

Rethinking productivity measurement in case of exporters

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Abstract

Recent work on production functions estimation revealed that substantial biases can be introduced into the estimates when the assumption of perfect competition and price exogeneity is not satisfied in the data itself. As Klette and Griliches (1996) show applying traditional econometrics in differentiated good markets will negatively bias the scale estimates of the production function. In fact, when deflated sales are used as a proxy for output in case of differentiated good industries scale economies (and subsequently productivity) cannot be estimated independently of markups. We extend this basic framework to show that, if exporting markups are smaller than those attainable in the domestic market, the Klette-Griliches estimation procedure will tend to overestimate exporting firm markups and underestimate their productivity. In addition, we provide an estimation algorithm based on the Olley-Pakes (1996) framework that could serve to ensure unbiased estimates of exporter productivity.

JEL classification: C14, D24, L11, L25

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Merjenje produktivnosti v primeru izvoznikov

Povzetek

V zadnjem času so analize empiričnega ocenjevanja produkcijske funkcije pokazale, da, v kolikor predpostavki popolne konkurence in eksogenosti cen v praksi nista zadovoljeni, lahko prihaja do znatne pristranosti ocen produktivnosti. Kot pokažeta Klette in Griliches (1996) bo uporaba klasičnih ekonometričnih metod na podatkih za diferencirane proizvode pomenila konsistentno podcenjevanje ekonomij obsega. Uporaba deflacioniranih prihodkov od prodaje kot približka za obseg proizvodnje pa pomeni, da ekonomij obseg (in posledično produktivnosti) ne moremo ocenjevati neodvisno od ocen profitne marže. V pričujočem prispevku z omenjenim pristopom pokažemo, da, v primeru ko so marže na izvoznih trgih pod tistimi na domačem trgu, bo Klette-Griliches pristop precenjeval marže izvoznih podjetij in podcenjeval njihovo produktivnost. Dodatno pa prikažemo tudi postopek, ki omogoča konsistentno oceno marž izvoznikov in oceno njihove produktivnosti.

Ključne besede: Merjenje produktivnosti, nepopolna konkurenca, izvoz, neposredne tuje investicije

1 Introduction

Debates surrounding the accurate measurement of productivity have been a mainstay in applied econometrics since the 1940s with the seminal work of Marschak and Andrews (1944). The road to identifying output differences that cannot be explained by differences in inputs is plagued by a number of obstacles. Questions ranging from those to do with the endogeneity of the inputs, issues of sample selection to measurement and misspecification issues are yet to be unequivocally resolved. This contribution continues the tradition of exploring possible issues in estimating productivity whereby we pay particular interest to the effects of the estimation approach on the productivity spread between exporting and non-exporting firms.

In the present paper we explore the potential issues in productivity estimation when firms differ in their exporting status and in the fact whether they are recipients of foreign direct investments or have invested in foreign-based production facilities themselves. By revising the theoretical structure of total factor productivity of exporters we hope to shed new light on the issue of missing evidence concerning learning-by-exporting. Following along the lines of some the work recently undertaken in estimating productivity in differentiated goods markets, we aim to show that the use of conventional techniques in the estimation of productivity consistently understates the actual exporting firms' productivity¹. Furthermore, our results indicate that the negative bias of the productivity estimates for exporting firms actually increases with the increased exposure to foreign markets (increase in the share of exports). We base our propositions on the framework established by Klette, Griliches (1996) specifically the implied proposition that productivity in differentiated good markets cannot be estimated independently of markups and scale economies when deflated sales are used as a proxy for output. They show that in differentiated good industries the use of deflated sales as an output proxy will lead to a downward bias on the scale estimates. The application of their approach to estimates of productivity was left to Melitz (2001), who shows that the true productivity differences will also be understated when prices are endogenous to the firm. In addition, he notes that, assuming exporting markups are lower than those attainable in the domestic market, the bias would be accentuated in case of exporting firms. Based on the propositions in Melitz (2001) and Martin (2005) we provide a basic model of production that enables us to evaluate the direction and the size of the ensuing productivity bias as well as provide an estimation approach that could serve to control for the set bias.

The remainder of the paper is organized as follows. We set out by describing the model of production commonly applied to productivity estimation in differentiated goods markets and introducing the alterations arising from the introduction of exporting (multinational production). The third section exploits some of the possible extensions that could broaden the applicability of our approach, while the directions and sizes of the biases our approach entails is discussed in the fourth section. Section five provides a possible approach to estimation that would control for the observed biases. Concluding remarks are presented in the last section.

¹At the same time overestimating the actual productivity of non-exporters.

2 The Model

The model we present in the remainder of this section is based on the Klette-Griliches (1996) and Klette (1999) framework and has been modified (along the lines of Melitz (2001) and Martin (2005)) to allow for the explicit consideration of exporting firms. Throughout the paper, we assume that firms are small relative to the industry. Also, we do not explicitly model transport costs in the case of exporting² as that would not substantially alter the results presented below.

2.1 Consumption

We follow Melitz (2001) and Martin (2005) in adopting the following representative consumer utility function

$$U \left(\left(\sum_{i=1}^N (\Lambda_i Q_i)^{(\sigma-1)/\sigma} \right)^{\sigma/(\sigma-1)}, M(Z) \right) \quad (1)$$

where $U(\cdot)$ is assumed to be differentiable and quasi concave, $M(Z)$ represents aggregate industry demand shifters, and Λ_i is the consumer's valuation of firm i 's product quality. (1) gives the conditional (conditioning on the price level and total industry revenue) demand functions for home (h) and foreign country (f) markets. We will allow for differences in the shape of the aggregate (and individual) demand curves between the two markets, leading to differing elasticities of demand (and different markups). We assume that a single producer maintains the same level of product quality in both markets although this assumption can be dropped without loss to generality, but at the expense of greater expositional burden.

$$Q_{hi} = \Lambda_i^{\sigma_h-1} \left(P_{hi}/\tilde{P}_h \right)^{-\sigma_h} \left(R_h/\tilde{P}_h \right) \quad (2)$$

$$Q_{fi} = \Lambda_i^{\sigma_f-1} \left(P_{fi}/\tilde{P}_f \right)^{-\sigma_f} \left(R_f/\tilde{P}_f \right) \quad (3)$$

where the price indices \tilde{P}_h and \tilde{P}_f are defined as

$$\tilde{P}_h = \left(\sum_{i=1}^N (P_{hi}/\Lambda_i)^{\sigma_h-1} \right)^{1/(\sigma_h-1)} \quad (4)$$

$$\tilde{P}_f = \left(\sum_{i=1}^N (P_{fi}/\Lambda_i)^{\sigma_f-1} \right)^{1/(\sigma_f-1)} \quad (5)$$

Although the home and foreign price indices determined here differ from those presented in Melitz (2001)³, the first order approximation for the percentage change in our indices

²The exporting revenue can simply be considered net of transport cost.

