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Import Competition, Productivity and Multi-Product Firms*

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Abstract

Using detailed firm-product level quarterly data, we develop an estimation framework of a Multi-Product Production Function (MPPF) and analyse firm-product level TFP estimations at various levels (industries, products). After documenting our estimation results, we relate productivity estimates with import competition, using firm and product level measures of import competition. We find that if productivity at the firm level tends to positively react to increased import competition, the multi-product firms response varies according to the relative importance of the product that faces stronger import competition in the firm's product portfolio. When import competition associated to the main product of a firm increases, the firm tend to increase its efficiency in producing that core product, in which it has a productivity advantage. However, when the degree of foreign competition increases for non core products of a firm, it tends to lower its efficiency in producing those goods.

JEL - Code : D24, L22, L25
Keywords : multi-product production function, productivity, import competition

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1 Introduction

Product market competition is often considered by economists as an important mechanism to promote efficiency. (see e.g. Aghion and Howitt, 1996 for a theoretical motivation; see also Holmes and Schmitz, 2010 for a recent review of the literature). It is supposed to discipline firms and provide them strong incentives to innovate and adopt new practices in order to remain profitable or simply survive. Several important contributions in the productivity literature (e.g. Olley and Pakes, 1996; Pavcnik, 2002) have established a clear relationship between productivity growth and increased competition.

In this paper, we study how increased import competition has been associated with productivity growth in a small open economy, Belgium. We estimate productivity growth over a long time period (1995-2007) using detailed and highly disaggregated quarterly data about firms' production patterns and we provide several contributions to the literature.

First, we suggest two approaches to estimate productivity with multi-product firms and the presence of pricing heterogeneity at a very disaggregated level. In our first approach, we use pricing information at the firm-product level to build a firm level price index (see e.g. Eslava et al., 2004, and Smeets and Warzynski, 2013) and deflate the firm's total revenue using this firm-specific deflator. We then estimate firm-level productivity using different techniques (OP, Wooldridge) and assess the importance of using the proper deflator. Our second approach directly uses production in physical quantities and extends the framework of Mundlak and Razin (1971) and Diewert (1973) to estimate multi product production function (MPPF). This technique does not require any assumption about the way firms are sharing their inputs between the various products it makes. It essentialy shows that under mild regularity conditions there will exist a multi-product transformation function that relates the output of any good to all the other goods a firm produces and to aggregate inputs use. Our approach generates a measure of productivity that is firm-product specific. Our estimation techniques are also adapted to the quarterly nature of the data.

Second, we relate our firm and firm-product level measures of productivity to import competition during a period where international trade dramatically increased, even in a country already largely open to imports. Our objective is to assess the disciplining effect of import competition on domestic firms. To do so, we suggest new measures of import competition adapted to the specific case of Belgium. Belgium is a small open economy and also an important platform in global trade (among other factors through the Antwerp harbor activity). Belgian firms are also very active in global value chains, and they re-export a substantial share of the goods that they import. In an attempt to deal with these factors, we define a first measure of import share based on imports expressed in physical units rather than in value in order to deal with the increase in value added associated with the re-export or offshoring; and we also use a second measure that introduce a corretion for re-exporting.

Third, we provide an empirical assessment of theoretical predictions of recent theories of international trade with multi-product firms (e.g. Bernard, Redding and Schott, 2010, 2011; Mayer, Melitz and Ottaviano, 2014). These papers consider that firms have a clear ordering of products based on their capability. The most important (core) product corresponds to the core competency of the firm. Since we are able to measure productivity at the firm-product level, we can estimate whether the core product is produce more efficiently than the relatively less important products in the firm's portfolio. We can also evaluate how the different products were affected by import competition.

Our MPPF estimation yields sensible results for the various methods that we use. At the firm-level, we find that the coefficients vary very little whether we use an industry-level producer price index or a firm-level price index. However, the standard deviation of our productivity measures is larger with the latter, suggesting more heterogeneity in physical TFP (TFPQ) than in revenue TFP (TFPR). Our productivity measures obtained from the firm-product estimation display even more dispersion.

When we look at the link between our measures of TFP and import competition, we find that competition is generally positively related to productivity. The sensitivity of productivity to imports differs depending on the level of aggregation at which the estimation is made. At the firm-level, the more disaggregated the analysis, the more clearly we can identify a relationship. At the firm-product level, we find a clear positive relationship only in first difference. But, at such a disaggregated level, we can also go one step further and test how the rank of the product affects the relationship. We find that import competition is strongly and positively related to productivity for the core product, but the relationship is often negative for the non-core products. We also find evidence that firms are more productive for their core products, in line with the predictions of several models of multi-product firms..

Our paper is related to a line of research using detailed information about products made by firm to provide a new perspective on productivity measurement.[1] Pioneering the work in this area, Roberts and Supina (2000) exploited the Census of Manufacturers to document price heterogeneity and its evolution across several product markets for a series of homogeneous products. They also estimated marginal cost controlling for the multi-product nature of production and computed a markup at the firm-product level. Using a similar dataset, Foster, Haltiwanger and Syverson (2008) computed two measures of TFP, physical TFP (TFPQ) and revenue TFP (TFPR), and showed that prices are positively correlated with TFPR, but negatively related to TFPQ, what can be explained by the fact that more efficient firms charge lower prices. However, they focus their analysis on homogeneous products and do not explicitly deal with multi-product firms (they are concerned with the main product of the firm).

More recently, Dhyne, Petrin and Warzynski (2014) also suggest an extension to the Diewert (1973) framework but limit their attention to a two-product setting in the Belgian bakery industry which had been exposed to an important change in the competition environment. They find that price deregulation was associated with an increase in price and quality, leading to an increase in consumer surplus. De Loecker et al. (2012) study the effect of trade liberalization in India on prices, marginal costs and markups. They suggest a novel algorithm to estimate production function and markups with physical quantity and multi-product firms where they endogenously derive

[1] Several papers have also suggested a different approach where the analysis stays at the firm-level (see e.g. Klette and Griliches, 1996; Levinsohn and Melitz, 2001; Mairesse and Jaumandreu, 2005; De Loecker, 2011).

the share of inputs allocated to each output. We offer a different method, using a more general extension of Diewert's approach, where we do not need to make any assumption about or even measure this share.

Our work is also inspired by a long tradition of estimating the link between import competition and firms' efficiency (see e.g. Pavcnik, 2002 and the survey by Holmes and Schmitz, 2010). However, our paper is focused on the importance of proper measurement of productivity in the presence of pricing heterogeneity and multi-product firms in order to properly assess this link. Rather than using a macroeconomic or a sectoral measure of import competition, we also try to carefully measure the degree of import competition faced by an individual firm according to its product mix.

The rest of the paper is structured as follows. Section 2 describes the detailed quarterly firm-product dataset that we build. In section 3, we explain the methodologies that we use to estimate MPPF. Section 4 shows the estimates of our MPPF and the results about the link between productivity - both at the firm-level and at the firm-product level - and our measures of competition. Section 5 concludes

2 A quarterly dataset of Belgian manufacturing firms

This paper is based on a very rich dataset combining firm-product level and firm-level information covering the Belgian manufacturing sector during the 1995Q1-2007Q4 period. At the firm-product level, we use high frequency data coming from the Belgian industrial production survey (here after PRODCOM survey) and the international trade data hosted at the National Bank of Belgium (NBB). These data are aggregated at the quarterly frequency for compatibility reasons with the other sources of information. At the firm level, we use quarterly information coming from 3 different sources: the VAT declarations, the Social Security declarations and the annual accounts.

