Lecture 6: Empirics, the Extensive Margin and Firm Level Heterogeneity in Productivity

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Econ 357 - **International Trade (Ph.D.)**

1 Introduction

We have seen in the previous lectures several models of international trade that take into account some measure of heterogeneity. On the one hand, heterogeneity in preferences, as captured by the CES/monopolistic model of Krugman and all models with preferences over differentiated goods (or differentiated industries). On the other hand, heterogeneity in technology, as captured by the Melitz/Chaney models, or the Eaton and Kortum/BEJK models.

There are several predictions that arise from these models. First, from the welfare point of view, heterogeneity matters. If consumers do value variety in some way or another, then opening up to trade, by allowing to consume a wider range of goods, will enhance welfare, above and beyond the fact that opening up to trade reduces the cost of imported goods. Second, from the technological point of view, opening up to trade will modify the set of goods that are traded (the extensive margin of trade), and will potentially have an important on aggregate productivity through reallocation of the factors of production.

What are the evidence in support of these theoretical models?

We will see with Eaton, Kortum and Kramarz (2005) that the simplest monopolistic competition model with heterogeneity in productivity (and maybe with some added heterogeneity in trade barriers) is able to fit the firm level data very tightly. We will see then that the extensive margin of trade plays an important role in explaining variations in aggregate trade volumes. Helpman, Melitz and Rubinstein (2004) use the zeros in the trade matrices to infer some measure of country specific fixed cost of entry, and improve on the existing gravity equation estimates. Broda and Weinstein (2005) develop a careful methodology, and a large dataset on finely disaggregated trade data, to estimate the relevant demand elasticities parameters necessary to infer the welfare gains from the increased variety of US imports. Looking also at very fine product categories, Hummels and Klenow (2004) argue that the extensive margin of trade (as well as differences in the quality of imports) accounts for most of the variations in aggregate trade flows. As for the evidence of the impact of trade opening on the reallocation of inputs between firms, and the importance of productivity heterogeneity, we will study the work of Pavcnik (2002) on Chilean firms.

Let us start with a series of stylized facts on firms that engage in international trade activities, mainly from Bernard, Jensen and Schott (2005).

Bernard, Jensen and Schott (2005)

Bernard, Jensen and Schott (2005) describe some characteristics of US exporters using Census data. They have access to firm level data. They know for a wide range of US firms how much they sell, what type of products they sell, to which country (and they know some of the characteristics of these countries), the concentration of trade among firms (meaning that they know both about exporters and non exporters), what kind of international transaction they undertake, whether at arms length of with related parties, and whether those exporters are also importers.

The most striking feature of the data is heterogeneity: less than 20% of US firms trade, but the employ 40% of workers outside of government and education. Most trade is concentrated among a small group of firms. The top 1% of trading firms accounts for 81% of US trade. Most trading firms trade few products, with few high income countries, but the small number of firms that trade many different products employ a large number of workers. Over time (1993 to 2000), both the number of products being traded and the number of trading partners has increased though. More than 50% of trading US firms both import and export, and those firms account for 90% of total trade. Firms that are even more "globally engaged", i.e. firms that import, export, and do at least one of the two with related parties (multinationals in other terms) account for 80% of total US exports and imports, and employ 18% of the US civilian workforce. These multinationals are more likely to export and import from low income countries (typically less popular markets). Over time, these firms increase imports and exports, and they increase their share of intra-firm trade with low-income countries, and increase their share of arms length trade with high-income countries.

Even in tradable sectors, non exporters are the majority. Non exporters are an order of magnitude smaller than exporters: US exporters sell domestically on average 4.8 times more than non exporters. They are more productive (33% higher labor productivity), more capital intensive, pay higher wages, use more technology, employ more skilled workers, and have a higher TFP than non exporters. Similar evidence exists ouside the US: Bernard and Wagner (1997) for Germany, Clerides; Lach and Tybout (1998) for Colombia, Mexico and Morocco; Aw, Chung abd Roberts (2000) for Korea and Taiwan; Delgado, Farinas and Ruano (2002) for Spain... and many others. Multinational firms account for a larger and larger fraction of the workforce. Between 1993 and 2000, US employment by US multinational rose from 17.5 million to 23.9 million, and US employment of US affiliates of foreign parents rose from 3.9 million to 5.4 million.