³Melitz's price index \tilde{P} is specified as

$$\tilde{P} = \frac{\left(\sum_{i=1}^N P_i^{\sigma-1} \right)^{\frac{1}{\sigma-1}}}{\left(\sum_{i=1}^N \Lambda_i^{\sigma-1} \right)^{\frac{1}{\sigma-1}}}$$

can also be obtained by taking a market share weighted average of percentage changes in firm level quality adjusted prices.

2.2 Production

Total production (for domestic and foreign markets) equals

$$Q_{it} = A_{it} [f(X_{it})]^\gamma \quad (6)$$

where $f(\cdot)$ is a general differentiable linear homogenous function, A_{it} is a Hicks neutral shift parameter (TFP) and \mathbf{X}_{it} is a vector of factor inputs. Invoking the mean value theorem we can write the output of the plant relative to the median plant as

$$q_{it} = a_{it} + \sum_x \alpha_x x_{it} \quad (7)$$

where

$$\alpha_x = \gamma f_x(\bar{\mathbf{X}}_{it}) \frac{\bar{X}_{it}}{f(\bar{\mathbf{X}}_{it})} \quad (8)$$

$f_x(\cdot)$ denotes the partial derivative of $f(\cdot)$ with respect to factor x , $\bar{\mathbf{X}}_{it}$ is some point in the convex hull spanned by \mathbf{X}_{it} and $\mathbf{X}_{Median,t}$ and all lower case letters denote log deviations from the median plant in terms of revenue; e.g. $r_{it} = \ln R_{it} - \ln R_{Median,t}$.

Regardless of the fact whether the markups are fixed or varying, profit maximization under the above demand function (2) implies a markup pricing rule

$$P_{ti}^h \gamma \frac{Q_{it}}{f(\bar{\mathbf{X}}_{it})} f_x(\bar{\mathbf{X}}_{it}) = \mu^h W_{zit} \quad (9)$$

$$P_{ti}^f \gamma \frac{Q_{it}}{f(\bar{\mathbf{X}}_{it})} f_x(\bar{\mathbf{X}}_{it}) = \mu^f W_{zit} \quad (10)$$

where the markup μ^h (μ^f) is

$$\mu_{it}^h = \frac{1}{1 - 1/\sigma^h} \quad \mu_{it}^f = \frac{1}{1 - 1/\sigma^f} \quad (11)$$

Throughout the exposition we maintain the assumption that firms allocate their production optimally between the two markets by equating the marginal revenue gained in the different markets. The relation between foreign and home prices is therefore

$$p_{it}^h = \ln \mu_{it}^h - \ln \mu_{it}^f + p_{it}^f \quad (12)$$

Whereas in the remainder of the paper we suppose that firms actually optimize their allocation of sales by equating the marginal revenues in both (all) markets, in reality this may not be the case and that could introduce additional iid errors into the estimation.⁴

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$$p_{it}^h = p_{it}^f + \ln \mu^h - \ln \mu^f + \xi_{it}$$

If labor and materials are the only variable inputs, then, conditional on capital, we can write

$$\alpha_j = \mu_{it}^h \frac{W_{xt} X_{it}}{P_{it}^h Q_{it}} = \mu_{it}^f \frac{W_{xt} X_{it}}{P_{it}^f Q_{it}} = \mu_{it}^h s_{xit}^h = \mu_{it}^f s_{xit}^f \quad (13)$$

where s_{xit} is the revenue share of factor X. The problem one is facing with the above specification is that the total quantity (Q_{it}) evaluated at either home (P_{it}^h) or foreign country prices (P_{it}^f) cannot be observed. One can, on the other hand, observe the sum of revenues from the domestic and foreign markets ($P_{it}^h Q_{it}^h + P_{it}^f Q_{it}^f$). Using the latter to proxy for the denominators in (13) will generate a bias compared with the theoretically proposed form.

$$\mu_{it}^h \frac{W_{xt} X_{it}}{P_{it}^h Q_{it}^h + P_{it}^f Q_{it}^f} = \mu_{it}^h \frac{W_{xt} X_{it}}{P_{it}^h Q_{it} \left[(1 - ex_{it}) + \left(\frac{\mu_{it}^f}{\mu_{it}^h} \right) ex_{it} \right]} = \frac{\mu_{it}^h s_{xit}^h}{(1 - ex_{it}) + \left(\frac{\mu_{it}^f}{\mu_{it}^h} \right) ex_{it}} \quad (14)$$

where ex represents the share of exports in total quantity produced and is defined as⁵

$$ex_{it} = \frac{Q_{it}^f}{Q_{it}} \quad (15)$$

clearly, in case of non-exporters the denominator of the rightmost part of (14) equals 1, while for exporters (assuming the foreign markups are lower than domestic⁶) it will be smaller than unity. This will cause estimates of domestic markups (μ_h) to be too low for exporting firms.⁷

Because of linear homogeneity of function $f(\cdot)$

$$\alpha_K = \gamma - \alpha_L - \alpha_M \quad (16)$$

Using (7) we therefore get

$$q_{it} = a_{it} + \mu_{it}^h v_{it} + \mu_{it}^h \varsigma_{it} + \gamma k_{it} \quad (17)$$

where

$$v_{it} = \sum_{x \neq k} \bar{s}_{xit} (x_{it} - k_{it}) \quad (18)$$

is an index of all variable factors weighted by their revenue shares and ς_{it} is an iid error introduced by the fact that the first order conditions might not hold exactly. Following the mean value theorem, \bar{s}_{xit} is the factor share prevailing at some point in the convex

⁵More often than not in empirical applications (15) cannot be measured and has to be approximated by revenue shares. This issue is discussed further below.

⁶We follow Melitz (2001) in making this assumption although it may not be generally applicable. Some firms may export to less competitive markets achieving markups above those in the domestic market despite incurring transport costs on exports. In estimating markups one could introduce an additional indicator variable for exporters to less developed markets in order to control for the issue.

