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PRODUCTIVITY MEASUREMENT FOR INTERNATIONAL FIRMS

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ABSTRACT: *This paper extends recent work by Martin (2005) on estimation of total factor productivity by allowing heterogeneity of markets in terms of competitive pressure. We show that conventional methods of total factor productivity estimation yield biased measures of TFP when firms charge market-specific prices. Specifically, if we assume that exporting price-cost markups are lower than domestic markups, then traditional total factor productivity measures will substantially underestimate exporter productivity and overestimate the productivity of non-exporters. Crucially, our results provide some possible clues on why empirical studies failed to find conclusive evidence on the learning-by-exporting hypothesis.*

Keywords: Productivity measurement, Imperfect competition, Exporting

JEL classification: C14, D24, L25

1. INTRODUCTION

Debates surrounding the accurate measurement of productivity have been a mainstay in applied econometrics since the 1940s, starting 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 endogeneity of 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 deal with a number of potential issues in productivity estimation when firms differ in their exporting status as well as in ownership status (foreign or

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domestic owned) and investment strategy (foreign investors). Following along the lines of some of 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 understate the actual exporting firms' productivity³. We base our propositions on the framework proposed by Griliches and Klette (1996), specifically, on the implied proposition that productivity in differentiated goods 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 for 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 productivity bias as well as provide an estimation approach. Furthermore, we show that the negative bias of the productivity estimates for exporting firms actually increases with the increased exposure to exporting. By revising the theoretical structure of total factor productivity of exporters we shed new light on the issue of missing evidence concerning learning-by-exporting. Namely, we show that the commonly applied total factor productivity⁴ measures understate the actual productivity differences between exporting and non-exporting firms hiding any potential learning.⁵ While our approach focuses specifically on the issues of measuring true output and markups across markets as a basis for constructing measures of productivity, De Loecker offers a different solution in the quest for finding evidence of learning by exporting by proposing that export status be included explicitly into the »law-of-motion« for productivity.⁶

The remainder of the paper is organized as follows. We start by describing the model of production commonly applied to productivity estimation in differentiated goods markets and introducing the alterations necessitated by the introduction of exporting (multinational production). The third section exploits the source and direction of the estimation bias in traditional TFP estimations as well as provide some of possible extensions that could broaden the applicability of our approach. Section four sets out the estimation procedure for elimination of the observed biases in TFP measures. Concluding remarks are presented in the last section.

³ At the same time overestimating the actual productivity of non-exporters, based on the assumption that markups are lower in exporting markets (Gullstrand et al. 2011). De Loecker and Warczynski (2011), on the other hand, find evidence that exporting markups are in fact higher than domestic sales' markups in case of Slovenia.

⁴ In practice, researchers often rely on using the residual of a production function as a measure of total factor productivity (see Griliches, Mairesse (1995) for a review).

⁵ Alas, given that we do not dispose with detailed product level exporting and production data with information on export destinations, we do not perform the empirical analysis of the changes in productivity estimates here.

⁶ Namely, assuming export status is correlated with capital stock, the coefficient on capital in productivity estimations will be biased upwardly. De Loecker suggests including export status as an additional state variable in the Olley-Pakes estimation algorithm.

2. THE MODEL

In modeling the market interactions we explored several possible approaches. Melitz-Ottaviano (2008) approach whose main attraction lies in the use of a linear demand function that enables the incorporation of endogenous markups, also yields a very tractable framework for analysis of trade liberalization. The primary detraction of using this framework for our work are the difficulties involved in estimating the production function with the nested linear demand function. As it turns out, individual firm prices are difficult to net out of the estimation equations and, given that they are rarely observable in firm-level data, the structural equation could not be estimated as is. Alternatively, Klette-Griliches (1996) estimate a very similar model to the one presented below, but choose to specify it in terms of growth rates⁷ which leads to a set of estimation equations that can be estimated with available firm-level data.⁸ Whereas their framework can easily be applied to estimate domestic markup and scale elasticities, the data requirements turn out to limit the applicability of this approach for exporters. Specifically, in order to consistently estimate both domestic and foreign markups we would require data on industry sales in all exports markets as well as suitably disaggregated deflators for those markets (for details see Appendix A).