2.1 The Belgian PRODCOM survey

From the monthly PRODCOM surveys filled by Belgian manufacturing firms, we have built quarterly time series of production at the PRODCOM 8 digit level (e.g. 15.96.10.00 for "Beer made from malt", 26.51.11.00 for "Cement clinker"). In this dataset, we observe production for 3,792 different product codes. This information is reported by manufacturing firms both in monetary (EUR) and physical units, which allows us to compute the unit value of each product at the firm level on a quarterly basis. The product classification is subject to minor revisions every year. However, as the first 4 digits of the PRODCOM code are refering to the CPA product classification (the product equivalent of the NACE classification), when this classification is revised (for instance in 2008, the CPA rev 2. classification has been introduced) the PRODCOM classification is entirely redifined. In order to moderate the impact of the update of the product classification, our sample ends in 2007Q4.

2.2 The VAT fiscal declarations

Belgian firms have to report on a monthly (for large firms) or quarterly basis their sales and purchases to the fiscal administration. Using that information, we have built quarterly time series for the turnover, the input consumption (purchages of non durable goods) and the investments (purchages of durable goods), from 1995Q1 to 2007Q4.

2.3 The Social Security declarations

Belgian firms report on a quarterly basis their level of employment and wages to the National Social Security Office. Based on these reports, we are able to follow total employment, at the firm level, from 1995Q1 to 2007Q4.

2.4 The Central Balance Sheet Office database

The Central Balance Sheet Office database provides detailed financial accounts for Belgian firms on an annual basis. We use this data source in conjonction with the VAT declarations in order to build quarterly time series for the capital stock. For the first year of observation of a given firm in our sample, we take the total fixed assets as reported in the annual account and using perpetual inventory methods, we build quarterly capital stock for the following years using the quarterly investments as reported in the VAT declarations. In order to build the capital stock, we assume a constant depreciation rate of 8% per year for all firms. Real capital stock is computed using the quarterly deflator of fixed capital gross accumulation.

The initial capital stock in $t = t_0$, where period t_0 represents the 4th quarter of the first year of observation of the firm, is given by

$$K_{t_0} = \frac{Total\ fixed\ assets_{first\ year\ of\ observation}}{P_{K;t_0}}$$

The capital stock in the subsequent periods is given by

$$K_t = (1 - 0.0194)\, K_{t-1} + \frac{I_t}{P_{K;t}}$$

When estimating the production function, we assume that the new investiment is not readily available for production and that it takes 4 quarters for a new unit of capital to be fully operational.

2.5 The international trade database

This database provides firm-level information on international transactions of goods, by product, classified according to the CN 8 digit product classification, and by country of destination for export or country of origin for imports. For this project, we use this information to compute various measures of import competition at the product level or at the firm-level (see Section 2.7).

2.6 Our sample

After merging all these data sources, we end up with a dataset that contains 925,641 quarterly observations, which refer to 3,792 products (PRODCOM 8 digit classification) and 11,485 firms, out of which 6,292 are multi-product firms at least during one quarter over our observation period.

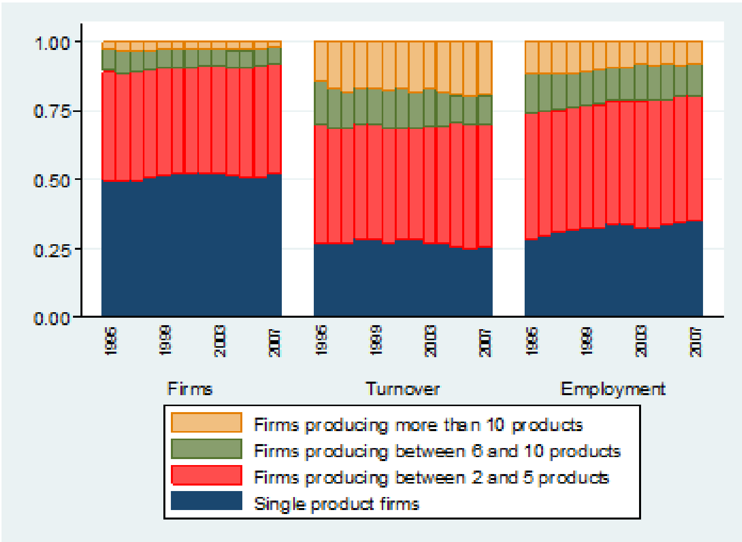


Figure 1: Contributions of single and multi-product firms

The median firm is observed during 32 quarters and produces between one and two products, while the median firm x product is observed during 16 periods. If single product firms tend to represents around 50% of the firms in a given period, Figure 1 indicates that multi-product firms have a larger weight in the economy as they represent between 70 and 75% of the total employment or total turnover recorded in our sample. The economic importance of multi-product firms in the manufacturing sector is therefore demonstrated and strengthens the interest to analyze with care the behaviour of those multi-product firms. From a purely statistical perspective, multi-product firms are also representing 84% of our observations.

As illustrated in Figure 2, the average multi-product firm in our sample produced 4.1 different products in 1995. If that number declined from 1995 to 2000, it increased thereafter until 2007 to almost come back to its initial level.

2.7 Measuring import competition

As mentioned above, one of the objectives of this paper is to analyze how firms react to changes in the degree of foreign competition.

A traditional measure of import competition at the macroeconomic level

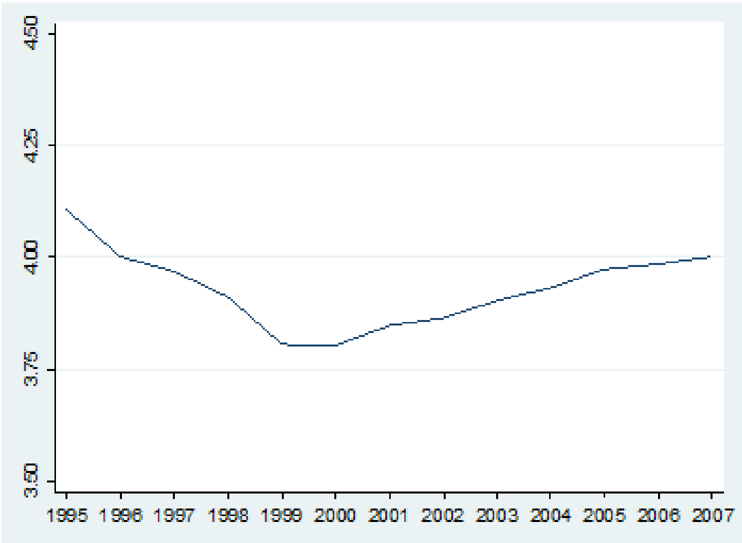


Figure 2: Average number of products produced by multi-product firms

is given by the import penetration rate of a country,

$$IPR_t = \frac{M_t}{Y_t - X_t + M_t}$$

where M, Y and X are respectively the total imports, GDP and total exports of a country.

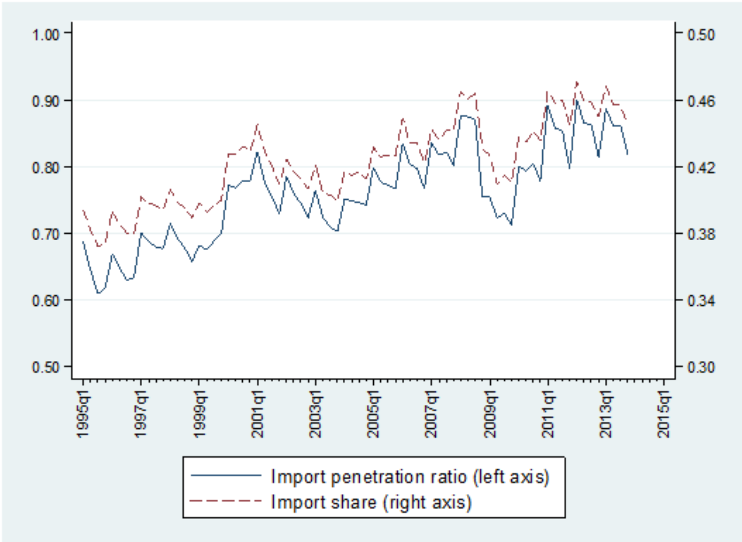
As illustrated in Figure 3.a, over our observation period, this index has followed an upward trend until the 2008 crisis, indicating an increase in the degree of foreign competition faced by Belgian producers.