⁷We explore the issue further below.

hull spanned by \mathbf{X}_{it} and $\mathbf{X}_{Median,t}$. If we subscribe to the common practice in productivity analysis⁸ and approximate the implied factor share by the average factor share at plant i and the share at the median plant, we can write \bar{s}_{xit} as

$$\bar{s}_{xit} \approx \frac{s_{it} + s_{Median,t}}{2} \quad (19)$$

Using the definition of firm revenue (in logged deviations from the median) for the two markets $r_{it} = q_{it} + p_{it}$ and the demand functions (2) to eliminate the plant level prices

$$r_{it}^h = \frac{1}{\mu_{it}^h} q_{it}^h + \frac{1}{\mu_{it}^h} \lambda_{it} \quad (20)$$

$$r_{it}^f = \frac{1}{\mu_{it}^f} q_{it}^f + \frac{1}{\mu_{it}^f} \lambda_{it} \quad (21)$$

one could then obtain total revenues of both the home and foreign markets ($R_{it} = R_{it}^h + R_{it}^f$).

Using equations 15, 17, 20, 21, and

$$r_{it} = r_{it}^h + \ln \left(\frac{1 + (\mu_{it}^f / \mu_{it}^h) ex_{it} / (1 - ex_{it})}{1 + (\mu_{Med,t}^f / \mu_{Med,t}^h) ex_{Med,t} / (1 - ex_{Med,t})} \right) \quad (22)$$

which, assuming constant markups, yields

$$\begin{aligned} r_{it} = & 1/\mu^h (a_{it} + \mu^h v_{it} + \mu^h \varsigma_{it} + \gamma k_{it}) + (1/\mu^h) \lambda_{it} + \\ & + \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \end{aligned} \quad (23)$$

Following Martin (2005), we define the measured TFP (MTFP) as

$$\begin{aligned} MTFP_{it} = & \left(\frac{\gamma}{\mu^h} - 1 \right) k_{it} + \frac{1}{\mu^h} (a_{it} + \lambda_{it}) + \varsigma_{it} + \\ & + \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \end{aligned} \quad (24)$$

which can, by introducing a new variable ω_{it} ,

$$\omega_{it} = \frac{1}{\mu^h} (a_{it} + \lambda_{it}) \quad (25)$$

be rewritten as

⁸for example Baily et al. (1992) and Martin (2005). A similar solution is implied in Criscuolo and Leaver (2005).

$$MTFP_{it} = \left(\frac{\gamma}{\mu^h} - 1 \right) k_{it} + \omega_{it} + \varsigma_{it} + \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it}/(1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t}/(1 - ex_{Med,t})} \right) \right] \quad (26)$$

Comparing equation 24 to Martin's analogue (27) reveals the sources of possible bias when exporting is not accounted for

$$MTFP_{it} = \left(\frac{\gamma}{\mu} - 1 \right) k_{it} + \frac{1}{\mu} (a_{it} + \lambda_{it}) + \varsigma_{it} \quad (27)$$

If the median firm is a non-exporter then last term in (23) is positive for all nonzero export shares⁹. This would introduce a (positive) term in measured TFP for exporting firms compared with non exporters that is not accounted for by traditional estimation methods. On the other hand, if the median firm has a non-zero export share, for some firms (non-exporters and firms with low export shares) the last term in (23) will be negative.¹⁰

In relation to Martin's (2005) specification of measured TFP the additional term reflects both the fact that total revenue consists of exporting and non-exporting revenue as well as our explicit account of markup differences in the two markets. We find that taking account of only the domestic markups is not sufficient for firms that are also engaged in foreign markets. The last fraction in (26) therefore serves to account for the impact of firms' revenue-share-weighted markups on measured total factor productivity. Our approach namely shows that exporters' productivity measures (based on deflated revenues) include, in addition to domestic markups, an "average markup of the firm"¹¹ measured in terms of logged deviations from the median firm's "average" markup.¹² Where for non-exporters domestic markups only affects the coefficient on capital, for exporting firms the difference in pricing between domestic and foreign markets is reflected in the additional right-hand-side term.

⁹This can be seen by observing that the derivative of the term in the brackets with respect to ex is positive (evaluated at $ex = 0$). Given that at $ex = 0$ the last term equals 0, the last term is positive for all $ex > 0$.

¹⁰For it to be positive, the following condition has to be satisfied:

$$\frac{1}{\mu^h} \ln(1 - ex_{it}) + \ln\left(\mu^h + \mu^f \frac{ex_{it}}{1 - ex_{it}}\right) > \ln\left(\mu^h + \mu^f \frac{ex_{Med,t}}{1 - ex_{Med,t}}\right)$$

the condition for the term to be increasing in ex_{it} , on the other hand, is

$$\frac{1 - ex_{it}}{\mu^f} + \frac{ex_{it}}{\mu^h} < 1$$

¹¹As represented by the revenue-share weighted average markup.

¹²The additional firm $(1 - ex_{it})^{1/\mu^h}$ appears as a correction due to the fact that domestic revenue r^h was used as a starting point in (22). Were exporting revenue used in its place the appropriate correction would have been ex^{1/μ^f} .

3 Extensions to the (basic) model

There are several possible directions in which one could extend the above model to include a broader spectrum of empirical eventualities. Amongst the possible additions to the model we focus primarily on the evaluation of firms receiving foreign direct investment or those investing in foreign markets, the possibility of varying markups, multiproduct and multimarket firms. These extensions serve to relax some of the assumptions that restrict the applicability of the model and ensuing estimation procedures.

3.1 Varying markups

An important issue, that has so far been ignored, is the question of markups heterogeneity. Namely, the assumption of constant elasticity of substitution, imposed by the choice of utility function, is very restrictive and abstracts away from some important issues. Given that it is highly unlikely that the substitution elasticities between any two varieties in a market are identical, which would imply that consumers view all market varieties as completely symmetrical, it follows that firms face different demand curves for their varieties. This further implies that firm markups are likely to differ in contrast with the commonly applied proposition of uniform markups.

The issue of varying markups for firms serving solely the domestic markets was resolved by Martin (2005). He notes that plants with higher markups (μ_{hi}) are likelier, all else equal, to have lower measured productivity. The regression model Martin proposes is

$$r_{it} = vi_{it} + \frac{\gamma}{\mu}k_{it} + \frac{1}{\mu}(a_{it} + \lambda_{it}) + \varsigma_{it}$$

revealing that the estimates of the capital coefficient ($\beta_K = \frac{\gamma}{\mu}$) will be too high for firms with markups above that of the median firm and too low for those with lower markups. The proportion of revenue variation attributed to capital would therefore be too high for high-markup firms (the fact is reinforced if higher markups are correlated with higher capital stocks), while the effective productivity ($(a_{it} + \lambda_{it})/\mu$) would be lower.¹³

Our approach, on the other hand, is slightly different. The proposition that high-markup firms will have lower measured productivity remains valid in general (although the markups in question are those gained solely in the domestic market). In addition to the impact of higher domestic markups, the difference between domestic and foreign markup for an individual firm also becomes significant. Final term in equation 23

$$\ln \left[(1 - ex_{it})^{\frac{1}{\mu_{it}^h}} \left(\frac{1 + (\mu_{it}^f/\mu_{it}^h)ex_{it}/(1 - ex_{it})}{1 + (\mu_{Med,t}^f/\mu_{Med,t}^h)ex_{Med,t}/(1 - ex_{Med,t})} \right) \right] \quad (28)$$

reveals that exporters able to achieve higher foreign-market markups will actually have higher measured TFP. The denominator in the brackets will likely be smaller than the numerator for predominantly exporting firms, since for non-exporters the denominator will equal 1. This effect is further amplified for firms that export most of their output (have a high export share ex_{it}).