The model we present in the remainder of this section is based loosely 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 exporting⁹ 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

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

where $U(\Theta)$ is assumed to be differentiable and quasi concave, $M(Z)$ represents aggregate industry demand shifters, σ is the elasticity of substitution and Θ_i is the consumer's valuation of firm i 's product quality. Equation (1) gives the conditional (conditioning on the price level and total industry revenue) demand functions for home (h) and foreign

⁷ Rather than in terms of logarithm deviations from the median, which we present.

⁸ De Loecker (2010) uses the Klette-Griliches framework and specifies an explicit demand system to show that the traditional productivity measures still capture price and demand shocks. The actual productivity gains, once prices are controlled for, only amount to approximately half of the gains measured with standard techniques.

⁹ The exporting revenue can simply be considered net of transport cost.

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. Home- and foreign-market demand equations are given by

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

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

where $P_{.i}$ represents firm prices in a given market and $R_{.}$ is the aggregate revenue in the respective markets. The price indices \tilde{P}_h and \tilde{P}_f are defined as

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

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

Although the home and foreign price indices determined here differ from those presented in Melitz (2001)¹⁰, the first order approximation for the percentage change in our indices 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

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

where $f(\oplus)$ is a general differentiable linear homogenous function, A_{it} represents a Hicks neutral shift parameter (TFP), X_{it} is a vector of inputs and λ is a returns-to-scale parameter. As Crozet et al (2011) point out A_{it} could quite clearly encompass both technical efficiency and/or quality and consumer taste driven shifts in demand. While the later interpretation is clearly relevant, given the lack of reliable measures of quality differences in most firm-level datasets we follow the majority of recent work in interpreting differences in A_{it} as differences in efficiency. Without loss to generality, though, one could attribute them to quality or demand shifts as well.

Invoking the mean value theorem we can write the output of a plant relative to the median plant as

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

¹⁰ Melitz's price index \tilde{P}_h is specified as $\tilde{P}_h = \left(\sum_{i=1}^N P_i^{\sigma_h - 1} / \sum_{i=1}^N \Theta_i^{\sigma_h - 1} \right)^{\frac{1}{\sigma_h - 1}}$.

where

$$b_x = \lambda f_x(\bar{\mathbf{X}}_{it}) \frac{\bar{X}_{it}}{f(\bar{\mathbf{X}}_{it})}. \quad (8)$$

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

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

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

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

where the markup M^h (M^f) is

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

Throughout the exposition we maintain the assumption that firms allocate their production optimally between the two markets by equating the marginal revenues generated in different markets. The relationship between foreign and domestic prices is therefore¹¹

$$\frac{P_{it}^h}{P_{it}^f} = \frac{M_{it}^h}{M_{it}^f} \quad (12)$$

where M_{it}^h (M_{it}^f) are domestic and foreign markups in deviations from the median firm's markups. 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 an additional error term into the estimation.¹² If labor and materials are the only variable inputs, then, conditional on capital stock, we can write

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

¹¹ The price equation is based on the equality between the marginal revenues in both markets:

$$\frac{P_{it}^h}{P_{it}^f} = \frac{M_{it}^h}{M_{it}^f}.$$

¹² $b_j^h = p_{it}^f + \ln \mu_{it}^h - \ln \mu_{it}^f + \xi_{it}$ where $\xi_{it} \sim \text{iid}(0, \sigma_\xi)$

where s_{xit}^h (s_{xit}^f) is the home (foreign)-revenue share of factor x . The problem 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) usually 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

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

where ex represents the share of exports in total quantity produced and is defined as¹³

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

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 domestic¹⁴) it will be smaller than unity. This will cause estimates of domestic markups (M^h) to be too low for exporting firms.¹⁵