The evolution is similar if we use the import share as an alternative index:

$$IS_t = \frac{M_t}{Y_t + M_t}$$

If this macroeconomic indicator may be useful to assess the overall degree of import competition, it may be of little help to assess the degree of international competition faced by a firm. In a classical "guns and butter" economy, producers of butter don't care much about increases in the number of imported guns. If the product produced by a Belgian firm is not imported at all, this firm is facing no import competition, even if the overall degree of import competition is increasing.

a. Total economy



b. Shampoo

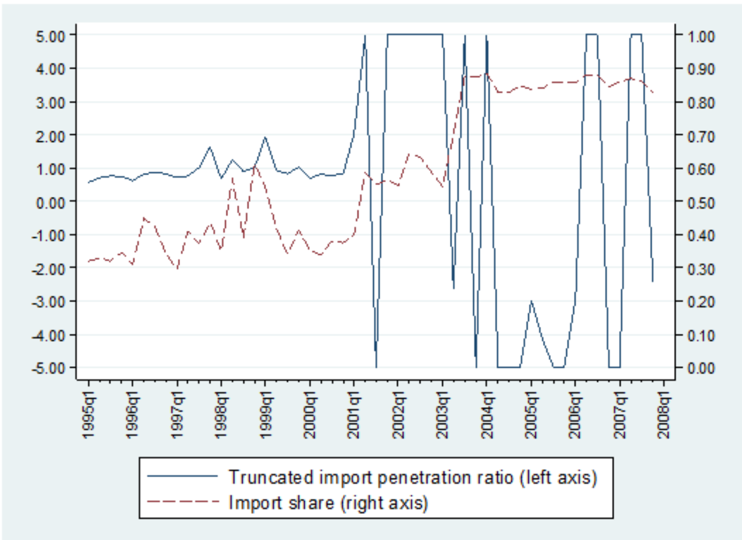


Figure 3: Import competition at the macro and micro level

The richness of our dataset allows us to identify the degree of import competition faced by a firm, taking into account the composition of its product portofolio. To do so, we have used information on exports, imports and total domestic production at the PRODCOM 8 digit product code level.

Both international trade data and the PRODCOM survey are not based on a sample of respectively exporters, importers and domestic producers but the reporting threshold for both sources are such that they cover 97% of the total exports, 95% of total imports and 90% of domestic production. Therefore, their respective sample covers almost the entire population. Measures based on the microeconomic data on trade and production at the product level may therefore be used to compute import competition index that are product specific. We have considered the same two measures of import competition.

Both indicators were computed for a given good g using

1. total exports, imports and domestic production (including custom work) of good g in period t in monetary unit, denoted IPR_{1gt} or IS_{1gt}

2. total exports, imports and domestic production of good g in period t in physical units, denoted IPR_{2gt} or IS_{2gt}.[2]

When looking at product level import penetration rates, it clearly emerges that - if this measure is a suitable measure of import competition at the macroeconomic level - it is inappropriate to measure that phenomenon at the product level.

Out of the 1,484 product categories for which we can compute a measure of import competition over the 1995Q1-2007Q4 period, only 220 have an import penetration ratio between 0 and 1. For the other product categories, this ratio can be negative and extremely volatile, if the value of exports in a given quarter comes close or exceeds the sum of domestic production and imports. Figure 3.b shows an example of such a product.

A more meaningful indicator of import competition at the product level seems to be the import share that lies by definition between 0 and 1.

[2] The computation of the import penetration rate or of the import share using physical units can only been done for products codes expressed in the same units in the prodcom survey and the international trade statistics.

If it has desirable statistical properties, this indicator is still not necessarily a relevant measure of import competition faced by domestic firm when it is measured in monetary units, especially in small open economies. Indeed, the Belgian international trade is strongly affected by re-exports[3] because Belgium has a world-class harbour which is used by foreign competitors has an entry gate to the EU single market. Therefore, a significant fraction of the product entering in Belgium through our harbours or airports are re-shipped in other EU markets. Therefore, when computing the import penetration ratio or the import share, the numerator and denominator should be corrected for re-export.

Ideally, in both expression, we should replace the imports by the amounts of imports net of re-exports. However, such a measure is not available because you cannot directly identify the amount of re-exports.

In order to do so, we made the assumption that when a firm imports and exports the same good g, its import of that particular product for the Belgian market is given by $Max\left\{M_{igt} - X_{igt}, 0\right\}$, which means that if a firm is producing and importing the same product, it first exports what has been imported and it only exports its domestic production if the amount exported is larger than the amount imported. Now, when it is based on trade flows in monetary units, the net imports may be equal to 0, even if some imported goods are indeed sold in Belgium, if the export prices is larger than the import prices. Therefore, the net imports should be expressed in physical units and that measure should be used to measure the degree of import competition faced by a producers of a given good g :

$$IS_{3gt} = \frac{\sum\limits_{i \,\in\, \text{Importers}} Max\left\{M_{igt} - X_{igt}, 0\right\}}{Y_{gt} - \sum\limits_{i \,\in\, \text{Importers}} Max\left\{M_{igt} - X_{igt}, 0\right\}}.$$

Finally, with our set of measures of import shares at the product level, we are able to compute the average degree of import competition faced by

[3] This motivates the production of two versions of international trade statistics by the National Accounts Institute : the exports and imports according to the community and national concepts. The national concepts excludes transactions from fiscal representatives of foreign firms that have no economic activities in Belgium.

firm i in period t according to its product portfolio, given by

$$IS_{kit} = \sum_{g} s_{igt} IS_{kgt}$$

for $k = 1, 2, 3$,and where s_{igt} represents the share of good g's sales in firm i's turnover at time t.

3 Methodology

The recent literature on productivity has been trying to address two important difficulties: dealing with pricing heterogeneity and the presence of multi-product firms. Our aim is to explore various ways to deal with these issues.

To better consider the issues at stake, consider a standard production function:

$$Q_{it} = \Theta_{it} f(X_{it}) \tag{1}$$

where Q is a measure of output, X is a vector of inputs, Θ is an index of technical progress, i is a firm index and t a time index.

Taking logs and assuming a Cobb-Douglas function for simplicity:

$$q_{it} = \alpha x_{it} + \vartheta_{it} \tag{2}$$

where lower cases denote logs, α is a vector of parameters to be estimated, $\vartheta_{it} = \omega_{it} + \epsilon_{it}$, ω is a measure of "true" (observed by the manager but not by the econometrician) productivity and ϵ is a true noise (unexpected shock to productivity).

In almost all cases, Q is not a real measure of output but firm revenue deflated by an industry-level price index P_{jt}. This leads to several difficulties in the estimation of productivity. First, our measurement of productivity might include a price bias, potentially correlated with the inputs (Klette and Griliches, 1996; De Loecker, 2011). Second, even if one has access to physical quantity data, adding up these quantities to a single measure of physical quantity for multi-product firms turns out to be an impossible task in most cases[4]. In this paper, we propose two different options to deal with these issues: one where the analysis stays at the firm-level, and another one where it is conducted at the firm-product level.

3.1 Option #1: Construct a firm-level price index

One way to solve the price bias would be to deflate the firm's revenue by a firm specific price index that reflects the evolution of the firm's prices. To compute such a price index, one needs detailed information about the price of each good g manufactured by firm i.

We define firm-level price growth as:

$$\Delta P_{it} = \sum_g \overline{s}_{igt} \Delta ln(P_{igt})$$

where

$$\Delta ln(P_{igt}) = ln(P_{igt}) - ln(P_{ig(t-1)})$$

and

$$\overline{s}_{igt} = (s_{igt} + s_{ig(t-1)})/2.$$

Taking the first quarter of 1995 as the base quarter ($P_{i,1995Q1}$=1), one can build the firm specific price index by simply adding the firm specific price change in the subsequent periods, as

$$P_{it} = P_{i(t-1)} + \Delta(P_{it})$$

For firms entering after the first period, we adjust the algorithm by using the industry average for the entry year as the starting value for the price index of those firms and then we follow the same procedure described above.