¹³Note that measured TFP of high markup firms would be too high while it would be too low for low markup firms. This proposition is in line with Nickell (1996) (.), who notes that firms in less competitive markets (achieving higher markups) exhibit lower productivities.

3.2 Multi-market firms

The analysis so far implicitly assumes that each firm is faced with at most two different markets yielding two possible markup levels (denoted as μ^h and μ^f). In reality each firm may be involved in dozens of markets with the associated demand elasticities (and markups). Again, the introduction of multiple markets would not crucially alter the above analysis as only the weights of the applied markups would change with the introduction of exports shares to different markets. The general version (for a larger number of potential export markets) of the revenue function is

$$r_{it} = \frac{1}{\mu_h} (a_{it} + \mu_h v_{it} + \mu_h s_{it} + \gamma k_{it}) + \lambda_{it}/\mu_h + \ln \left[(1 - \sum_{m=1}^M ex_{it}^m)^{\frac{1}{\mu_{it}^h}} \left(\frac{1 + 1/\mu_{it}^h \sum_{m=1}^M (\mu_{it}^m ex_{it}^m / (1 - ex_{it}^m))}{1 + 1/\mu_{Med,t}^h \sum_{m=1}^M (\mu_{Med,t}^m ex_{Med,t}^m / (1 - ex_{Med,t}^m))} \right) \right] \quad (29)$$

where subscript m denotes a foreign market (ex_{it}^m is the share of a firm's revenue coming from market m and μ^m is the markup achieved in market m). Instead of basing the estimation solely on the markup achieved in the home country, as is the case with non-exporters, exporting firms face a weighted average markup across their markets where the weights are revenue shares in individual markets. As it turns out, exporting to a larger number of markets in itself does not ensure higher measured total factor productivity. Higher productivity could ensue only in cases where exporting to a larger number of markets was also an indication of a larger total export share.

3.3 Multi-product firms

Up to this point, we have assumed that each firm produces only one differentiated product. In reality, however, one can rarely find industries where firms produce only one, albeit differentiated product. In this section we therefore assume that firms produce at least one variety, similar to what Melitz (2001) and Levinsohn and Melitz (2002) propose. Our approach is slightly more complicated since we base it on the exporting heterogeneity. Now each firm i produces J_i varieties and sells them in domestic market and, providing it chooses to become an exporter, in a foreign market. We assume that due to certain sunk costs it has to bear in order to start exporting an exporting firm exports each of its J_i products. This assumption is not problematic in the case of common markups in the domestic (μ^h) and foreign market (μ^f), but imposes a restriction in the varying markups case.

Let the production and demand functions for each of J_i varieties produced by firm i still satisfy

$$Q_{ij} = A_{ij} [f(X_{ij})]^\gamma \quad (30)$$

and

$$Q_{hij} = \Lambda_{ij}^{\sigma_h - 1} \left(P_{hij} / \tilde{P}_h \right)^{-\sigma_h} \left(R_h / \tilde{P}_h \right) \quad (31)$$

or

$$Q_{fij} = \Lambda_{ij}^{\sigma_f - 1} \left(P_{fij} / \tilde{P}_f \right)^{-\sigma_f} \left(R_f / \tilde{P}_f \right) \quad (32)$$

respectively. Subindex j represents a variety produced by a firm i , so that $j = 1, 2, \dots, J_i$, while

$$J = \sum_{i=1}^N J_i \quad (33)$$

represents the aggregate number of varieties produced. By maintaining the same structure for the production and demand as in the basic setting, we implicitly rule out the possibility of economies of scope and the possibility that varieties may be less differentiated within firms than across firms (e.g. trademarks). For each firm we observe only the aggregate domestic and foreign sales

$$\begin{aligned} R_i &= \sum_{j=1}^{J_i} R_{ij} = \sum_{j=1}^{J_i} \left(R_{ij}^h + R_{ij}^f \right) = \sum_{j=1}^{J_i} \left(P_{ij}^h Q_{ij}^h + P_{ij}^f Q_{ij}^f \right) = \\ &= \sum_{j=1}^{J_i} P_{ij}^h Q_{ij}^h + \sum_{j=1}^{J_i} P_{ij}^f Q_{ij}^f \end{aligned} \quad (34)$$

and aggregate input use $X_i = \sum_{j=1}^{J_i} X_{ij}$.

We assume that firms have to bear a sunk cost in order to introduce a new variety. Apart from this cost, there is another cost of producing an additional variety if a firm produces with increasing returns to scale ($\gamma > 1$). In this case, allocating a given input bundle over a larger number of varieties implies lower total output because of the concavity of cost function for each variety and the preclusion of economies of scope.

Let φ_{it} denote the quality adjusted productivity index, so that $\varphi_{it} = a_{it} + \lambda_{it}$. Average composite productivity level, $\tilde{\varphi}_{it}$, can now be constructed for each multiproduct firm in such a way that its total sales and input use match those of a hypothetical firm producing the same number of varieties, each having an identical quality adjusted productivity level $\tilde{\varphi}_{it}$. Put differently, $\tilde{\varphi}_{it}$ is the productivity level that converts $\frac{X_i}{J_i}$ units of inputs into $\frac{R_i}{J_i}$ sales according to the revenue production function outlined in (23). Average revenue per firm i 's variety becomes:

$$\begin{aligned} r_{it} - \delta_{it} &= \frac{\gamma}{\mu^h} (k_{it} - \delta_{it}) + v_{it} + \varsigma_{it} + \frac{1}{\mu^h} \tilde{\varphi}_{it} + \\ &+ \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \end{aligned} \quad (35)$$

where $\delta_{it} = \ln(J_{it})$. Expressing the total revenue from the equation above yields the following relationship between the firm total sales and its total input use and average productivity level:

$$\begin{aligned} r_{it} &= \frac{\gamma}{\mu^h} k_{it} + v_{it} + \varsigma_{it} + \frac{1}{\mu^h} [\tilde{\varphi}_{it} + (\mu^h - \gamma)\delta_{it}] + \\ &+ \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \end{aligned} \quad (36)$$