2 Testing the Heterogeneous Firms model

If we have access to firm level trade data, we can hope to test the model with heterogeneous firms. We can both estimate the fit of the different versions of this model, and calibrate the different parameters that are relevant, which will allow us to perform some counterfactuals analysis. We have seen that there is a whole range of possible combinations of perferences, market structures, firm heterogeneity, and trade barriers.

1. Krugman uses CES preferences, monopolistic competition, identical firms, and variable trade barriers.

2. Melitz/Chaney use CES preferences, monopolistic competition, heterogeneous firms (with Pareto distributed productivity), and variable and fixed trade barriers.

3. Eaton and Kortum/BEJK use CES preferences, perfect competition (EK) or Bertrand competition (BEJK), heterogeneous firms (with Fréchet distributed productivity), and variable trade barriers.

4. Melitz and Ottaviano use non CES preferences (with bounded marginal utility for each good), monopolistic competition, heterogeneous firms (with Pareto distributed productivity shocks), and variable trade barriers.

All these models give similar qualitative predictions for the selection of firms into the export market (they all have an important extensive margin of trade). However, they give different quantitative predictions for several patterns of the distribution of firms. They also give different predictions for the impact of trade on prices. They are more or less easy to work with, and more or less easy to amend.

We will see in Eaton, Kortum and Kramarz (2005) which model can get the closest to the actual firm level data. As a preview, we will see that the monopolistic model with fixed and variable trade barriers per country (as in Chaney) gets a very good fit of the data. Amending this model to allow for some heterogeneity in the costs that different firms face can get us even closer to the actual data.

2.1 Eaton, Kortum and Kramarz (2005)

- Eaton, Kortum and Kramarz (2005) use a unique dataset on firm level trade to calibrate a model of international trade with heterogeneous firms.

- They develop a generic model, of which Ricardian trade (à la Eaton and Kortum) or monopolistic trade (à la Melitz/Chaney) are special cases. To do so, they introduce the range of possible goods as a parameter of the model. When the range of goods is small, it is likely that several firms will compete in producing each good, and we get to the EK case. If the range of goods is large, it is very unlikely that two firms will compete to produce the same good, and we converge to the monopolistic case.

- They bring this model to the data, estimate the different relevant parameters using the simulated method of moments, and compare the fit of different versions of the model.

Data:

- EKK use firm level data on sales of manufacturing French firms, in 1986. This amounts to 234,000 firms, selling to 113 markets (including France). They drop export to smaller destinations. For each of these firms, on top of balance sheet data, and employment data (not used in this paper), they know how much of what good each of these firms sells to which market. This destination dimension of the data is almost unique. This micro dataset accounts for

- Bernard, Jensen and Schott (2005) have recently put together a similar dataset for US exporters and importers, using data from the US customs (for imports) and data from the US Census (for exports). In addition, BJS also know about the type of relationship between the buyer and the seller (whether it's an arms length transaction between 2 independent entities, or intra-firm transation between 2 related entities).

Where do Eaton and Kortum or BEJK fail?

If there aren't any fixed costs of entering foreign markets, the in the Eaton and Kortum model (or BEJK), the average size of sales of firms from i in country n will simply be proportional to the size of market n. In the Metliz/Chaney model with fixed cost on the other hand, the average sales in n of firms from i is proportional to the fixed cost of entering market n. It does not depend on the size of market n, or the variable cost towards market n. Why:

- When the size of n increases, each exporter (from i) increases its sales. This drives up the observed average sales of exporters.
- At the same time, if the size of n increases, and the fixed cost remains constant, it becomes easier to enter in n. Some low productivity firms from i start exporting. These guys are (by construction) smaller than the existing exporters. This drives the observed average sales of exporters down.
- In the case of Pareto distributed productivity shocks, these two effects exactly cancel out.

In the data on French firms, the average size of French exports to any market is pretty flat. More importantly, this average size is almost not correlated with the size of the destination market. So the data strongly reject the model without fixed costs.

Where do Melitz/Chaney fail?

The Melitz and Chaney's model of monopolistic competition with fixed costs of entry and Pareto distributed productivity shocks fail in two dimensions.