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

$$b_K = \lambda - b_L - b_M \quad (16)$$

Using (7), we get

$$q_{it} = a_{it} + M_{it}^h v_{it}^h + M_{it}^h \zeta_{it} + \lambda k_{it} \quad (17)$$

where

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

is an index of all variable factors weighted by their revenue shares, k_{it} is capital of firm i at time t measured in log deviations from the median (in terms of revenue) firm and ζ_{it} is an iid error introduced due to the fact that the first order conditions might not hold exactly. Following the mean value theorem, \bar{s}_{xit}^j is the factor share prevailing at some point in the convex hull spanned by X_{it} and $X_{\text{Median},t}$. If we follow the common practice in productivity

¹³ More often than not in empirical applications (15) cannot be measured and has to be approximated by revenue shares. This issue is discussed further below.

¹⁴ We 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.

¹⁵ We explore the issue further below.

analysis¹⁶ 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 firm prices

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

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

we obtain total revenues of both the home and foreign markets $R_{it} = R_{it}^h + R_{it}^f$.

Using equations 15, 17, 20, 21 and¹⁷

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

which, assuming markups are constant across firms, yields¹⁸

$$r_{it} = 1 / \mu^h (a_{it} + \mu^h v_{it} + \mu^h \zeta_{it} + \lambda k_{it}) + (1 / \mu^h) \theta_{it} + \ln \left[\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}} \right)^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \quad (23)$$

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

$$MTFP_{it} = \left(\frac{\lambda}{\mu^h} - 1 \right) k_{it} + \frac{1}{\mu^h} \% (a_{it} + \theta_{it}) + \zeta_{it} + \ln \left[\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}} \right)^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \quad (24)$$

¹⁶ See for example Baily et al. (1992) and Martin (2005). A similar solution is implied in Criscuolo and Leaver (2005).

¹⁷ This follows since $R_{it} = R_{it}^h + R_{it}^f$ can be rewritten as $R_{it} = P_{it}^h Q_{it}^h \left[1 + \frac{ex_{it}}{(1 - ex_{it})} \frac{M_{it}^f}{M_{it}^h} \right]$.

¹⁸ Note also that the logged quantity of goods sold in the domestic market (in terms of deviation from the median) can be expressed as $q_{it}^h = \ln \left(\frac{1 - ex_{it}}{1 - ex_{Med,t}} \right) + q_{it}$.

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

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

be rewritten as

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

3. THE SOURCE OF ESTIMATION BIAS

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

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

If the median firm is a non-exporter then the last term in (23) is positive for all nonzero export shares.¹⁹ 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.²⁰

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«²¹ measured in terms of logged deviations from the median firm's »average« markup. 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.

¹⁹ This 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 $ex>0$.

²⁰ For it to be positive, the following condition has to be satisfied:

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

The condition for the term to be increasing in ex_{it} , on the other hand, is $\frac{1 - ex_{it}}{\mu^f} + \frac{ex_{it}}{\mu^h} < 1$.

²¹ As represented by the revenue-share weighted average markup.

There are several possible directions in which one could extend the above model to make it applicable to a broader spectrum of empirical issues. Amongst the possible additions to the model we focus primarily on 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 Variable markups

An important issue, that has so far been ignored, is the heterogeneity of markups. 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. The symmetry inherent to Dixit-Stiglitz type utility frameworks implies that the elasticity of substitution between any two varieties produced is equal. Furthermore, CES utility functions abstract away from any changes in the elasticity of demand²², keeping it constant instead. Whereas CES utility functions can be modified to allow for changes in the elasticity of substitution with changes in the number of varieties produced (see for instance Melitz, 2003) these modifications tend to preserve the symmetry of the produced varieties. Relaxing this assumption would further imply that markups are likely to be firm specific in contrast with the commonly applied proposition of uniform markups.

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

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

revealing that the estimates of the capital coefficient ($\beta_k = \gamma/\mu$) 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 ($((\alpha_{it} * \lambda_a) / \mu)$) would be lower.²³

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

²² In demand functions stemming from a constant elasticity of substitution utility function the elasticity of demand equals the elasticity of substitution by design.

²³ Note 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.

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

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}).