Measured TFP then becomes:

$$MTFP_{it} = \left(\frac{\gamma}{\mu^h} - 1 \right) k_{it} + \frac{1}{\mu^h} (\tilde{\varphi}_{it} + (\mu^h - \gamma)\delta_{it}) + \varsigma_{it} + \quad (37)$$

$$+ \ln \left[(1 - ex_{it})^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it}/(1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t}/(1 - ex_{Med,t})} \right) \right]$$

In a multiproduct setting, we therefore obtain an additional term $\frac{\mu^h - \gamma}{\mu^h} \delta_{it}$ that has to be taken into account. Melitz (2001) shows that in order for a firm to produce more than one variety, $\mu^h - \gamma$ must be positive. Two firms with identical quality adjusted productivity level $\tilde{\varphi}_{it}$ will have different measured TFP levels if they produce different number of varieties. For a more diversified firm, we will obtain higher productivity estimates. The logic behind this is as follows. Let's look first at the constant returns to scale case. The measured productivity difference between two firms with identical productivity parameters $\tilde{\varphi}_{it}$ will be $\frac{\mu^h - 1}{\mu^h} \Delta \delta_{it} = \frac{1}{\sigma^h} \Delta \delta_{it}$ - a positive value. Greater the substitutability between varieties the smaller the effect of broadening firm's range of varieties. In fact, in perfect competition ($\sigma^h \rightarrow \infty$) the additional term dissipates. With increasing returns to scale, the bias will be smaller than in the constant returns to scale case. The reason is that under increasing returns to scale, a multi-product firm reduces the total output when increasing the bundle of varieties produced. However, firms will be willing to incur this efficiency loss as long as they can compensate the reduced output of each variety by setting higher prices. With decreasing returns, the measured productivity difference would be larger than the constant returns case. Just the opposite holds in this case: spreading production over fewer varieties increases output efficiency. The optimum number of varieties is determined by taking account of the sunk cost of introducing new variety into the production.

3.4 Foreign-owned firms

Exploring further, we allow differences between domestic and foreign-owned firms. First, we assume that both share the same production function but differ in productivity parameter A_{it} , and vector of factor prices. Specifically, we assume that foreign subsidiaries have lower cost of capital compared to domestic firms, but have to pay equal wages. This implies that, according to the markup pricing rule, foreign subsidiaries choose different factor intensities than domestic firms. Empirical work done on comparing the technology of affiliates of MNEs with indigenous companies shows evidence on higher capital intensity of foreign-owned firms. Dunning (1993) provides an empirical survey of the issue, while more recent studies include Ramstetter (1994, 1999), De Doms and Jensen (1998), Ngoc and Ramstetter (2004) and Kimura and Kiyota (2006). Girma et al. (1999) show that foreign firms have higher capital-labour ratios even in developed host countries such as Great Britain.

For foreign-owned firms we are therefore likely to obtain an upward biased coefficient on labour and consequently a downward biased capital coefficient. The direction of bias on both coefficients is the opposite of the one in the sample of indigenous firms. Providing we assume lower cost of capital for foreign subsidiaries, investment-cost and value functions in the Bellman equation of Olley and Pakes (1996) become different since we no longer can expect same values for state variable factor prices. Cost of investment function has to be augmented with unit cost of investment, conditional on firm's ownership status

$$V_t(\omega_t, k_t, o_{t-1}) = \max \{ \Phi, \sup \pi_t(\omega_t, k_t, o_{t-1}) - c(o_{t-1}) i_t + \beta E[V_{t+1}(\omega_{t+1}, k_{t+1}, o_t) | J_t] \} \quad (38)$$

where o_t is state variable defining ownership status, Φ is firm's sell-off value, $\pi(\cdot)$ is the restricted profit function, $c(o_{t-1})$ is the unit cost of investment depending on lagged ownership type, i_t is level of investment, β is the firm's discount factor, and J_t embodies information available to the firm at time t . To keep things tractable, we maintain common discount factor for both types of firms. At the same level of productivity and capital stock, foreign firms are expected to respond with higher current level of investment, so the investment demand functions following from the solution of control problem will be different for domestic and foreign-owned firms. The unobservable productivity variable therefore cannot be expressed as a function of observables identically for both ownership types. Same values of investment and capital stock are the consequence of different productivity levels: lower for foreign and higher for domestic firms. Due to systematic overestimation of unobserved productivity level for foreign firms and negative correlation between labour input and measurement bias on unobserved productivity, we get positive bias on labour coefficient in the first step of our estimation.

The second complication stems from the fact that adding a vector of factor prices as an additional state variable alters also shutdown function for foreign-owned firms. Because the investment costs are lower in these firms, their boundary exit states will be lower as well, all other things being equal. Treating both groups identically, we will obtain downward biased estimated probabilities of staying in business for foreign subsidiaries. Because the bias in probability is negatively correlated with capital stock, we will be getting overestimated capital coefficients for foreign firms in the third step of estimation. How will we allow for different investment demand function and exit rule for foreign and domestic firms in our estimation procedure? Ideally, we would estimate the above functions separately for both groups and use them in the rest of the estimation. However, due to serious limitations concerning number of observations for foreign subsidiaries in each of the narrowly defined industry, estimations for this group would most probably be inconsistent. One must, therefore, resign to differentiating both types of firms with a simple dummy variable indicating the ownership status. Implicitly we assume that the investment demand function and exit function differ only in the intercept, but apart from that respond to the changes in their arguments identically.

4 Discussion

Equation 24 shows what the traditionally applied factor share based TFP measures capture (assuming the framework we propose holds) when estimating total factor productivity. The difference between our proposed TFP decomposition and the standard one is captured primarily by the changes in factor coefficients. As shown by Martin (2005) traditional TFP decompositions fail to account for economies of scale in factor use and the endogeneity of firm prices (or markups). Our work represents a natural extension of Martin's framework to include firms involved in foreign market operations. We show that, when exporting is explicitly accounted for an additional term appears in the structure of TFP. This correction serves to account for both the revenue share of exporting and the difference in markups between the markets. Although, this extension seems innocuous it serves an important purpose as it helps explain the productivity differences between exporting and non-exporting firms. In addition, this differences are further amplified as firms' export shares grow. This could serve to explain the persistent lack of empirical evidence on the learning-by-exporting hypothesis as exporter productivity may have been

consistently underestimated.