First, there is not a perfect hierarchy of markets, as these models would predict. That is, in the strict version of these models, markets should be ranked in a strictly increasing order of accessibility (which depends on market size and trade barriers). A firm that enters less accessible markets should always enter more accessible markets. This pattern is violated in the data at the firm level. A quick fix is to assume some firm level random demand shocks, and firm level random shocks to fixed trade barriers.

The second issue is that the distribution of the sales of firms in any market does not follow a Pareto distribution, except in the upper tail. That is, there are "too few" low productivity firms. EKK fix this problem by moving away from the Melitz/Chaney framework, and allowing more than one firm in producing each differentiated variety. I don't have a clear explanation of why this fixes the problem though...

Calibrations and simulations:

- EKK calibrate a generalized version of EK. EK, as well as Chaney (2006), are (asymptotically) special cases. The new assumption they add to the EK set-up is that there are a fixed costs of entering any market n, and this entry cost varies between country n, and it varies (in a radom way) between goods. They also assume that each good faces some random demand shock. Chaney corresponds to the case where there is only one supplier of each good per country (it is a monopolist for that good), and no demand shock; EK correspond to the case where this fixed cost is zero.

- They only have data on French sellers, not on other sellers from other countries. So they must infer from the data the number of sellers in each market. The model predicts that the fraction of sellers from i ($i =$France) in market n is the same as the fraction of income that n consumers spend on imports from i. From this, they get the total number of sellers in any market n, J_n, as a function of the number of French sellers in n, J_{in} ($i =$France), and the French market share in market n, π_{in},

$$J_n = \frac{J_{in}}{\pi_{in}}$$

- EKK use the relationship between the average sales of French firms selling to k or more markets and k to infer the ratio of the elasticity of substitution between goods (σ), and the dispersion of producvitiy shocks (θ parameter in the Pareto, or in the Fréchet),

$$\tilde{\theta} = \frac{\sigma}{\theta - 1} \approx 1.5$$

  The prediction for the relationship between the domestic size of firms and the number of countries it enters predicted by Chaney very tightly fits the data.

- The simple (almost) monopolistic case is also an easy benchmark in which to estimate the size of trade barriers. We've seen over and over again that gross profits are simply proportional to sales, with a coefficient of proportionality of $1/\sigma$. With the Pareto distribution assumption, we can come with a simple estimate of the entry cost into market n. The fixed cost of entering market n, E_n, satisfies,

$$\sigma E_n = \left(1 - \frac{1}{\tilde{\theta}}\right) E\left[x_{Fn}\right]$$

where $E\left[x_{Fn}\right]$ is the average size of French ex[ports in market n.

- EKK find that entry costs are (mildly) larger in larger countries. Entry costs range between \$10,000 and less than \$1 million.

- From this estimate of the entry cost in different markets, we can derive one of the components of the price index. EKK estimate that a doubling of a country's size will increase of welfare (reduction in the ideal price index) of .046% due to an increased variety of goods. Welfare is not very responsive to changes in country size in this kind of models with heterogeneous firms with a dispersed distribution of firm size. The reason is the following: the most productive firms can easily enter any market, including the smallest one. So consumers even in the smallest countries have access to those goods produced by the most productive firms. Those are the goods that contribute most to welfare (they are the cheapest). Increasing country size will increase the range of varieties available, but mostly through the entry of more expensive goods produced by less productive firms, which do not contribute to welfare much.

- However, one of the predictions of the simpler Chaney model is that we should observe a strict hierarchy of markets: markets are ordered by how costly they are to reach for French firms, and any firm that enters the k-th most popular market should also reach each of the $k-1$ more popular markets. This strict ordering of popularity is not observed in the data, even though we are not that far from it. Only 27% of French firms follow the order of the 7 most popular destinations for French firms. This number is far from 100%, it is also far from 5.5%, which would be the case if popularity of markets were just random.

- To match the ordering of markets better, EKK calibrate a richer version of the model. They use the simulated method of moments. They calibrate some parameters, randomly generate an economy for different values of the parameters of interest, and keep the configuration of those parameters that generate the economy that is the closest to the actual economy.