These proposed changes, though, do not deal with the principal restriction of Dixit-Stiglitz type utility functions as they maintain the symmetric positioning of varieties. In order to properly account for the markup heterogeneity a different utility function (for instance a translog function) would have to be employed. Furthermore, in estimation procedures markups would have to be treated as endogenous variables.

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). The introduction of additional 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

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

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 gained 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 variety of the product. In this section we assume that firms produce at least one variety, similar to what Melitz (2001) and Levinsohn and Melitz (2002) propose. Our approach, however, is based on 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 sunk costs of market entry are large relative to product specific sunk costs of exporting 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 is very restrictive in the variable markups scenario.

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

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

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 of production and demand as above, 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

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

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 X_i/J_i units of inputs into R_i/J_i sales according to the revenue production function outlined in (23). Average revenue per firm i 's variety becomes:

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

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:

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

Measured TFP then becomes:

$$MTFP_{it} = \left(\frac{\gamma}{\mu^h} - 1 \right) k_{it} + \frac{1}{\mu^h} \% (\tilde{\varphi}_{it} + (\mu^h - \gamma)\delta_{it}) + \varsigma_{it} + \ln \left[\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}} \right)^{\frac{1}{\mu^h}} \left(\frac{\mu^h + \mu^f ex_{it} / (1 - ex_{it})}{\mu^h + \mu^f ex_{Med,t} / (1 - ex_{Med,t})} \right) \right] \quad (37)$$

In a multiproduct setting, we therefore obtain an additional term $\delta_{it} (\mu^h - \gamma) / \mu^h$ 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 $\Delta \delta_{it} (\mu^h - 1) / \mu^h = \Delta \delta_{it} / \sigma^h$ - 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.

4. ESTIMATION

The difference between our proposed TFP decomposition and the one traditionally employed is captured primarily by the changes in factor coefficients.²⁴ 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 to explain the productivity differences between exporting and non-exporting firms. In addition, these differences are further amplified as firms' export shares increase. This could explain the persistent lack of empirical evidence on the learning-by-exporting hypothesis.

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 quantity based export share exit will be approximated by the share of export revenues in total revenues, $\bar{e}x_{it}$:

$$\bar{e}x_{it} = \frac{R_{it}^f}{R_{it}^f + R_{it}^h} = \frac{Q_{it}^f P_{it}^f}{Q_{it}^f P_{it}^f + Q_{it}^h P_{it}^h} \quad (38)$$

Evidently, the use of the above proxy introduces an additional source of bias into the estimation procedure. A slight reformulation of equation (38) shows the direction of the bias this approximation is introducing into the regressions

$$\bar{e}x_{it} = \frac{Q_{it}^f}{Q_{it}^f + Q_{it}^h} \frac{(Q_{it}^f + Q_{it}^h) P_{it}^f}{Q_{it}^f P_{it}^f + Q_{it}^h P_{it}^h} = ex_{it} \frac{Q_{it}^f + Q_{it}^h}{Q_{it}^f + Q_{it}^h} \frac{P_{it}^h}{P_{it}^f} \quad (39)$$

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 estimated markups for

²⁴ Equation 24 shows what the traditionally applied factor share based TFP measures capture when estimating total factor productivity.

the two markets, we can mitigate the above bias by using the following definition of export share²⁵

$$ex'_{it} = \bar{ex}_{it} \frac{R_{it}^f + R_{it}^h}{R_{it}^f + R_{it}^h \frac{\mu^f}{\mu^h}} \quad (40)$$

In addition, in estimating exporter productivity one is also faced with the problem of the missmeasurement of 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 (14) reveals the home-country markups obtained using total revenue²⁶ as a proxy for the total quantity produced (evaluated at home country prices) are likely to be downward biased.

$$\tilde{\mu}^h = \mu^h \left[(1 - ex_{it}) + \left(\mu^f / \mu^h \right) ex_{it} \right] \quad (41)$$

In fact, the bias will be more pronounced the larger the share of exports and the larger the difference between home and foreign country markups²⁷. 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 home-market prices as is suggested in (14), one would obtain upwardly biased estimates of foreign markups.²⁸

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

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

²⁵ For a generalization of the export share correction for a larger number of exporting markets see Appendix A.