A crucial issue in our approach to the estimation of productivity is the construction of an appropriate proxy of the export share. As mentioned above, in empirical applications the export share ex_{it} will be approximated by the share of export revenues in total revenues, \widetilde{ex}_{it} :

$$\widetilde{ex}_{it} = \frac{R_{it}^f}{R_{it}^f + R_{it}^h} = \frac{Q_{it}^f P_{it}^f}{Q_{it}^f P_{it}^f + Q_{it}^h P_{it}^h} \quad (39)$$

Evidently, the use of the above proxy introduces an additional source of bias into the estimation procedure. A slight reformulation of equation (39) shows the direction of the bias this approximation is introducing into the regressions

$$\widetilde{ex}_{it} = \frac{Q_{it}^f}{Q_{it}^f + Q_{it}^h} \frac{(Q_{it}^f + Q_{it}^h) P_{it}^f}{Q_{it}^f P_{it}^f + Q_{it}^h P_{it}^h} = ex_{it} \frac{Q_{it}^f + Q_{it}^h}{Q_{it}^f + Q_{it}^h \frac{P_{it}^h}{P_{it}^f}} \quad (40)$$

For individual firms there will obviously be some bias in either direction. Other things being equal, firms with higher domestic markups will, by construction, have understated export shares, while for firms with lower domestic markups the proposed export shares will likely be too high. We believe that, using firm revenue and markups for the two markets, we can mitigate the above bias by using the following definition of export share

$$ex'_{it} = \widehat{ex}_{it} \frac{R_{it}^f + R_{it}^h}{R_{it}^f + R_{it}^h \frac{\mu^f}{\mu^h}} \quad (41)$$

Amongst the issues one faces in empirical estimations of exporter productivity using the above model of production is the missmeasurement of the revenue shares of factors in production. Given the proposed use of factor cost shares in total revenue as proxies for factor revenue shares (evaluated at domestic or foreign prices), we will retrieve a weighted average of domestic and exporting markups instead of recovering individual markups. As equation 14 reveals the home-country markups obtained using total revenue¹⁴ as a proxy for the total quantity produced (evaluated at home country prices) are likely to be downward biased.

$$\widetilde{\mu}^h = \mu^h [(1 - ex_{it}) + (\mu^f / \mu^h) ex_{it}] \quad (42)$$

In fact, the bias will be more pronounced the larger the share of exports and the larger the difference between home and foreign country markups¹⁵. On the other hand, in cases of firms exporting to less competitive markets the bias would actually be positive as the bracketed term would be larger than 1. If, alternatively, one were to base the approximation of factor shares on revenue evaluated at exporting prices instead of domestic as is suggested in (14), one would obtain upwardly biased estimates of foreign markups.¹⁶

¹⁴Revenue obtained in domestic and foreign market.

¹⁵For firms exporting to less competitive markets (markets with a higher markup) the direction of bias would be opposite.

¹⁶As expected, (42) and (43) reveal that the estimates of domestic and foreign markup would in fact be equal (a weighted average of domestic and foreign markups).

$$\tilde{\mu}^f = \mu^f [(\mu^h/\mu^f)(1 - ex_{it}) + ex_{it}] \quad (43)$$

The bias our proposed methodology introduces into the estimation therefore depends on the export share and firm prices (markups) in its respective markets.

- firms with high (above median) domestic prices and high home-country markups (relative to those in exporting markets) will face underestimated shares of output exported as well as a negatively biased estimates of domestic markups. Their measured total factor productivity estimates will therefore tend to be overestimated;
- for firms with low domestic prices and relatively high foreign-country markups (compared with the home country) the revenue based export share would overstate the actual share of exported output and there would likely be a negative bias on the estimates of measured total factor productivity;
- for firms with high domestic prices and domestic markups lower than those in the foreign markets the direction of the bias will be ambiguous and will depend on individual sources of bias in estimation (if the missmeasurement of export shares dominates, measured total factor productivity will be downward biased, otherwise upward bias is more likely);
- similarly, in the case of firms with domestic prices below that of the median firm's, whereby their home-country markups are higher than those they achieve abroad, the export share will be overstated while there may be a downward bias on the domestic markup estimates. Depending on the size of the two counteracting biases measured total factor productivity may either be over- or underestimated.

5 Estimation

Any estimation approach dealing with production function estimation has to contend with some crucial endogeneity issues. Firstly, as first noted in the seminal paper by Marschak and Andrews (1944) there could be a correlation between unobserved productivity shocks and the input variables (vi_{it} and k_{it}) due to the fact that certain aspects of productivity innovations (such as managerial ability, land quality, quality of materials) are known to the firm (but not to the econometrician) when deciding upon factor inputs. Secondly, in plant level data endogeneity can also be introduced through the correlation between firm exit (exit decision) and the unobserved productivity variables. The so called selection bias occurs as firm exit is likely to depend on firm size and capital/labor ratio and is not exogenous.

In addition to controlling for simultaneity and selection biases, we adapt the estimation procedures in order explicitly account for exporting (international involvement) in firm decisions. Following Van Biesebroeck (2005) and De Loecker (2005) we modify the Olley and Pakes (1996) estimation algorithm to include exporting, inward and outward foreign direct investment status as additional state variables. Alternatively, we could follow Rizov and Walsh (2005) in adding an additional selection rule (parallel to the selection into the sample) with selection into exporting. The difference between the two approaches that attempt to integrate exporting into the Olley-Pakes algorithm is that the one pioneered by

Van Biesebroeck essentially assumes the validity of learning-by-exporting¹⁷, while the Rizov and Walsh approach builds exclusively on the self-selection premise. Where the former considers exporting to be a state variable (along with firm capital stock and productivity level) with its law of motion determined by other contemporaneous state variables and lagged exporting status¹⁸, the latter proposes that selection into exporting serves to split the sample (into exporters and non-exporters) based on their productivity.¹⁹ The advantage of Van Biesebroeck’s approach lies in the fact that exporting status is endogenous and enters directly into the production function, because, as he correctly points out, if exporting in fact improves productivity and is correlated with inputs it belongs in the first stage production function. Rizov and Walsh’s approach, on the other hand, benefits primarily from the fact that, by estimating productivity separately on exporting and non-exporting firm samples, the estimation retains considerable flexibility of the production function coefficients.²⁰