- **Calibrated parameters:** EKK calibrate systematic differences in productivity scaled by variable trade barriers from actual trade shares,

$$\frac{T_i \left(\tau_{in} w_i\right)^{\theta}}{\Phi_n} = \pi_{in}$$

- **Simulated method of moments:** EKK then estimate the following parameters,

$$\Theta = \left(\underbrace{\tilde{\theta}}_{\substack{\text{heterogeneity} \\ \text{parameters: } \frac{\sigma}{\theta - 1}}}, \underbrace{J}_{\substack{\text{number} \\ \text{of goods}}}, \underbrace{\phi, \gamma}_{\substack{\text{entry cost} \\ \text{parameters}}}, \underbrace{\sigma_a^2, \sigma_h^2, \rho}_{\substack{\text{entry cost and} \\ \text{demand parameters}}} \right)$$

  They match the following moments economy simulated using those parameters to the equivalent moments of the actual economy

  1. Number of French firms entering each 113 markets
  2. Fraction of firms selling the amount sold by the actual 5th percentile of sales in each country.
  3. Fraction of firms selling the amount sold by the actual 75th percentile of sales in each country.
  4. Fraction of firms selling the amount sold by the actual 95th percentile of sales in each country.
  5. Number of firms selling to k or more markets.
  6. Average sales in France of firms selling to k or more markets.
  7. Number of firms selling to subsets of the 7 most popular markets.

- The simulated economy (with the best estimated parameters) matches very closely the actual popularity of markets. Among others, as in the data, there are exactly 27% of French firms that sell to the 7 most popular markets according to the proper hierachy of these markets for all French firms.

- The fixed entry cost into different markets also allows them to better match the skewness of the distribution of domestic sales in the upper tail of the distributions: there are fewer very large firms than the simpler Pareto case would predict.

2.2 Ostrovsky (2005)

- The idea of having trade barriers varying between firm has been developped in a more systematic way by Ostrovsky (2005). He argues that in some markets like many fungible commodities, it is hard to justify a large degree of differentiation between goods. He proposes a model of international trade where firms are identical, products are very homogenous, but different firms face different trade barriers.

- He applies the model to international trade flows in the global steel supply chain (iron ore suppliers, iron and steel crap suppliers, steel producers and steel consumers).

- Such a model with heterogeneous trade barriers is better able to replicate the observed trade data. Most importantly, it can easily explain the large number of zeros in the trade data. Even if goods have some degree of differentiation, with random trade barriers, most countries will import only from a subset of suppliers who face relatively low trade barriers. He calibrates the standard deviation of those trade barriers shocks. He gets plausibly small standard deviations for these shocks, of about 12% of average trade barriers.

- For a market such as the global steel supply chain, if one were to calibrate a simple model of trade with differentiated goods (but homogeneous firms), one would need implausibly large elasticities of substitution. Moreover, even with such a calibrated elasticity, the model would still predict that all countries trade with one another.

- Heterogeneity in trade barriers is an alternative, or rather a complementary, explanation for the observed patterns of international trade.

3 The Extensive Margin of Trade

Most of the models we have seen so far leave a large role for the extensive margin of trade in determining bilateral trade flows. In the original Krugman (1980) model, opening up to trade does not change the sectoral composition of consumption. Welfare increases only through an increase in the number of different varieties of goods available. In Melitz (2003) and in Chaney (2006), the existence of fixed trade barriers and heterogeneity in productivity implies that only a subset of firms (varieties) actually trade internationally. Even for less extreme movements of trade barriers than going from autarky to trade, the number of firms exporting varies. In Eaton and Kortum (2002), BEJK (2004), or Melitz and Ottaviano (2004), heterogeneity in productivity, even in the absence of fixed trade barriers, leads to an endogenous selection of firms into the export market. EKK describes the large variations in the number of French firms selling in different markets. Ostrovsky derives a model with heterogeneous trade barriers to account for the existence of many zeros in the trade matrices. In all those models, some underlying heterogeneity between firms (or sectors) implies that not all firms/countries trade with all countries in the world.

We will see now a few papers that describe empirically the importance of the extensive margin of trade. Helpman, Melitz and Rubinstein (2004) build a model very similar to Chaney (2006) in order to use the information carried in the zeros in the trade data to infer some estimate of the fixed barriers of entering different countries. Broda and Weinstein (2005), using detailed price and quantity data on US exports from many countries over time estimate the elasticity parameter of a generalized CES utility, in order to estimate the welfare gain from the increased variety of goods accessible to US consumers over time. Hummels and Klenow (2005) describe the increase in varieties that contributes to a large part of the increase in global trade.