Once we have defined our firm-level price index, we use it to deflate firm's revenue instead of the industry level price index.

[4] Even if butter and guns were measured in the same physical units (kg or tons), the production of a firm that produces the two goods could not be simply measured by the total weight.

3.2 Option #2: The extended Diewert approach

As documented in Section 2.6, 54% of the firms in our dataset are, at least during one quarter, multi-product firms and those multi-product firms represent 81% of our observations. Thus, when considering firm-product level analysis of productivity, we have decided to focus only on multi-product firms and on models of multi-product production functions.

Our second approach builds on and extends Diewert (1973), who shows that under mild regularity conditions there will exist a multi-product transformation function that relates the output of any good g to all the other goods a firm produces and to aggregate input use.[5] The fact that the transformation function has the aggregate levels of inputs as arguments is helpful as we have no information on how inputs are distributed among the multiple goods in production.[6]

We add to the Diewert setup a productivity term ω_{ijt} which we assume follows a first-order Markov process and which may be correlated with both inputs and outputs.

Dhyne, Petrin and Warzynski (2014) estimate a MPPF for the bakery industry where most firms produce exactly 2 products (bread and cake). In this simple case, one can write:

$$q_{iBt} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \gamma_C q_{iCt} + \omega_{ijt} + \eta_{ijt} \tag{3}$$

where q_{iBt} and q_{iCt} denote the output quantities (in logs) of bread and cakes respectively. The production parameters $\beta = (\beta_l, \beta_k, \beta_m)$ now have the interpretation as the percentage change in bread output due to a percent change in each of the total input levels respectively while holding the production of cake constant. γ_C is the change in bread output that results from increasing the output of cake by one percent holding overall input use constant. The function is only well-defined when $\beta > 0$ and $\gamma_c < 0$, and this provides a simple test of specification.

However, in reality, many firms produce more than 2 goods (around 4 on average) and industries are composed of firms with different product portfolios. We generalize the theory by simplifying the problem and assuming we

[5] See also Mundlak and Razin (1971).

[6] This is almost always true in plant- or firm-level data.

can aggregate all the other products produced by the firm (except good g).[7] We are therefore suggesting an hybrid method, and we estimate instead:

$$q_{igt} = \beta_0 + \beta_l l_{it} + \beta_k k_{it} + \beta_m m_{it} + \gamma_{-g} r_{i(-g)t} + \omega_{igt} + \eta_{igt} \tag{4}$$

where q_{igt} denotes the log of physical quantity of a good g produced by firm i and $r_{i(-g)t}$ denote the log of revenue of all the other goods produced by firm i, deflated by firm i specific price index for all these other goods it produces.

To estimate this function, we must take into account that both inputs and the output variable of the other products produced by the firm are likely to be correlated with the unobserved (to the econometrician) productivity shock. One advantage of this setup is that the proxy methods for the estimation of production function parameters are readily adapted to the transformation function setting. We use the Wooldridge (2009) versions of Levinsohn and Petrin (2003) and Olley and Pakes (1996) to allow for correlation between the technical efficiency error and both the inputs and the revenue of the other goods. Once the transformation function is estimated, the productivity shocks can be directly recovered.

When bringing this equation to the data, we only considered the 3 main products of a firm's portfolio as long as they represent at least 5% of the firm's turnover. The production of minor goods may be totally disconnected from changes in inputs and additional revenues making the estimation of this equation extremely difficult (it pushes the γ_{-g} coefficient towards large negative values).

3.3 Accounting for Simultaneity

We review the Olley-Pakes and Levinsohn-Petrin methodologies within the Wooldridge (2005) framework with annual data. We then show how we extend these frameworks to settings with quarterly data.

[7] Roberts and Supina (2000) make a similar simplification when estimating cost functions.

3.3.1 Wooldridge OP/LP Methodology with Annual Data

The production function is written with the log of output as a function of the log of inputs and shocks

$$y_t = \beta_l l_t + \beta_k k_t + \beta_m m_t + \omega_t + \epsilon_t$$

where l_t denotes labor, k_t denotes capital, and m_t denotes the intermediate input (such as materials or energy). ω_t is the productivity shock, a state variable observed by the firm but unobserved to the econometrician and assumed to be a first-order Markov. ω_t is the source of the simultaneity problem as freely variable inputs l_t and m_t respond to it. k_t is a state variable and is allowed to be correlated with $E[\omega_t|\omega_{t-1}]$, but it is assumed that $\xi_t = \omega_t - E[\omega_t|\omega_{t-1}]$, the innovation in the productivity shock, is uncorrelated with k_t. ϵ_t denotes an i.i.d. shock that is assumed to be uncorrelated with all of the inputs.

OP write investment as a function of the two state variables

$$i_t = \mathbf{i}_t(\omega_t, k_t)$$

and Pakes (1996) provides conditions under which investment is strictly monotonic in ω_t holding k_t constant. OP then invert this function to get the control function with arguments i_t and k_t.[8] Wooldridge (2005) uses a single index restriction to approximate unobserved productivity, so in the OP setting one has

$$\omega_t = h_t(i_t, k_t) = \mathbf{c}(i_t, k_t)'\beta_\omega$$

where $\mathbf{c}(i_t, k_t)$ is a known vector function of (i_t, k_t) chosen by researchers. He also writes the nonparametric conditional mean function $E[\omega_t|\omega_{t-1}]$ as

$$E[\omega_t|\omega_{t-1}] = q(\mathbf{c}(i_{t-1}, k_{t-1})'\beta_\omega)$$

for some unknown function $q(\cdot)$.[9]

[8] LP write intermediate input demand as a function of the state variables $m_t = \mathbf{m}_t(\omega_t, k_t)$ and provide weak conditions under which $\mathbf{m}_t(\cdot,\cdot)$ is strictly monotonic in ω_t holding k_t constant. The intermediate demand function can then be inverted to obtain the control function for ω_t as a function of observed m_t and k_t, written as $\omega_t = h_t(m_t, k_t)$.

[9] LP use m_t and m_{t-1} instead of i_t and i_{t-1} respectively for ω_t and $E[\omega_t|\omega_{t-1}]$.

Rewriting the production function as

$$y_t = \beta_l l_t + \beta_k k_t + \beta_m m_t + E[\omega_t|\omega_{t-1}] + \xi_t + \epsilon_t \tag{5}$$

yields

$$[\xi_t + \epsilon_t](\theta) = y_t - \beta_l l_t - \beta_k k_t - \beta_m m_t - q(\mathbf{c}(i_{t-1}, k_{t-1})'\beta_\omega)$$

with $\beta = (\beta_l, \beta_k, \beta_m, \beta_\omega)$, $\theta = (\beta, q)$. Let the set of conditioning variables be $x_t = (k_t, k_{t-1}, m_{t-1}, l_{t-1})$ and let θ_0 denote the true parameter value. Wooldridge shows that the conditional moment restriction

$$g(x_t; \theta) \equiv E[[\xi_t + \epsilon_t](\theta)|x_t] \text{ and } g(x_t; \theta_0) = 0$$

is sufficient for identification of $(\beta_l, \beta_k, \beta_m)$ and $E[\omega_t|\omega_{t-1}]$. It is also robust to the Ackerberg, Caves, and Frazer (2006) criticism of OP/LP. In equation (5) a function of i_{t-1} and k_{t-1} conditions out $E[\omega_t|\omega_{t-1}]$. ξ_t is not correlated with k_t, so k_t can serve as an instrument for itself. Lagged labor l_{t-1} and lagged materials m_{t-1} serve as instruments for l_t and m_t.

3.4 Extension to Quarterly Production Data

While the theory of Wooldridge OP/LP extends directly to quarterly data, one challenge that we found was that control functions that were based on the previous quarter's data were too highly correlated with the current period data to be able to estimate parameters with any precision. While we could aggregate the data to the annual level and proceed as before, the resulting efficiency loss is equivalent to reducing the sample size to one-fourth of what we observe. For this reason we develop a modified version of Wooldridge OP/LP that permits the use of all of the quarterly data.