²⁶ Revenue obtained in domestic and foreign market.

²⁷ For firms exporting to less competitive markets (markets with a higher markup) the direction of bias would be opposite.

²⁸ As expected, (41) and (42) reveal that the estimates of domestic and foreign markup would in fact be equal (a weighted average of domestic and foreign markups). For a generalization of the bias to the case of many exporting markets see Appendix A.

vidual 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). Finally, 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. PROPOSED ESTIMATION APPROACH

Any estimation approach dealing with production function estimation has to contend with some crucial endogeneity issues. As first observed by Marschak and Andrews (1944) there could be a correlation between unobserved productivity shocks and the input variables (v_{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 propose an augmented estimation procedures in order explicitly account for exporting (international investments) in firm decisions. In line with Van Biesebroeck (2005) and De Loecker (2007) the Olley and Pakes (1996) estimation algorithm could be modified to include exporting, inward as well as 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-exporting²⁹, 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 status³⁰, the latter proposes that selection into exporting serves to split the sample (into exporters and non-exporters) based on their productivity.³¹ 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

²⁹ Van 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).

³⁰ Essentially, exporting status serves as an additional determinant of investment and exit decisions in the second stage of the Olley-Pakes algorithm.

³¹ In 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.

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.³² None of the above approaches, though, deal with the issue of measuring true output when sales are used as an output measure and will therefore maintain and potentially exacerbate the misspecification of the relative productivity of exporters.

In line with the theoretical disposition we propose an estimation procedure based on market revenue (net of variable costs) as the dependent variable

$$r_{it}^h - v_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}}\right) + \varepsilon_{it} \quad (43)$$

$$r_{it}^f - v_{it} = \frac{\gamma}{\mu^f} k_{it} + \frac{1}{\mu^f} \ln\left(\frac{ex_{it}}{ex_{Med,t}}\right) + u_{it} \quad (44)$$

where ε_{it} and u_{it} are the respective the error terms. Commonly in production function estimation firm-specific productivity is not observed and therefore one has to control for its effects on the regressors and regressant.

We hence propose that an augmented version of the Olley-Pakes estimation approach akin in spirit to Van Biesebroeck (2005) is used to estimate exporter production functions.³³ Where in Olley and Pakes (1996) capital and age are the endogenous variables we believe one has to account for the endogeneity of both capital (kit) and export share variables ($\ln(ex_{it} / ex_{Med,t})$). In order to control for the unobserved productivity we employ the firm-investment function, but adapt it to include exporting status as an added state variable. This addition serves to account for the fact that exporters are likely to adopt different investment strategies than non-exporters and the response of investment to productivity shocks may differ as a consequence. In contrast to Olley and Pakes (1996) and in line with Baldwin (2005), we propose foregoing the first stage of the estimation algorithm as the coefficients on variable factors do not have to be estimated. The second stage of estimation closely follows the Olley-Pakes algorithm as we control for sample selection bias³⁴ and, finally, in the third stage using nonlinear least squares account for the endogeneity of capital and export share variables. Additionally, we propose to control for the measurement biases introduced due to data limitations by using markup estimates to correct factor-cost shares (as shown in equation 14) and export shares (as detailed in equation 40). Taking advantage of the concavity of the system of equations and use of an iterative process where markup estimates of the preceding stage are employed in the following stage in order to control for the measurement issues.

³² Coefficient estimates on the inputs are allowed to differ between exporting and non-exporting firms.

³³ A detailed description of the estimation procedure is given in the Appendix.

³⁴ In modeling firm survival we also accounted for the possible differences in attrition between domestic and exporting firms by including exporting status as one of the determinants of firm survival.

The approach we propose explicitly controls for several aspects of firm exporting behavior that are commonly ignored in standard production function estimation. In addition to including exporting status as an added state variable in the estimation, we also account for the possible differences in pricing policies in firms' markets. Following the reasoning of Griliches and Klette (1996) we simultaneously estimate markups and returns to scale which yield consistent estimates of markups. These, in turn, can be applied to construct more precise measures of exporter total factor productivity affording us a new perspective on the true productivity gap between exporting and non-exporting firms. The success of this approach rests in part on the availability of detailed information on firm exports at the product level ensuring that industry benchmark (in terms of revenue) matches closely to the observed firms.