3.1 Helpman, Melitz and Rubinstein (2004)

- Many countries trade with only a subset of other countries. Large countries typically export to most places, and import goods from most places, but smaller countries tend to both specialize into exporting to a small subset of countries, and importing from a small subset of countries as well. Note that if one were to disaggregate trade data at the sectoral level (like Ostrovsky does for the steel supply chain), one would find even more zeros in the trade data.

- Helpman, Melitz and Rubinstein (2004) this interesting pattern of the data to calibrate of model à la Melitz and infer some measure of fixed trade barriers from bilateral trade flows data, and improve on the gravity equation type regressions.

- They build a generalized version of the Melitz model similar to Chaney (2006). Like in Chaney (2006), there are potentially many asymetric countries, with country pair specific fixed and variable trade barriers (f_{ij}, τ_{ij}).

- In addition to the Melitz model, they assume that productivity shocks are drawn from a bounded distribution. In the Melitz model with unbounded productivity shocks, no matter how large trade barriers are, there is always a subset of firms that is productive enough so that it can overcome such high barriers. Therefore, taken litterally, such a model cannot account for the existence of zeros in the bilateral trade matrices. Once we introduce bounds on the distribution of productivity shocks, it is possible that for large enough trade barriers, no firm is able to export.

- They use this property of the model to infer information on fixed trade barriers between countries from the existence of zeros in bilateral trade barriers. Such an estimation allows them to improve on gravity type regressions, by correcting for some selection bias (zeros were treated as missing variables in traditional gravity estimations).

3.2 Broda and Weinstein (2005)

The original Krugman (1980) paper based on Dixit-Stiglitz preferences that are used in all the models we have studied so far (with the exception of Melitz and Ottaviano) predicts that an increase in the number of varieties accessible to consumers should increase their welfare, even if the prices of these varieties remain constant. Furthermore, most of the models we have studied predict that a gradual reduction in trade barriers (let alone more radical moves from autarky to some degree of openness) should gradually increase the number of varieties accessible to consumers. This is what we have labelled the extensive margin of trade: as trade barriers go down, more firms are able to start exporting, and the number of varieties traded worldwide (and hence consumed in any given country) increases. Beyond the positive impact of reducing the price of existing exports, a fall of trade barriers should further increase welfare by increasing the range of goods available.

In the context of Dixit-Stiglitz CES preferences, this is very easy to see. The indirect utility of agents is simply the inverse of the price index. If fixed and variabletrade barriers are (τ, f), if only foreign firms with a productivity above $\bar{\varphi}(\tau, f)$ export, the utility of consumers is,

$$\lambda W = \left(\int_{\varphi_{\min}}^{+\infty} \varphi^{1-\sigma} dF(\varphi) + \int_{\bar{\varphi}}^{+\infty} (\tau\varphi)^{1-\sigma} dF(\varphi) \right)^{\frac{1}{\sigma-1}}$$

with λ a normalizing constant (the constant mark-up, to some power). If trade barriers go down (say both $\tau' < \tau$ and $f' < f$), two things happen.

The price charged by exporters will go down (τ goes down), which will contribute to an increase in welfare. Beyond that, the threshold for exports, $\bar{\varphi}$, will go down (from both τ and f going down). This is an additional source of enhanced welfare. Welfare is now,

$$\lambda W' = \left(\begin{array}{l} \int_{\varphi_{\min}}^{+\infty} \varphi^{1-\sigma} dF(\varphi) \\ + \underbrace{\int_{\bar{\varphi}'}^{\bar{\varphi}} (\tau'\varphi)^{1-\sigma} dF(\varphi)}_{\text{extensive margin welfare gain}} \\ + \underbrace{\left(\frac{\tau}{\tau'}\right)^{\sigma-1}}_{\text{intensive margin welfare gain}} \int_{\bar{\varphi}}^{+\infty} (\tau\varphi)^{1-\sigma} dF(\varphi) \end{array} \right)^{\frac{1}{\sigma-1}} > \lambda W$$

Important note:

It is important to notice that the increase in welfare from the extensive margin may not be qualitatively very important. The new exporters are typically less productive firms (φ low). In this simple monopolistic set-up, these firms will charge a high price compared to existing exporters. A large number, raised to some negative power $(1-\sigma)$ may not add up to much. This little note explains why a calibration exercise in Eaton and Kortum doesn't predict that smaller/more remote countries have such a lower welfare per capita, since the only things they miss are expensive goods, which do not contribute to welfare so much.