We continue to assume that firms see their current productivity shock when deciding on the freely adjustable inputs l_t and m_t. However, when forecasting the expected value of this season's productivity shock, we assume firms' use the productivity shock from the same season of the previous year. As we show the only change in the setup is that we must use a control function based on investment and capital (or materials and capital) from four quarters prior to the current quarter for the moment to be valid.

The relevant expectation for the estimation equation under this new assumption becomes $E[\omega_t|\omega_{t-4}]$, so we now write the conditional mean as

$$E[\omega_t|\omega_{t-4}] = q(\mathbf{c}(i_{t-4}, k_{t-4})'\beta_\omega)$$

for some unknown function $q(\cdot)$.[10] The production function is then written

$$y_t = \beta_l l_t + \beta_k k_t + \beta_m m_t + E[\omega_t|\omega_{t-4}] + \xi_t + \epsilon_t \tag{6}$$

where ξ_t is now given as $\xi_t = \omega_t - E[\omega_t|\omega_{t-4}]$. The new residual for the moment condition is given as

$$[\xi_t + \epsilon_t](\theta) = y_t - \beta_l l_t - \beta_k k_t - \beta_m m_t - q(\mathbf{c}(i_{t-4}, k_{t-4})'\beta_\omega).$$

The new set of conditioning variables is $x_t = (k_t, k_{t-4}, i_{t-4}, m_{t-1}, l_{t-1})$. The conditional moment restriction

$$g(x_t;\theta) \equiv E[[\xi_t + \epsilon_t](\theta)|x_t] \text{ and } g(x_t;\theta_0) = 0$$

which is sufficient for identification of $(\beta_l, \beta_k, \beta_m)$ and $E[\omega_t|\omega_{t-4}]$. This estimator continues to be robust to the Ackerberg, Caves, and Frazer (2006) criticism of OP/LP. In this setup the control function of i_{t-4} and k_{t-4} conditions out $E[\omega_t|\omega_{t-4}]$. ξ_t continues to not be correlated with k_t under the timing assumptions from OP/LP so k_t can serve as an instrument for itself. Lagged labor l_{t-1} and lagged materials m_{t-1} serve as instruments for l_t and m_t. This framework can be easily extended for the estimation of MPPF. In this case, the revenue of the other goods, $r_{(-g)t}$, is instrumented with $r_{(-g)t-1}$.

4 Results

In this section, we first present the results we obtain from the estimation of a classical firm level revenue production function and of our MPPF at

[10] LP uses m_{t-4} instead of i_{t-4}.

Table 1: Production function - Manufacturing

	PPI deflator				Firm-level price deflator			
	L	K	M	#	L	K	M	#
OLS	0.199***	0.047***	0.756***	156,713	0.180***	0.034***	0.786***	152,198
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)	
Olley and Pakes	0.180***	0.068***	0.751***	130,519	0.163***	0.055***	0.783***	127,013
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)	
Wooldridge	0.170***	0.085***	0.769***	112,914	0.156***	0.074***	0.795***	110,389
	(0.00)	(0.00)	(0.00)		(0.00)	(0.00)	(0.00)	

The Olley and Pakes and Wooldridge estimators are modified to capture the quarterly frequency of our dataset. Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time dummies. Observations characterized by negative value added or outliers with respect to the share of turnover reported in the PRODCOM survey relative to the one reported in the VAT declaration, the turnover per employee, the capital stock per employee and the turnover per material inputs are excluded of the estimation sample.

various levels of analysis. We then use our estimates to compute firm level and firm x product level TFP estimates and we characterize the properties of the distribution of those estimated productivities. Finally, we relate our TFP estimates with our firm specific or product specific import shares and analyze how firms respond to changes in the degree of foreign competition.

4.1 Estimation at the firm-level

Table 1 shows the estimation according to our various techniques when we pool all firms from the manufacturing industry. By doing so, we are explicitely assuming that all firms share a similar technology as we condition the parameters of the production function to be similar across industries. Despite its obvious limitations, this is often used in practice in many empirical papers. What we observe is that the coefficient of labor is going down and the coefficient of capital is going up as we are moving from OLS to OP and Wooldridge[11], keeping constant returns-to-scale. This is in line with previous results and the intuition that the most advanced methods are correcting for the endogeneity bias. We also observe that the coefficients do not vary a lot when we deflate output with the industry PPI compared to when we use our firm specific index.

In Table 2, we pool observations by 2-digit industry and we focus only on

[11] We also used the LP and ACF estimators to check the robustness of our results.

Table 2: Production function by NACE rev. 2, 2 digit industries

	PPI deflator				Firm-level price deflator			
	L	K	M	#	L	K	M	#
Manufacture of food products	0.126*** (0.00)	0.084*** (0.01)	0.807*** (0.00)	18,613	0.123*** (0.00)	0.084*** (0.01)	0.813*** (0.00)	16,903
Manufacture of beverages	0.098*** (0.01)	0.126** (0.05)	0.769*** (0.01)	1,636	0.100*** (0.01)	0.102* (0.05)	0.797*** (0.01)	1,604
Manufacture of textiles	0.157*** (0.01)	0.106*** (0.02)	0.775*** (0.01)	4,510	0.127*** (0.00)	0.056*** (0.01)	0.827*** (0.00)	7,450
Manufacture of wearing apparel	0.159*** (0.01)	0.011 (0.04)	0.812*** (0.01)	2,745	0.133*** (0.01)	-0.015 (0.04)	0.853*** (0.01)	2,509
Manufacture of wood and of products of wood and cork	0.151*** (0.01)	0.070*** (0.02)	0.769*** (0.01)	4,465	0.135*** (0.01)	0.049* (0.02)	0.798*** (0.01)	4,082
Manufacture of paper and paper products	0.190*** (0.01)	0.108*** (0.02)	0.760*** (0.01)	3,305	0.159*** (0.01)	0.095*** (0.02)	0.799*** (0.01)	3,183
Printing and reproduction of recorded media	0.308*** (0.01)	0.115*** (0.01)	0.607*** (0.01)	9,014	0.284*** (0.01)	0.109*** (0.01)	0.636*** (0.01)	8,650
Manufacture of chemicals and chemical products	0.102*** (0.01)	0.089*** (0.02)	0.846*** (0.01)	5,320	0.086*** (0.00)	0.084*** (0.02)	0.868*** (0.00)	5,191
Manufacture of pharmaceutical products	0.136*** (0.02)	0.076 (0.05)	0.815*** (0.02)	1,046	0.127*** (0.02)	0.078 (0.05)	0.823*** (0.02)	1,041
Manufacture of rubber and plastic products	0.168*** (0.01)	0.129*** (0.02)	0.753*** (0.01)	7,033	0.127*** (0.01)	0.123*** (0.02)	0.810*** (0.01)	6,356
Manufacture of other non-metallic mineral products	0.184*** (0.00)	0.059*** (0.01)	0.767*** (0.00)	8,424	0.168*** (0.00)	0.052*** (0.01)	0.791*** (0.00)	7,821
Manufacture of basic metals	0.161*** (0.01)	0.047 (0.03)	0.800*** (0.00)	2,861	0.146*** (0.01)	0.034 (0.02)	0.816*** (0.00)	2,697
Manufacture of fabricated metal products	0.263*** (0.00)	0.100*** (0.01)	0.673*** (0.00)	21,155	0.199*** (0.00)	0.074*** (0.01)	0.750*** (0.00)	19,526
Manufacture of computer, electronic and optical products	0.199*** (0.02)	0.045 (0.05)	0.775*** (0.01)	1,341	0.151*** (0.01)	0.077 (0.05)	0.833*** (0.01)	1,808
Manufacture of electrical equipment	0.243*** (0.01)	0.149*** (0.04)	0.740*** (0.01)	1,905	0.160*** (0.01)	0.108** (0.04)	0.866*** (0.01)	2,913
Manufacture of machinery and equipment n.e.c.	0.279*** (0.01)	0.056** (0.02)	0.697*** (0.01)	7,622	0.205*** (0.01)	0.034 (0.02)	0.794*** (0.01)	7,592
Manufacture of motor vehicles, trailers and semi-trailers	0.167*** (0.01)	0.031 (0.04)	0.795*** (0.01)	1,677	0.110*** (0.01)	-0.009 (0.05)	0.867*** (0.01)	1,496
Manufacture of furniture	0.224*** (0.01)	0.116*** (0.02)	0.719*** (0.01)	6,988	0.147*** (0.01)	0.091*** (0.02)	0.811*** (0.01)	6,485
Other manufacturing	0.207*** (0.01)	0.057 (0.04)	0.762*** (0.01)	1,911	0.193*** (0.01)	0.044 (0.04)	0.777*** (0.01)	1,909