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 reasons 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 an 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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APPENDIX A

Melitz and Ottaviano (2008) use the linear demand system with horizontal product differentiation developed by Ottaviano, Tabuchi, and Thisse (2002). The primary advantage of the set system is the modeling of endogenous markups which the authors use to generate and endogenous distribution of markups across firms with markups responding to the toughness of market competition. Clearly, this approach enables the formation of a very tractable model of market competition and trade, but its empirical verification turns out to be quite challenging. The representative consumer demand function in this case assumes the following form

$$U = q_0^c + \alpha \int_{i \in \Omega} q_i^c di - \frac{1}{2} \gamma \int_{i \in \Omega} (q_i^c)^2 di - \frac{1}{2} \eta \left(\int_{i \in \Omega} q_i^c di \right)^2 \quad (\text{A1})$$

where q_0^c and q_i^c are the respective individual consumption levels of the numeraire good and differentiated good (each variety i). Parameters α and η index the substitution pattern between the two goods, while γ indexes the degree of product differentiation between varieties. $Q^c = \int_{i \in \Omega} q_i^c di$ is the representative consumer's consumption level over all available varieties. With the inverse demand function for variety i given by

$$p_i = \alpha - \gamma q_i^c - \eta Q^c \quad (\text{A2})$$

for $q_i^c > 0$. The linear market demand system for varieties is therefore

$$q_i \equiv L q_i^c = \frac{\alpha L}{\eta N + \gamma} - \frac{L}{\gamma} p_i + \frac{\eta N}{\eta N + \gamma} \frac{L}{\gamma} \bar{p}, \quad \forall i \in \Omega^* \quad (\text{A3})$$

where N is the measure of consumed varieties in Ω^* (a subset of Ω including only those varieties that are consumed) and $\bar{p} = (1/N) \int_{i \in \Omega^*} p_i di$ is their average price. In order to consistently estimate such a demand function (or a production function in which the above demand was nested) one would have to obtain data on individual firm prices (p_i), the number of consumers (size of the market) as well as the average price of differentiated goods. Unfortunately, our dataset does not include any information on goods prices effectively preventing us from employing such a demand function.

Klette and Griliches (1996), on the other hand, base their approach on a more standard demand function, which is similar to the one we present in this paper. In terms of growth rates³⁵ their demand function is given by

$$q_{it} = q_{it} - \sigma(p_{it} - p_{it}) + u_{it}^d \quad (\text{A4})$$

Given that output at either the firm or at the industry level is not observable, we are restricted to using deflated sales as a proxy for output. In growth rates deflated sales can be represented as

³⁵ I.e. taking the logarithmic differences between year 't' and 't-1'.

$$r_{it} = q_{it} + p_{it} - p_{it} \quad (\text{A5})$$

Combining the last two equations yields

$$p_{it} - p_{it} = \frac{1}{1-\sigma} (r_{it} - q_{it} - u_{it}^d) \quad (\text{A6})$$

the right-hand side of (A6) represents the omitted price variable when deflated sales are used as an output measure. Klette and Griliches proceed to use the above omitted price specification as a regressor in a production function. Reformulating their approach to encompass both domestic and exporting firms, we obtain the following estimation equations

$$r_{it}^h = \tilde{\beta}_0^q + \frac{\sigma_h - 1}{\sigma_h} (\tilde{\beta}_1^q x_{it} + \tilde{\beta}_2^q k_{it} + (1 - ex_{it})) + \frac{1}{\sigma} q_{it}^h + \tilde{v}_{it}^{qh} \quad (\text{A7})$$

$$r_{it}^f = \tilde{\beta}_0^q + \frac{\sigma_f - 1}{\sigma_f} (\tilde{\beta}_1^q x_{it} + \tilde{\beta}_2^q k_{it} + ex_{it}) + \frac{1}{\sigma_f} q_{it}^f + \tilde{v}_{it}^{qf} \quad (\text{A8})$$

