0.972	0.943
303	99	0.059	0.206	0.546	3.288	1.210	0.736
304	103	0.209	0.914	0.879	1.962	0.669	0.572
305	300	0.048	0.143	0.995	1.816	0.615	0.570
309	128	2.052	4.340	2.120	2.130	0.814	0.714
311	311	0.077	0.832	0.340	2.544	1.062	0.953
319	87	0.075	0.633	0.395	2.228	0.607	0.484
321	63	0.721	1.047	2.514	1.518	0.771	0.843
322	53	1.086	2.060	2.433	2.001	0.641	0.553
323	8	0.699	1.558	2.729	4.277	0.693	0.295
329	120	0.063	0.262	0.909	1.801	0.746	0.733
340	137	0.010	0.093	0.300	2.074	0.945	0.920

Table A3: Calibrated values and constructed transport costs (sigma=4)

sec	Obs	η	κ	ε	Φ	τ	st dev
121	7	0.401	1.440	1.739	1.247	0.749	0.049
129	76	0.309	0.979	2.049	1.374	0.719	0.132
131	33	1.223	3.592	2.156	1.948	1.318	0.010
142	21	0.533	1.374	2.337	1.346	0.765	0.044
143	5	1.813	3.307	4.001	1.518	0.465	0.210
151	17	1.429	2.561	3.212	1.650	0.843	0.054
152	8	1.902	0.796	1.400	1.491	4.215	0.097
161	7	0.604	2.049	1.943	1.753	0.926	0.032
170	19	2.278	1.467	1.720	0.766	1.770	0.071
181	13	0.943	1.468	4.667	1.722	0.662	0.087
182	39	0.583	2.850	1.652	2.218	0.566	0.161
192	13	0.051	0.329	1.055	2.434	1.416	0.007
193	41	0.755	2.606	1.965	1.539	0.618	0.106
201	44	3.075	2.506	1.265	0.242	2.354	0.199
204	73	0.465	2.721	1.197	1.483	0.477	0.115
205	114	1.505	2.919	4.950	2.049	0.623	0.094
209	166	0.099	0.566	1.164	1.731	0.490	0.119
211	13	0.857	2.106	2.600	1.413	0.756	0.043
219	14	0.902	2.675	3.102	2.360	0.681	0.081
220	195	0.017	0.410	0.299	1.486	0.524	0.130
231	8	0.773	1.789	2.788	1.150	0.284	0.290
239	61	0.566	1.779	2.316	1.601	0.510	0.106
240	10	0.714	4.138	4.177	10.541	2.657	0.047
251	42	1.196	2.527	4.430	1.847	0.439	0.176
252	8	1.339	3.074	4.122	3.210	1.213	0.017
259	65	0.380	1.510	1.736	1.428	0.489	0.109
261	48	0.009	0.166	0.663	1.216	0.515	0.112
262	44	0.741	1.015	3.047	1.031	0.672	0.133
271	28	0.043	0.405	1.121	0.936	0.584	0.140
272	91	0.043	0.499	0.599	1.490	0.464	0.117
281	27	0.077	0.615	0.855	2.016	0.917	0.039
289	228	1.203	2.733	3.152	1.507	0.478	0.138
291	146	0.689	1.661	3.060	1.389	0.322	0.183
292	223	0.101	0.704	0.980	1.403	0.287	0.255
293	53	1.328	3.504	2.866	1.450	0.353	0.237
299	383	0.015	0.381	0.248	1.524	0.410	0.163
301	153	0.040	0.380	0.660	1.563	0.438	0.158
302	60	0.042	0.560	0.510	1.443	0.412	0.152
303	99	0.425	1.324	2.657	1.811	0.476	0.176
304	103	1.128	2.202	4.132	1.409	0.299	0.247
305	300	0.094	0.613	1.050	1.356	0.280	0.219
309	128	0.087	0.934	0.638	1.466	0.354	0.165
311	311	0.061	0.646	0.636	1.599	0.442	0.143
319	87	0.365	0.761	3.805	1.495	0.274	0.292
321	63	0.050	0.148	2.949	1.243	0.339	0.241
322	53	1.187	2.415	4.047	1.421	0.289	0.230
323	8	0.367	1.819	1.670	2.046	0.296	0.315
329	120	0.558	1.510	2.627	1.351	0.331	0.194
340	137	0.108	0.256	2.883	1.447	0.402	0.180

Table A4: Calibrated values and constructed transport costs (sigma=7)