Results are those obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset. Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time dummies. Observations characterized by negative value added or outliers with respect to the share of turnover reported in the PRODCOM survey relative to the one reported in the VAT declaration, the turnover per employee, the capital stock per employee and the turnover per material inputs are excluded of the estimation sample.

the Wooldrige estimates (estimates with the other 2 methods are available from the authors). The restriction on the parameters is less strong, but the estimation is still made at a relatively highly aggregated level, although slightly more acceptable by looking at common practice. Our coefficients are in line with the expectations, and we observe some heterogeneity across sectors. We also find that coefficients appear to vary depending on the type of deflator used, but the difference is not too large. Out of the 21 NACE rev2. 2 digit industries[12], 18 are characterized by 3 positive input coefficients and returns to scale between 0.98 (Manufacture of wood and of products of woods and cork) and 1.13 (Manufacture of electrical equipment) when using our quarterly adjusted Wooldridge method with firm specific price deflator.

We also conducted the analysis at the NACE Rev 2. 4-digit level (Table 3 only shows the estimates for the food industry, using the Wooldridge approach and the firm specific price deflator). At that level of analysis, we only considered the NACE Rev 2. 4 digit industries for which we observed at least 500 observations.This illustrates the trade-off that we face: the more disaggregated the level of analysis, the more similar the technology is likely to be, but the less observations we can use. Out of the 115 NACE 4 digit industries we considered, 84 industries are characterized by 3 positive input coefficients and returns to scale between 0.87 (Manufacture of footwear) and 1.32 (Manufacture of ovens, furnaces and furnace burners) when using the quarterly adjusted Wooldridge method with firm specific price deflator .

Considering the NACE Rev 2. 2 digit and 4 digit industries for which we obtained reasonnable estimations of the production coefficients (the 18 NACE 2 digit and the 84 NACE 4 digit industries mentionned above), we estimated in-sample total factor productivity and analyzed their distribution across firms.Table 4 shows some measures of the TFP dispersion according to our various methods, deflators used and levels of aggregation of the analysis. Not surprisingly, we can observe more dispersion when the analysis is made at a more disaggregated level. We also notice that the dispersion increases when we use the price deflator instead . Finally, our preferred estimation

[12] Two industries are not reported in Table 2 because they covered less than 500 observations. Theses two industries are "Manufacture of tobacco products" and "Manufacture of other transport equipment".

Table 3: Production function by NACE Rev. 2, 4 digit industries
Manufacture of food products only

	L	K	M	#
Manufacture of food products	0.123***	0.084***	0.813***	16,903
	(0.00)	(0.01)	(0.00)	
Processing and preserving meat	0.126***	-0.005	0.863***	370
	(0.01)	(0.05)	(0.01)	
Processing and preserving of poultry meat	0.107***	0.185***	0.874***	727
	(0.01)	(0.04)	(0.01)	
Production of meat and poultry meat products	0.094***	0.106***	0.876***	2,595
	(0.01)	(0.03)	(0.01)	
Processing and preserving of fish	0.050**	0.03	0.910***	469
	(0.02)	(0.04)	(0.010)	
Processing and preserving of potatoes	0.030	-0.057	0.880***	386
	(0.05)	(0.15)	(0.03)	
Processing and preserving of fruits and vegetables	-0.033	-0.037	0.949***	671
	(0.02)	(0.09)	(0.03)	
Manufacture of ice cream	-0.015	0.455***	0.828***	212
	(0.07)	(0.14)	(0.03)	
Manufacture of grain mill products	0.121***	0.095**	0.829***	439
	(0.02)	(0.04)	(0.01)	
Manufacture of bread and cake	0.261***	0.116***	0.668***	5,235
	(0.01)	(0.02)	(0.01)	
Manufacture of rusks and biscuits	0.107***	0.020	0.851***	941
	(0.02)	(0.03)	(0.01)	
Manufacture of cocoa, chocolate and sugar	0.141***	0.113***	0.826***	1,973
	(0.01)	(0.04)	(0.01)	
Processing of tea and coffee	0.049*	0.176**	0.910***	313
	(0.02)	(0.06)	(0.01)	
Manufacture of condiments and seasonings	0.184***	0.080	0.836***	476
	(0.02)	(0.06)	(0.01)	
Manufacture of other food products N.E.C	0.041*	0.136**	0.921***	656
	(0.02)	(0.04)	(0.02)	

Results are those obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset, using firm specific price deflators. Standard errors in brackets.*, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time dummies. Observations characterized by negative value added or outliers with respect to the share of turnover reported in the PRODCOM survey relative to the one reported in the VAT declaration, the turnover per employee, the capital stock per employee and the turnover per material inputs are excluded of the estimation sample.

Table 4: Total factor productivity dispersion

	PPI deflator			Firm price deflator			
		Interquartile range			Interquartile range		N
	Std dev.	75-25	90-10	Std dev.	75/25	90/10	
Firm level estimation - estimation sample							
OLS							
Manufacturing	0.223	0.266	0.535	0.232	0.273	0.551	145,865
Industry - 2 digit	0.409	0.660	1.057	0.572	0.718	1.472	131,098
Industry - 4 digit	0.489	0.600	1.178	0.716	1.095	1.794	120,902
OP							
Manufacturing	0.216	0.259	0.520	0.225	0.265	0.534	121,655
Industry - 2 digit	0.397	0.594	0.995	0.564	0.602	1.271	118,735
Industry - 4 digit	0.581	0.676	1.357	0.861	1.231	2.113	100,818
Wooldridge							
Manufacturing	0.218	0.265	0.525	0.228	0.272	0.545	105,230
Industry - 2 digit	0.499	0.771	1.215	0.684	0.909	1.742	100,803
Industry - 4 digit	0.965	1.169	2.143	1.206	1.509	2.751	86,628
Firm level estimation - crossing sample							
OLS							
Manufacturing	0.199	0.243	0.484	0.206	0.249	0.500	66,140
Industry - 2 digit	0.412	0.690	1.063	0.593	0.764	1.612	66,140
Industry - 4 digit	0.500	0.595	1.169	0.726	1.115	1.795	66,140
OP							
Manufacturing	0.199	0.243	0.483	0.206	0.249	0.498	66,140
Industry - 2 digit	0.405	0.604	1.010	0.601	0.583	1.725	66,140
Industry - 4 digit	0.545	0.623	1.271	0.798	1.137	2.026	66,140
Wooldridge							
Manufacturing	0.203	0.249	0.493	0.209	0.255	0.509	66,140
Industry - 2 digit	0.435	0.732	1.120	0.641	0.906	1.762	66,140
Industry - 4 digit	0.918	1.170	2.117	1.189	1.490	2.590	66,140

Based on in-sample TFP estimates computed using the estimation results for total manufacturing and by NACE rev. 2, 2 digit and 4 digit industries. At the more disagregated levels, we only considered industries for which the coefficients of the three inputs were estimated to be positive.

method, the Wooldridge approach, yields more dispersion at the 2-digit and 4-digit level.