Broda and Weinstein try to quantify the gains from the extensive margin of trade, that is the welfare gains from having access to a broader range of varieties. To do so, they collect data on prices of imported goods (the US consumers are their concern). This is the first contribution of their paper. To compute the welfare gains from increased varieties, they need to come up with some estimate of the elasticity of substitution between goods, σ (they actually estimate a myriad of elasticities, about 30,000). This is the second (major) contribution of their paper.

Data: the importance of the extensive margins of trade.

Broda and Weinstein first describe the patterns of imports by the US. Aggregate exports rose from 4.8% of GDP in 1972 to 11.5% of GDP in 2001. This is due to both larger quantities of each goods being imported, and more goods being imported. If one define a good as a 10-digit Harmonized System good from a specific location, the number of goods imported rose from 74,667 in 1972 to 259,215 in 2001. This is due to both the US importing goods from more countries, and the US importing a wider range of goods: 7,731 goods were imported from 9.7 countries on average in 1972, versus 16,390 goods from 15.8 countries on average in 2001. All together, this means that the number of varieties (either new goods, or goods from new sources) has increased by 251% over 1972-2001!

The source of increased exports:

Very broadly, there are three reasons for the increase in the import share in the US:

- A reduction in trade barriers (both artificial, trade policy, and technological, transportation technology, the techtonic movements of continents may have played a little role too...).
- Relaxation of capital controls (typically barriers to foreign investment), a topic that we will cover in the last part of this class.
- The relative growth of many East Asian and other economies outside the US (a simple gravity model tells you that as the share of the US in the whole world shrinks, its imports as a share of GDP will rise).

Broda and Weinstein estimates of demand elasticities:

Broda and Weinstein develop a complicated procedure to estimate a large number of elasticities of substitution between goods. We know from the theory that this will be the key parameters that will allow us to translate prices into welfare. To do so, they apply and improve upon a method developped by Rob Feenstra. The important point is that it is not straightforward to estimate demand elasticities from prices and quantities data. One has to come up with instruments for demand and supply shocks. They do that by using both the time series and the cross section patterns in the data. They assume that demand shocks affect all US consumers in the same way, whereas supply shocks hit each country exporting to the US separately. This allows them to separate demand and supply elasticities.

One important note on their empirical procedure: Broda and Weinstein estimate the elasticities of substitution between 10-digit HS "varieties" within 5-digit HS "sectors". A variety within a sector corresponds to a given 10-digit HS sector, imported from a given country. The 10-digit "varieties" are as close as one can get to actual firm level data (what we expect to be the relevant definition of a variety in the Krugman setting), with reliable and large scale information on prices and quantities. This is not strictly speaking "varieties". Note that there are sufficiently many different subsectors within each of their "sectors" so that most of the variations in prices and quantities corresponds between varieties, and not selection of different firms from a given exporter. In that sense, the estimated elasticities are, to some extent, immune to the criticism developped in Chaney (2005).

Broda and Weinstein estimates of welfare gains:

With those estimated elasticities at hand, Broda and Weinstein are able to estimate the additional welfare gains for US consumers coming from access to a wider range of goods. The welfare gain from the rise in the number of varieties between 1972 and 2001 is 28%. This means that not taking into account those new varieties, one would underestimate the welfare gains from increased trade by 1.2% per year.

3.3 Hummels and Klenow (2005)

Hummels and Klenow (2005) try to disentangle empirically the contribution of the extensive versus the intensive margin of trade. Their main finding is that the extensive margin accounts for 60% of trade. More precisely, the extensive margin of trade accounts for 60% of the greater exports of larger economies. To come up with this number, they look at trade between 126 exporters and 59 importers, disaggregated across 5,000 product categories (6-digit). This finding broadly supports the models with heterogeneous firms and fixed costs (or bounded marginal utilities...). Reminiscent of the empirical regularities uncovered by Eaton, Kortum and Kramarz, they find that the elasticity of the extensive margin with respect to GDP is close to $\frac{2}{3}$ (.7), with a very tight standard deviation.