5.1 Accounting for endogeneity

The endogeneity issues arise from the profit maximization problem of plants. The inclusion of exporting share in the production function estimation introduces an additional source of possible endogeneity. Exporting share serves both as an indicator of export status ($ex = 0$ or $ex > 0$) as well as a measure of the importance of foreign markets for the firm. Based on the learning-by-exporting hypothesis export status (and intuitively export share as well) positively impacts the level of productivity, while the notion of self selection establishes the reverse causality. Following Van Biesebroeck (2005), the Olley-Pakes framework can be extended to include exporting as a state variable. Whereas Van Biesebroeck explored the possible effects of exporting on productivity growth (learning-by-exporting) we are only interested in obtaining credible measures of exporter productivity. The Olley-Pakes (1996) approach bases on controlling for simultaneity by inverting the firm-investment function $I_t = i_t(\omega_t, a_t, k_t)$ ²¹ to express the unobserved productivity variable (ω_t). In contrast, Van Biesebroeck adapts the investment relationship to encompass exporting by replacing the firm-age variable (a_t) with the lagged exporting status (EX_{t-1}). The reasoning behind the introduction of exporting into the investment function is driven by the commonly observed superiority of exporting firms in terms of capital intensity, investment, size and productivity compared with non-exporters.²² The added difference in Van Biesebroeck’s application is that lagged export status does not evolve deterministically as was the case with age. Instead, current export status is chosen simultaneously with current investment. The state variables at the start of period t hence change to k_t , EX_{t-1} , and ω_t , while the two control variables are $\Delta EX_t = EX_t - EX_{t-1}$ and I_t .²³ The

¹⁷Van Biesebroeck’s version of the Olley-Pakes algorithm does not include controls for the self-selection into exports based on productivity although the issue is implied (pp. 385).

¹⁸Essentially, exporting status serves as an additional determinant of investment and exit decisions in the second stage of the Olley-Pakes algorithm.

¹⁹In further steps of the estimation, Rizov and Walsh (2005) validate their approach by estimating the factor coefficients (and subsequently productivity) on two separate subsamples of exporters and non-exporters.

²⁰Coefficient estimates on the inputs are allowed to differ between exporting and non-exporting firms.

²¹The conditions for monotonicity of the relationship between investment (I_t) and the unobserved productivity variable (ω_t) is given in Pakes (1991).

²²This leads Van Biesebroeck (2005, pp. 385) to state that even controlling for inputs and productivity exporters will make different investment decisions than non-exporters.

²³Additionally, one could consider both outward and inward foreign direct investment as state variables

evolution of the state variables is determined by

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (44)$$

$$EX_t = EX_{t-1} + \Delta EX_t \quad (45)$$

while ω_{t+1} is assumed to follow a stochastic Markov process as a function of only ω_t (in contrast to Van Biesebroeck we do not presume learning-by-exporting, but do acknowledge the effects exporting status may have on investment and exit decisions and incorporate those in the algorithm).

$$\omega_{it} = E\{\omega_{it}|\omega_{it-1}\} + \nu_{it} \quad (46)$$

Similarly, as in Olley and Pakes (1996), the investment function is an unknown function of the three state variables $I_t = i_t(k_t, EX_{t-1}, \omega_t)$. In addition, Van Biesebroeck also proposes a policy function for the change in export status implying self-selection into exporting, $\Delta EX_t = \Delta ex_t(k_t, EX_{t-1}, \omega_t)$, but does not employ it in the estimation algorithm.²⁴ It is important to note that this exporting decision only affects the firm's productivity level the following period (as can be seen by inverting the investment function), just as current investment only raises future capital stock.²⁵

Following Martin (2005) home- and foreign-market revenue functions can be rewritten using the above assumptions as

$$r_{it}^h - vi_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln(1 - ex_{it}) + E\{\omega_{it}|\omega_{it-1}\} + \nu_{it} + \varsigma_{it} \quad (47)$$

$$r_{it}^f - vi_{it} = \frac{\gamma}{\mu^f} k_{it} + \frac{1}{\mu^f} \ln(ex_{it}) + E\{\omega_{it}|\omega_{it-1}\} + \nu_{it} + \varsigma_{it} \quad (48)$$

Employing the inverted investment function to express out the unobserved productivity term $\omega_{it} = \phi_\omega(I_{it}, k_{it}, EX_{t-1})$, where $\phi(\cdot) = i^{-1}(\cdot)$, (47) can be rewritten as

$$r_{it}^h - vi_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln(1 - ex_{it}) + q(I_{it-1}, k_{it-1}, EX_{t-2}) + \nu_{it} + \varsigma_{it} \quad (49)$$

where $q(\cdot) = E\{\omega_{it}|\phi_\omega(\cdot)\}$. Using a higher order polynomial to approximate for $q(\cdot)$ reduces (49) to a simple least squares problem. We suppose that multicollinearity between ex_{it} and EX_{it-2} is not a critical issue given that the latter is an indicator variable while

whose evolution would be determined by

$$OFDI_t = OFDI_{t-1} + \Delta OFDI_t$$

and

$$IFDI_t = IFDI_{t-1} + \Delta IFDI_t$$

²⁴Firm exporting decision for the following period depends on the lagged exporting status, current capital stock, and current productivity level (including the part unobservable to the econometrician).

²⁵The assumptions on the investment function $i(\cdot)$ that ensure its invertibility are stated in Van Biesebroeck (2005).

the former is theoretically continuous. On the other hand, γ/μ may not be identifiable from (49) as k_{it} will be correlated with k_{it-1} as well as I_{it-1} . Estimates obtained from running a regression on equation 49 will therefore be used for initial values only in a more econometrically efficient procedure. Following Olley and Pakes (1996) we start by estimating

$$r_{it}^h - vi_{it} = \psi(ex_{it}, k_{it}, I_{it}, EX_{it-1}) + \varsigma_{it} \quad (50)$$

where $\psi(ex_{it}, k_{it}, I_{it}, EX_{it}) = (\gamma/\mu^h)k_{it} + (1/\mu^h) \ln(1 - ex_{it}) + \phi_\omega(k_{it}, I_{it}, EX_{t-1})$. As was the case in Olley-Pakes (1996), we are not able to separate the effects of exporting status (and exporting share) on the investment choice from their effect on output. We can therefore use a nonparametric estimator of the above equation to obtain predictions of $\hat{\psi}$ for each observation. Subsequently, (50) can be reformulated in terms of a nonlinear least squares problem

$$r_{it}^h - vi_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln(1 - ex_{it}) + h(\hat{\psi}_{it-1} - \frac{\gamma}{\mu^h} k_{it-1} + \frac{1}{\mu^h} \ln(1 - ex_{it-1})) + \nu_{it} + \varsigma_{it} \quad (51)$$

where $h(\cdot) = \{\omega_{it}|\cdot\}$ is approximated by a polynomial. The issue of endogeneity may also arise in connection with the export share variable (ex_{it}), since more productive firms may choose to export a larger share of their sales and/or larger firms (in terms of revenue) could face higher export shares due to the restricted size of the domestic market. We believe that the issue is not critical though as the dependent variable in our case is in logged deviations from the median while the export share variable is in logs only. In addition, the estimation algorithm presented above corrects for the possible remaining endogeneity.