6.4 Sector code and basic statistic

Code	Sector name	Obs	K/L	export per sales	transport cost per sales	emp
121	Livestock products	7	16.60	0.03709	0.04611	1566.57
122	Seafood products	17	9.13	0.02670	0.03319	356.06
123	Flour and grain mill products	4	28.27	0.00582	0.04836	421.50
129	Miscellaneous foods and related products	76	16.64	0.04345	0.04118	680.13
131	Soft drinks, carbonated water, alcoholic, tea and tobacco	33	24.67	0.00680	0.03640	1118.70
132	Prepared animal foods and organic fertilizers	4	20.07	0.00351	0.04937	332.75
141	Silk reeling plants and spinning mills	2	25.33	0.00881	0.02017	377.00
142	Oven fabric mills and knit fabrics mills	21	19.94	0.03809	0.01951	651.05
143	Dyed and finished textiles	5	18.39	0.10097	0.03286	421.60
149	Miscellaneous textile mill products	34	11.20	0.07673	0.02336	212.44
151	Textile and knitted garments	17	7.54	0.02836	0.01921	497.35
152	Other textile apparel and accessories	8	4.66	0.05999	0.02884	210.50
161	Sawing, planing mills and plywood products	7	8.64	0.01998	0.03757	320.57
169	Miscellaneous manufacture of wood products, including bamboo and rattan	3	5.59	0.01323	0.02492	242.67
170	Manufacture of furniture and fixtures	19	8.75	0.03026	0.03723	667.53
181	Pulp and paper	13	29.33	0.04740	0.04220	1811.85
182	Paper woked products	39	13.60	0.08307	0.03401	363.74
191	Newspaper industries	2	8.22	0.01808	0.09213	173.00
192	Publishing industry	13	8.71	0.00506	0.07008	445.38
193	Printing and allied industries	41	12.78	0.05602	0.02284	963.51
201	Chemical fertilizers and industrial inorganic chemicals	44	24.62	0.14074	0.04486	405.89
202	Industrial organic chemicals and chemical fibers	118	23.77	0.12479	0.03153	979.69
204	Oil and fat products, soaps, synthetic detergents, surface-active agents and paints	73	12.77	0.09610	0.03592	436.45
205	Drugs and medicines	114	13.18	0.06023	0.01235	1199.10
209	Miscellaneous chemical and allied products	166	14.33	0.09560	0.02670	487.78
211	Petroleum refining	13	113.81	0.03477	0.01039	1214.62
219	Miscellaneous petroleum and coal products	14	13.97	0.05185	0.04496	131.00
220	Plastic products, except otherwise classified	195	10.92	0.07968	0.03237	321.20
231	Tires and inner tubes	8	16.14	0.22359	0.03730	3731.88
239	Miscellaneous rubber products	61	9.78	0.08455	0.02623	354.61
240	Manufacture of leather tanning, leather products and fur skins	10	5.31	0.04493	0.01863	172.00
251	Glass and its products	42	18.17	0.14240	0.04798	647.98
252	Cement and its products	8	41.98	0.01032	0.09718	919.38
259	Miscellaneous ceramic, stone and clay products	65	14.57	0.09153	0.03263	654.43
261	Iron and steel	48	26.49	0.09115	0.03762	845.15
262	Miscellaneous iron and steel	44	13.70	0.07921	0.03005	310.23
271	Smelting and refining of non-ferrous metals	28	22.45	0.11278	0.01918	684.61
272	Non-ferrous metals worked products	91	12.54	0.10148	0.02224	664.52
281	Fabricated constructional and architectural metal products, including fabricated plate work and sheet metal work	27	14.50	0.02023	0.03384	1128.00
289	Miscellaneous fabricated metal products	228	10.39	0.09586	0.02648	267.72
291	Metal working machinery	146	8.70	0.18899	0.01716	286.16
292	Special industry machinery	223	9.37	0.22328	0.01744	410.10
293	Office, service industry and household machines	53	8.30	0.16487	0.01585	1469.74
299	Miscellaneous machinery and machine parts	383	8.64	0.12987	0.01688	382.80
301	Industrial electric apparatus	153	6.60	0.12147	0.01639	787.59
302	Household electric appliances	60	7.27	0.12628	0.01956	1281.10
303	Communication equipment and related products	99	7.70	0.14077	0.01284	2048.72
304	Electronic data processing machines, digital and analog computer, equipment and accessories	103	8.39	0.22493	0.01117	1492.75
305	Electronic parts and devices	300	10.25	0.22991	0.01378	549.05
309	Miscellaneous electrical machinery equipment and supplies	128	9.57	0.16824	0.01321	426.49
311	Motor vehicles, parts and accessories	311	11.10	0.11263	0.02074	1799.35
319	Miscellaneous transportation equipment	87	12.39	0.24868	0.01473	684.98
321	Medical instruments and apparatus	63	8.08	0.18143	0.01457	392.25
322	Optical instruments and lenses	53	7.21	0.22803	0.00999	526.51
323	Watches, clocks, clockwork-operated devices and parts	8	8.63	0.28535	0.01540	1032.88
329	Miscellaneous precision instruments and machinery	120	6.73	0.17950	0.01247	320.94
340	Miscellaneous manufacturing industries	137	10.77	0.13154	0.01877	395.45
Total		4189	11.81	0.13304	0.02206	707.63
	Note: The basic statistic is exporters only. Obs is the number of exporters.					

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