where x_{it} is an index of the (short-run) variable factors, defined as $\sum_{j \in (L, M)} s_{it}^j x_{it}^j$ with s_{it}^j as the cost share of factor j , k_{it} stands for capital, $\sigma_h(\sigma_f)$ is the domestic (foreign) elasticity of substitution, $q_{it}^h(q_{it}^f)$ are the home (foreign) industry sales and ex_{it} is the export share.³⁶ Estimating the above equations requires detailed data on the industry price indices (both domestic and for the respective exporting markets) as well as industry sales data. Again, our dataset does not include detailed information on disaggregated foreign industry characteristics (prices or sales), which seriously limits the effectiveness of estimating these equations.

APPENDIX B

Extension of the correction for mismeasurement of the export share to the many country case

$$ex_{it}^n = \tilde{ex}_{it}^n \frac{\sum_{m=1}^M R_{it}^m}{R_{it}^n + \sum_{m \neq n} \frac{\mu^n}{\mu^m} R_{it}^m} \quad (\text{B1})$$

where ex_{it}^n is the true measure of export share to market n , while $m=1, \dots, M$ indexes the exporting markets.

³⁶ Klette and Griliches use the Tornquist index for growth in the variable inputs, i.e. the shares are constructed as the average share for the two years used to construct growth rates.

Similarly, the measure of bias for the missmeasurement of the index of variable factors (vi_{it}^n) can be extended for the many country case

$$\tilde{\mu}^n = \mu^n \left[\left(\mu^h / \mu^n \right) \left(1 - \sum_{m=1}^M ex_{it}^m \right) + \sum_{m \neq n} (ex_{it}^m \frac{\mu^m}{\mu^n}) + ex_{it}^n \right] \quad (B2)$$

APPENDIX C

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 $I_t = i_t(\omega_t, a_t, k_t)^{37}$ to express the unobserved productivity variable (ω). 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.³⁸ 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 .³⁹ The evolution of the state variables is determined by

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (C1)$$

$$EX_t = EX_{t-1} + \Delta EX_t \quad (C2)$$

³⁷ The conditions for monotonicity of the relationship between investment (I_t) and the unobserved productivity variable (ω) is given in Pakes (1991).

³⁸ This leads Van Biesebroeck (2005, pp. 385) to state that even controlling for inputs and productivity exporters will make different investment decisions than non-exporters.

³⁹ Additionally, one could consider both outward and inward foreign direct investment as state variables whose evolution would be determined by $OFDI_t = OFDI_{t-1} + \Delta OFDI_t$ and $IFDI_t = IFDI_{t-1} + \Delta IFDI_t$.

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).

$$\omega_{it} = E\{\omega_{it} | \omega_{it-1}\} + v_{it} \quad (C3)$$

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.⁴⁰ 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.⁴¹

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

$$r_{it}^h - v_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}}\right) + E\{\omega_{it} | \omega_{it-1}\} + v_{it} + \zeta_{it} \quad (C4)$$

$$r_{it}^f - v_{it} = \frac{\gamma}{\mu^f} k_{it} + \frac{1}{\mu^f} \ln\left(\frac{ex_{it}}{ex_{Med,t}}\right) + E\{\omega_{it} | \omega_{it-1}\} + v_{it} + \zeta_{it} \quad (C5)$$