5.2 Accounting for sample selection

Ericson and Pakes (1995) construct a model formalizing the idea plant exit (or plant death) depends, in part, on the firm's expectation of its future productivity and, given serial correlation, its current productivity. This would cause firms in the sample to be chosen (to a certain extent) based on unobserved productivity. This therefore generates a selection bias in traditional estimation procedures. Olley and Pakes (1996) define an exit rule where firms compare the sell-off (scrap) value of the firm to the expected discounted returns of staying in business until next period. As it turns out, since firms with larger capital stock can expect higher future returns for any productivity level²⁶, the capital coefficient will be negatively biased if no steps are taken to correct for the bias. Analogous to the Olley and Pakes (1996) approach, Van Biesebroeck (2005) defines the lower threshold level of ω as a function of k_{it} and EX_{t-1} .

$$\underline{\omega}_{it} = \underline{\omega}_{it}(k_{it}, EX_{t-1}) \quad (52)$$

Following Van Biesebroeck the probability of end-of-period productivity falling below this threshold is hence

$$\Pr(\text{survival}) = \Pr(\omega_{it+1} \geq \underline{\omega}_{it+1}(k_{t+1}, EX_t) | \omega_{it+1}(k_{t+1}, EX_t), \omega_{it}) \quad (53)$$

²⁶Therefore they are likely to stay in operation even at lower ω realizations.

by the law of iterated expectations and using the transition equations, (53) can be rewritten as²⁷

$$P(\text{survival}) = P_t(k_{t+1}, EX_t, \omega_t) = P'_t(k_t, I_t, EX_{t-1}, \Delta EX_t) = P''_t(k_t, I_t, EX_{t-1}, EX_t) \quad (54)$$

where the lagged export status is needed as one of the predictors of the unobserved productivity term ω_{it} , while the current export status serves as a determinant of the exit threshold (Van Biesebroeck, 2005). To obtain an estimate of exit (or continuation) probability a Probit is run with current capital stock, investment and export status as well as lagged export status as dependant variables. Following OP if P_{it} (the probability of continuation) changes monotonically with ω_{it} , the probability function is invertible and ω_{it} can be expressed as a function of $P(\text{exit})$, k_{it} , EX_{t-1} . As we can control for both the exit threshold (using the exit probability) and the unobserved productivity, equation 47 becomes²⁸

$$r_{it}^h - vi_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln(1 - ex_{it}) + h(P_{it-1}, \hat{v}_{it-1} - \frac{\gamma}{\mu^h} k_{it-1} + \frac{1}{\mu^h} \ln(1 - ex_{it-1})) + \nu_{it} + \varsigma_{it} \quad (55)$$

which can be estimated in two steps (in contrast to OP) with the procedure following the one outlined in the previous section. The appropriate estimates of the capital coefficient and the export share coefficient are obtained in the second step. By running parallel regressions on domestic and exporting revenues, one can obtain estimates of domestic and foreign markups and can, by assuming constant markups, obtain an estimate of the exporting correction in MTFP measures.

5.3 Correcting for the measurement error

We noted above that data limitations will likely prevent accurate measurement of factor shares in total output evaluated at domestic or foreign prices. These will have to be approximated with factor-cost shares in total revenue which will in turn lead to the missmeasurement of the variable factors index (vi_{it}). In fact, our proposed framework would (at least at the initial stages of the estimation) be unable to differentiate between the variable factors index based on domestic prices and the one based on exporting prices. We, hence, stipulate that in case when home-market revenue²⁹ is considered, the empirically viable variable-factor index \hat{v}_{it} will overstate the true variable-factor index, while, at the same time, \hat{v}_{it} will likely understate the true index in case of foreign market revenue. In order to compensate for the measurement error, the estimates of the two markups would have to be adjusted by the corrective factor (equations 42 and 43) and used in the following step of the iteration. We suggest that in the first stage of the estimation process

²⁷The second and third equalities follow from (44) and (45).

²⁸The foreign revenue equivalent, which would enable one to retrieve the foreign-market markups, would be

$$r_{it}^f - vi_{it} = \frac{\gamma}{\mu^f} k_{it} + \frac{1}{\mu^f} \ln ex_{it} + q(I_{it-1}, k_{it-1}, EX_{t-2}, P_{it-1}) + \tilde{\nu}_{it} + \tilde{\varsigma}_{it}$$

²⁹The case when in the calculation of factor revenue share the total quantity produced is evaluated at domestic prices.

$\widehat{v}l_{it}$ is used in (55), where the obtained markups are then used to recalculate $\widehat{v}l_{it}$. This iterative process would continue until the markup estimates in consecutive stages do not differ substantially.

6 Concluding remarks

Lately, a growing body of empirical literature on trade with firm heterogeneity has emerged unequivocally confirming the pronounced differences between non exporting firms, exporters, and multinational firms (firms investing in foreign productive capacity). Concerning the cause of this differences, robust support has been found for the self-selection hypothesis, where more productive plants engage in exporting and multinational production while their less productive counterparts restrict their activities to solely the domestic market. On the other hand, despite a few notable exceptions, evidence on the existence of learning-by-exporting or learning-by-foreign investment has proven far more illusive. We propose that one of the possible solution for these findings (or the lack thereof) could lie in the missmeasurement of firm productivity (or firm productivity differences between exporting and non-exporting firms). We believe that, by not controlling for the exporting status and the degree of foreign-market involvement (export share) specifically in cases where we are dealing with differentiated product markets, the total factor productivity of exporting firms may in fact be seriously understated. In contrast, standard estimation approaches may positively bias the productivity measures of non-exporting firms. As a consequence, these findings indicate that the productivity differences between firms with foreign market presence may in fact be even larger than commonly observed. This could, in turn, shed additional light on the missing evidence of learning effects, specifically since our framework predicts that these productivity differences tend to grow with the increasing exposure to the foreign markets. Finally, we also provide a tentative estimation approach that deals with the issues of factor input and exporting share endogeneity, the question of sample selection as well as offers a way to correct for the measurement errors stemming from data availability.

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