4.2 Estimation at the firm-product level

We next use our extended Diewert approach to estimate MPPF. Our left hand side variable is now the physical quantity of a given good produced by the firm, and we pooled within a 2-digit PRODCOM category all observations for the three main goods of multi-product firms, as long as these products contributed at least to 5% of the turnover of a firm (the analysis was also conducted at the 4-digit and even 8-digit, although for a limited set of products for which we had enough observations). Table 5 shows the estimates using the Wooldridge approach. The estimation was conducted only for the broad categories for which we observed at least 5,000 observations.

Out of the 12 main PRODCOM 2 digit categories we considered, we obtained reasonnable estimates of our MPPF for 8 categories. These catégories are characterized by positive coefficients for the input factors and retunrs to scale between 0.80 (Pulp, paper and paper products) and 1.27 (Fabricated metal products, except machinery and equipment). As expected, we observe large differences across categories, as fims differ in their technologies and product scope. In particular, the negative coefficient of $r_{i(-g)t}$ captures how the constraint of producing more other goods limits the physical production of good g, controlling for the use of inputs. This coefficient varies according to the product category and appears larger in wearing appearel and basic metals, where firms also produce a larger number of products.

4.3 The link between productivity and imports

As mentioned above we have generated our estimates of TFP using industries and broad product categories for which we had reasonable production coefficents. Then, we have related them to various measures of import competition. For this exercise, we have focused on the results with the Wooldridge method. We discuss how our productivity measures, with MPPF estimated according to different options and at different levels of aggregation, are related to our three different measures of import shares (import shares using

Table 5: Multi-product Production functions
Estimation by broad PRODCOM 2 digit product categories

	Using Firm-specific price index				
	L	K	M	R(-g)	#
Food products and beverages	0.211***	0.115***	1.192***	-0.534***	17,565
	(0.02)	(0.04)	(0.02)	(0.02)	
Textiles	-0.041	0.421***	1.391***	-0.451***	1,656
	(0.05)	(0.12)	(0.07)	(0.03)	
Wearing apparel; fur	0.343**	0.114	1.230***	-0.714***	1,249
	(0.11)	(0.23)	(0.15)	(0.17)	
Pulp, paper and paper products	0.015	0.158	1.003***	-0.375***	1,568
	(0.07)	(0.15)	(0.06)	(0.03)	
Chemicals, chemical products and man-made fibers	0.045	0.170*	1.491***	-0.444***	3,905
	(0.05)	(0.08)	(0.05)	(0.03)	
Rubber and platic products	0.098	0.372***	1.267***	-0.563***	3,982
	(0.06)	(0.11)	(0.06)	(0.04)	
Other non metallic mineral products	0.271***	0.376***	0.775***	-0.399***	3,875
	(0.06)	(0.10)	(0.05)	(0.02)	
Basic metals	0.185**	0.125	1.501***	-0.741***	1,935
	(0.07)	(0.17)	(0.07)	(0.06)	
Fabricated metal products	0.906***	0.447***	0.458***	-0.543***	3,456
	(0.07)	(0.13)	(0.05)	(0.03)	
Machinery and equipment	0.082	0.981***	1.232***	-0.455***	1,204
	(0.12)	(0.19)	(0.07)	(0.07)	
Electrical machinery and aparatus N.E.C.	-0.422	0.122	1.590***	-0.268*	643
	(0.24)	(0.14)	(0.25)	(0.14)	
Furnitures; other manufactured goods N.E.C.	0.770***	1.014***	1.001***	-0.439***	4,147
	(0.07)	(0.12)	(0.07)	(0.03)	

Results are those obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset.Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time dummies and PRODCOM 8 digit dummies.Firm x product observations are pooled at the level of PRODCOM 2 digit categoires. Only products expressed in the mostly observed physical units of a given PRODCOM 2 category are considered. Firms characterized by negative value added or outliers with respect to the production of good g and the other revenu per employee and the growth rate of production are excluded of the estimation sample. Products were only considered if they represented at least 5% of the firm turnover and if they were one of three main products of the firm.

Table 6: Firm specific TFP and import competition

	Manufacturing		Industry 2-digit		Industry 4-digit	
	(1)	(2)	(3)	(4)	(5)	(6)
Import share defined in value (IS_1)						
Import share (t-4)	0.027***	0.009	0.033***	0.009	0.071***	0.026***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Productivity (t-4)		0.594***		0.593***		0.656***
		(0.00)		(0.00)		(0.00)
N	55,782	40,310	53,901	38,893	46,090	33,169
R^2	0.23	0.525	0.895	0.938	0.973	0.986
Import share defined in quantity (IS_2)						
Import share (t-4)	0.027***	0.006	0.033***	0.008	0.071***	0.021***
	(0.01)	(0.00)	(0.01)	(0.00)	(0.01)	(0.01)
Productivity (t-4)		0.595***		0.593***		0.657***
		(0.00)		(0.00)		(0.00)
N	55,782	40,310	53,901	38,893	46,090	33,169
R^2	0.23	0.525	0.895	0.938	0.973	0.986
Net import share defined in quantity (IS_3)						
Import share (t-4)	0.022***	0.004	0.033***	0.008	0.082***	0.024***
	(0.01)	(0.00)	(0.01)	(0.01)	(0.01)	(0.01)
Productivity (t-4)		0.595***		0.593***		0.656***
		(0.00)		(0.00)		(0.00)
N	55,782	40,310	53,901	38,893	46,090	33,169
R^2	0.23	0.525	0.895	0.938	0.973	0.986

The productivity variable is the in-sample estimated TFP based on the results obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset, using a frim specific price deflator. Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time x NACE 4 digit dummies. Outliers with respect to the total factor productivity are excluded of the estimation sample. At the more disagregated level, we only considered sectors for which the coefficients of the three inputs were positive and for which the estimated return to scale was between 0.7 and 1.4.

monetary units, import shares using physical units, net import shares).

At the firm level, we regress firm-level TFP over the 4 quarters lagged level of our firm-specific import competition variables:

$$\omega_{it} = \alpha_1 IS_{i(t-4)} + \nu_j + \delta_t \tag{7}$$

where ν_j is an industry dummy and δ_t is a quarter-year dummy. We also look at the relationship controlling for productivity in $t-4$.

Table 6 shows the results. All specifications include industry and quarter-year dummies. In the first column under all scenarios (3 different levels of aggregation and two different deflators), the coefficient shows the relationship between TFP and import share without any further control. We see that the coefficient is always larger with the firm-level deflator, and also becomes larger when we move from the more aggregated estimation (for the whole manufacturing) to the less aggregated one (at the 4-digit level). These results indicate a positive relation between lagged import competition and current firm's performance. However, as we do not control for any firm specific component in TFP, this result may reflect the fact that firms facing strong foreign competition are more productive but this is not informative of the reaction of a firm to changes in the competitive environment.

In order to solve this problem, we control for past productivity in column 2. Once we include this extra variable, the coefficient of import share is reduced quite dramatically, but remains positive and significant is most cases. This result can be interpretated with more confidence as an indication that firms increase their performance in response to an increase in foreign competition.

At the firm-product level, we regress firm-product level TFP over the lagged level of product import share

$$\omega_{igt} = \alpha_1 IS_{g(t-4)} + \nu_g + \delta_t \tag{8}$$

We also add more controls (past productivity, share of the product) to test the robustness of the relationship, as we did for the firm-level analysis.

Table 7 displays the results of the link between firm-produt level productivity and product-level import share. All specifications include quarter-year and product dummies. Column 1 shows a negative relationship without controlling for anything. The coefficient is large and highly significant.

Column 2 shows that, once you control for the ranking of the product, productivity is lower for the 2nd and 3rd product of the firm (relative to the most important one), but the coefficient of imports remains negative and very large.

Column 3 introduces lagged productivity (in $t-4$, i.e. one year earlier). Once we do that, we see that the import share is no longer significant. Past productivity is also highly correlated with current TFP.