Employing the inverted investment function to express out the unobserved productivity term $\omega_{it} = \phi_{\omega}(I_{it}, k_{it}, EX_{t-1})$, where $\phi_{\omega}(\bullet) = i^{-1}(\bullet)$, (C4) can be rewritten as

$$r_{it}^h - v_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}}\right) + q(I_{it-1}, k_{it-1}, EX_{t-2}) + v_{it} + \zeta_{it} \quad (C6)$$

where $q(\bullet) = E\{\omega_{it} | \phi_{\omega}(\bullet)\}$. Using a higher order polynomial to approximate for $q(\bullet)$ reduces (C6) to a simple least squares problem. We suppose that multicollinearity between ex_{it} and EX_{t-2} is not a critical issue given that the latter is an indicator variable while the former is theoretically continuous. On the other hand, γ/μ may not be identifiable from (C6) as k_{it} will be correlated with k_{it} as well as I_{it-1} . Estimates obtained from running a regression on equation C6 will therefore be used for initial values only in a more econometrically efficient procedure. Following Olley and Pakes (1996) we start by estimating

$$r_{it}^h - v_{it} = \psi(ex_{it}, k_{it}, I_{it}, EX_{it-1}) + \zeta_{it} \quad (C7)$$

where $\psi(ex_{it}, k_{it}, I_{it}, EX_{it}) = (\gamma / \mu^h) k_{it} + (1 / \mu^h) \ln[(1 - ex_{it}) / (1 - ex_{Med,t})] + \phi_{\omega}(k_{it}, I_{it}, EX_{t-1})$.

⁴⁰ Firm 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).

⁴¹ The assumptions on the investment function $i(\bullet)$ that ensure its invertibility are stated in Van Biesebroeck (2005).

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 ψ for each observation. Subsequently, (C7) can be reformulated in terms of a nonlinear least squares problem

$$r_{it}^h - v_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}}\right) + h(\hat{\psi}_{it-1}) - \frac{\gamma}{\mu^h} k_{it-1} + \frac{1}{\mu^h} \ln(1 - ex_{it-1}) + v_{it} + \zeta_{it} \quad (C8)$$

where $h(\bullet) = \{\omega_{it} | \bullet\}$ is approximated by a polynomial. The issue of endogeneity may also be 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.

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 level⁴², 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} .

$$\underline{\omega}_{it} = \underline{\omega}_{it}(k_{it}, EX_{t-1}) \quad (C9)$$

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

$$\Pr(survival) = \Pr(\omega_{it+1} \geq \underline{\omega}_{it+1}(k_{it+1}, EX_t) | \underline{\omega}_{it+1}(k_{it+1}, EX_t), \omega_{it}) \quad (C10)$$

by the law of iterated expectations and using the transition equations, (C10) can be rewritten as⁴³

⁴² Therefore they are likely to stay in operation even at lower ω realizations.

⁴³ The second and third equalities follow from (C1) and (C2).

$$P(\text{survival}) = P_i(k_{i+1}, EX_i, \omega_i) = P'_i(k_i, I_i, EX_{i-1}, \Delta EX_i) = P''_i(k_i, I_i, EX_{i-1}, EX_i) \quad (\text{C11})$$

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 (C4) becomes⁴⁴

$$r_{it}^h - vi_{it} = \frac{\gamma}{\mu^h} k_{it} + \frac{1}{\mu^h} \ln\left(\frac{1 - ex_{it}}{1 - ex_{Med,t}}\right) + h(P_{it-1}, \hat{\psi}_{it-1} - \frac{\gamma}{\mu^h} k_{it-1} + \frac{1}{\mu^h} \ln(1 - ex_{it-1})) + v_{it} + \zeta_{it}$$

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.

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 miss-measurement 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 revenue⁴⁵ is considered, the empirically viable variable-factor index vi_{it} will overstate the true variable-factor index, while, at the same time, vi_{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 41 and 42) and used in the following step of the iteration. We suggest that in the first stage of the estimation process vi_{it} is used in (53), where the obtained markups are then used to recalculate vi_{it} . This iterative process would continue until the markup estimates in consecutive stages do not differ substantially.

⁴⁴ The foreign revenue equivalent, which would enable one to retrieve the foreign-market markups, would be $r_{it}^f - vi_{it} = \frac{\gamma}{\mu^f} k_{it} + \frac{1}{\mu^f} \ln ex_{it} + q(I_{it-1}, k_{it-1}, EX_{t-2}, P_{it-1}) + \tilde{v}_{it} + \tilde{\zeta}_{it}$.

⁴⁵ The case when in the calculation of factor revenue share the total quantity produced is evaluated at domestic prices.