They also develop a method to infer quality of exports from price, quantity and output data. They argue that if large exporters systematically sell high quantities at high prices, this is consistent with these exporters producing higher quality goods. Therefore, they project prices and quantities on GDP measures to estimate some measure of the quality of exports.

4 Firm Level Productivity: Pavcnik (2002)

$$\Pi_{ijt} = f(k_{ijt}, \omega_{ijt})$$
k_{ijt} capital stock
ω_{ijt} productivity (Markov process)

$$V_t = \max\{L_t, \sup \Pi_t(k_t, \omega_t) - c(i_t + dE[V_{t+1}(k_{t+1}, \omega_{t+1}) | \Omega_{it}])\}$$
V_t value of the firm
$c(i_t)$ cost of investment
d discount factor
Ω_{it} information of i at t
$$k_{t+1} = (1-\delta) k_t + i_t$$

$$\Rightarrow \begin{cases} \omega_t < \underline{\omega}_t(k_t) \text{ (exit)} \\ i_t = i_t(\omega_t, k_t) \text{ (investment)} \end{cases}$$

$$y_t = \beta_0 + \beta x_t + \beta_k k_t + e_t$$
with $e_t = \omega_t + \mu_t$
and μ_t zero mean

$$\hat{\omega}_t = y_t - \hat{\beta}_0 - \hat{\beta} x_t - \hat{\beta}_k k_t$$

$$y_t = \beta x_t + \lambda_t(k_t, i_t) + \mu_t$$
with λ_t polynomial approximation
$\Rightarrow$ consistent $\hat{\beta}$

$$\begin{aligned} y_{t+1} - \beta x_{t+1} &= \beta_0 + \beta_k k_{t+1} + \omega_{t+1} + \mu_{t+1} \\ &= \beta_0 + \beta_k k_{t+1} + E[\omega_{t+1} | \omega_t, k_t] + \xi_{t+1} + \mu_{t+1} \\ &= \beta_k k_{t+1} + g(\omega_t) + \xi_{t+1} + \mu_{t+1} \\ &= \beta_k k_{t+1} + g(\lambda_t(k_t, i_t) - \beta_k k_t) + \xi_{t+1} + \mu_{t+1} \end{aligned}$$
with ξ_t unanticipated shock on ω_t
$\Rightarrow$ consistent $\hat{\beta}_k$

$$E\left[\omega_{t+1} | \omega_t, k_{t+1}, \omega_{t+1} > \underline{\omega}_{t+1}(k_{t+1})\right] = \Phi\left(\omega_t, \underline{\omega}_{t+1}\right) - \beta_0$$

$$P_t = \Pr\left[\omega_{t+1} > \underline{\omega}_{t+1}(k_{t+1}) | \omega_t\right] = p_t\left(\underline{\omega}_{t+1}(k_{t+1}), \omega_t\right) = p_t(k_t, i_t)$$
with p_t polynomial approximation

$$y_{t+1} - \beta x_{t+1} = \beta_k k_{t+1} + \Phi\left(\lambda_t\left(k_t, i_t\right) - \beta_k k_t, P_t\right) + \xi_{t+1} + \mu_{t+1}$$

with Φ_t polynomial approximation

$\Rightarrow$ estimate of ω_t

those estimates are 40% to 300% above OLS

$$Prod_{it} = \alpha_0 + \alpha_1\left(Time\right) + \alpha_2\left(Trade\right) + \alpha_3\left(Trade \times Time\right) + \alpha_4 Z_{it} + v_{it}$$

$Prod_{it}$ is plant's productivity estimate

$Time$ vector of time effects

$Trade$ vector of trade dummies (import or export oriented sector

$Trade \times Time$ vector of interactions

Z_{it} vector of plant specific controls

$$W_t = \sum_i s_{it} Prod_{it} = \overline{Prod}_t + \sum_i \left(s_{it} - \bar{s}_t\right)\left(Prod_{it} - \overline{Prod}_t\right)$$

covariance (reallocation) accounts for $\frac{2}{3}$ of productivity gains