In column 4, we also add the ranking of the product, and we see again that productivity is lower for the less important products.

When we look at the interaction between import share and the ranking (column 5), we see that imports are positively related to productivity for the core product, but have a negative link for the lower ranked products.

Table 7: Firm x Product specific TFP and import competition

	(1)	(2)	(3)	(4)	(5)	(6)
Import share defined in value (IS_1)						
Import share (t-4)	-0.348***	-0.298***	0.068	0.074	0.259***	0.165***
	(0.086)	(0.081)	(0.049)	(0.048)	(0.050)	(0.051)
Productivity (t-4)			0.889***	0.869***	0.872***	0.868***
			(0.003)	(0.003)	(0.003)	(0.003)
2nd product		-0.400***		-0.076***		-0.035***
		(0.011)		(0.006)		(0.010)
3rd product		-0.977***		-0.211***		-0.175***
		(0.018)		(0.010)		(0.018)
Import share*2nd product					-0.256***	-0.168***
					(0.021)	(0.033)
Import share*3rd product					-0.570***	-0.151***
					(0.030)	(0.053)
N	32,393	32,390	22,393	22,392	22,393	22,393
R^2	0.981	0.983	0.997	0.997	0.997	0.997
Import share defined in quantity (IS_2)						
Import share (t-4)	-0.351***	-0.308***	0.020	0.020	0.195***	0.091**
	(0.070)	(0.066)	(0.041)	(0.040)	(0.042)	(0.044)
Productivity (t-4)			0.896***	0.873***	0.878***	0.872***
			(0.003)	(0.004)	(0.004)	(0.004)
2nd product		-0.367***		-0.065***		-0.038***
		(0.011)		(0.006)		(0.010)
3rd product		-1.015***		-0.202***		-0.172***
		(0.017)		(0.010)		(0.017)
Import share*2nd product					-0.220***	-0.119***
					(0.021)	(0.033)
Import share*3rd product					-0.522***	-0.128***
					(0.030)	(0.048)
N	27,953	27,950	19,411	19,410	19,411	19,411
R^2	0.934	0.942	0.988	0.988	0.988	0.988
Net import share defined in quantity (IS_3)						
Import share (t-4)	-0.386***	-0.330***	0.012	0.014	0.201***	0.079*
	(0.073)	(0.068)	(0.042)	(0.041)	(0.044)	(0.004)
Productivity (t-4)			0.896***	0.873***	0.880***	0.872***
			(0.003)	(0.004)	(0.003)	(0.004)
2nd product		-0.366***		-0.065***		-0.046***
		(0.011)		(0.006)		(0.009)
3rd product		-1.015***		-0.201***		-0.175***
		(0.017)		(0.010)		(0.015)
Import share*2nd product					-0.232***	-0.103***
					(0.024)	(0.035)
Import share*3rd product					-0.558***	-0.131***
					(0.034)	(0.050)
N	27,934	27,931	19,402	19,401	19,402	19,402
R^2	0.934	0.942	0.988	0.988	0.988	0.988

The productivity variable is the in-sample estimated TFP based on the results obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset, using a frim specific price deflator to deflate the revenu of the other goods. Only products that are either the main, the second and the third products in a firm portfolio are considered. Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include time and PRODCOM 8 digit dummies. Outliers with respect to the total factor productivity are excluded of the estimation sample. At the more disagregated level, we only considered broad PRODCOM 2 digit product categories for which the coefficients of the three inputs were positive and for which the estimated return to scale was between 0.7 and 1.4.

In the last column, we add both the ranks themselves and the interaction. Both the rank effect appears and the interaction rank-imports seem to survive, even if the effect of import share don't seem to differ much for the second and third products.

These results suggest that import competition affects the various products that firms produce very differently. Firms tend to be more efficient in the production of their core product (relative to non-core products), as suggested by recent theoretical contributions (see Mayer, Melitz, Ottaviano, 2014) but they are also increasing their core-product efficiency in response to increase foreign competitive pressures. However, if their non-core products tend to be more exposed, firms seem to start abandon these products by investing less in those production lines.

Finally, we also run our analysis in first difference. At the firm level, we run the following specification:

$$\omega_{it} - \omega_{i(t-4)} = \alpha_1[IS_{i(t-4)} - IS_{i(t-8)}] + \nu_j + \delta_t \tag{9}$$

where we again include industry and quarter-year dummies.

At the firm product level, the equivalent specification is:

$$\omega_{igt} - \omega_{ig(t-4)} = \alpha_1[IS_{g(t-4)} - IS_{g(t-8)}] + \nu_g + \delta_t \tag{10}$$

where we include instead product dummies together with quarter-year dummies.

There are at least two reasons to run a first difference specification. First, the link between productivity and competition is dynamic by nature; second, we are better able to control for firm or firm-product specificities in such a framework.

Results are shown in Table 8. The first panel displays the results for the firm-level analysis using our estimates at the 4-digit. We find a positive coefficient but overall not significant. This might be due to the fact that there is not enough variation left at the firm-level once we get rid of the firm-fixed effect. The results for the firm-product level analysis are presented in the second panel. In this case, we find strong and positive estimates when we use our preferred measures of import competition that control for

Table 8: Productivity growth and changes in import competition

	Firm-level (deflated by P)	Firm-product level
	Industry 4-digit	
Import share defined in value (IS_1)		
Δ import share (t-4)	0.011	0.090*
	(0.011)	(0.054)
N	46,710	22,218
R^2	0.008	0.034
Import share defined in quantity (IS_2)		
Δ import share (t-4)	0.002	0.159***
	(0.011)	(0.044)
N	33,946	19,236
R^2	0.01	0.026
Net import share defined in quantity (IS_3)		
Δ import share (t-4)	0.003	0.160***
	(0.012)	(0.044)
N	33,935	19,224
R^2	0.01	0.026

The productivity variable is the in-sample estimated TFP based on the results obtained with the Wooldridge estimator modified to capture the quarterly frequency of our dataset, using similar selection criteria as those used for Table 6 and 7. Standard errors in brackets. *, ** and *** significant at respectively the 10, 5 and 1% level. All equations include either time x NACE 4 digit or time and PRODCOM 8 digit dummies.

re-exporting. This would tend to indicate that we need enough variation to properly identify a link betwen these two variables, and this is provided at the firm-product level.

5 Conclusion

In this paper, we develop several tools to estimate TFP with multi-product firms using detailed quarterly data on physicial quantities produced by firms. We use our estimates to study the link between productivity and import competition. If our results show a generally positive relationship between firm level productivity and import competition, pointing towards the disciplinary effect of competition on efficiency, we document that the sensitivity of this relationship depends on the technique used and on the level of aggregation at which the production function is estimated.

Our analysis also confirms recent predictions of theoretical models of multi-product firms in trade (e.g. Mayer, Melitz and Ottaviano, 2014) as firms are shown to be more productive for their core products.

In addition, based on our firm-product analysis, it seems that the disciplinary effect of import competition on firm efficiency is not uniformely distributed across the various manufactured goods of the firm's products portfolio. Our results indicate that this disciplinary effect is at play only for the core products. When non core activities are considered, increased foreign competition does not seem to generate efficiency gains. On the contrary, it may be associated with lower efficiency, what might lead to a relative withdrawal in the production of those goods.

Even if still preliminary, our work leads to several important policy implications. First, and most importantly, products matter and they constitute the right unit of analysis. In global competition, firms need to be better at producing products relative to their competitors, and this is particularly true for their core activities. Second, the methods that we use yield more precise measure of what productivity means that could guide policy makers in several important areas (forecasting, reform evaluation, etc...).

As next steps in our research agenda, we want to analyze the relationship between price, productivity and imports. We also want to follow up on Dhyne, Petrin and Warzynski (2014) and estimate demand functions to obtain measures of product quality and determine whether higher import competition led to quality upgrading. We also plan to estimate costs function for multi-product firms, so that we can look at the link between imports, marginal costs and markups.

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