Access to new imported varieties and total factor productivity:

Firm level evidence from France

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Abstract

In order to explore how trade enhances growth through the creation and import of new varieties, Broda, Greenfield and Weinstein (2006) build an exact index measuring productivity gains due to expanded imported varieties and conduct their analysis using highly disaggregate trade data (73 countries and 200 goods). However, a major drawback of their work, which they acknowledge in their conclusion, is that their description of production and innovation, at the country level, appears as stylized and deprived of micro foundations. Clearly, the model they suggest and the framework they develop relates to mechanisms that are happening at the firm/sector level rather than at the country level. Moreover, Broda, Greenfield and Weinstein limit themselves to a simple accounting exercise and do not formally demonstrate that their variety index is correlated to TFP growth.

This paper empirically tests the effects of expanded imported varieties on firm level TFP. We work on a database of continuing French firms and construct Broda, Greenfield and Weinstein index of import of varieties. Running firm level regressions, we find that the impact of varieties on TFP is significant but the elasticity is relatively low. To cope with reverse causality effect and measurement errors, we introduce the sector level increase in varieties as an instrument for the firm level increase in varieties. This IV approach gives an elasticity of TFP to the Broda, Greenfield and Weinstein index very close to one, which validates the prediction of their framework.
Introduction

With the rising integration of world markets, a process of disintegration of the production process and trade liberalization has been at work. Among the most famous examples of this “slicing in the “value chain” (Krugman 2006) phenomenon, the Barbie dolls or Nike shoes and clothing could be *inter alia* mentioned. It is commonly acknowledged that one of the principle means through which countries benefit from this integration process and more generally from international trade is by the expansion of varieties. The first paper to quote in the field of research is of course the seminal work by Krugman (1979) which presents a simple general equilibrium model in which countries gain from trade through the import of new varieties. More recently, Romer (1994) argue that if consumers value variety and countries cannot produce all varieties due to a fixed cost in the production of each variety, countries stand to gain from trade because it expands the set of available varieties.

Quantifying quality growth is difficult. The hedonic pricing methodology was developed by Court (1939) and revived by Griliches (1961) and Griliches and Alderman (1961) but is however still only applied to a limited number of goods (cars, houses, computers) because of exacting data requirements. Among the important contributions are Triplett (1969), Ohta and Griliches (1976 and 1980), Feenstra (1987 and 1988), Gordon (1990), and Raffland Trajtenberg (1995). Shapiro and Wilcox (1996 p 124) describes the measurement of quality as necessitating “house-to-house” combat i.e. detailed good-by-good studies. The main assumption behind hedonic pricing is the “characteristics approach” to demand theory (see, for example, Lancaster (1971)). According to this approach, goods are defined as bundles of characteristics (qualities), and consumers have preferences over those
characteristics. Thus, a consumer will decide not only whether to buy an automobile, for example, but which automobile best matches her preferences over the available characteristics. The real world is full of examples of goods being sold with different added-on components, attributes, sizes and colors, that is, with different characteristics (qualities), in different varieties. Moreover, the reason that different varieties of a commodity sell at different prices must be due to differences in their sets of characteristics. Therefore it is reasonable to assume that, in equilibrium, there is a well-defined relationship between the price of a commodity and its characteristics. For more details on the development of the hedonic methodology we can refer, for example, to Berndt (1990). Broadly speaking, the most standard approach consists in writing the price of variety $i$ of a specific commodity at time $t$ as a function of a set of qualities $X$ and some disturbance $u$. Additionally, the hedonic approach is based on the assumption that the multitude of varieties of a particular commodity can be analyzed in terms of a few characteristics or basic attributes of a commodity. Given the high correlation among some characteristics, this assumption is not as strong as it may seem. Generally a semi logarithmic form is chosen, relating the logarithm of the price to the absolute values of the qualities. One advantage of this form is that the coefficients on the Xs will represent percentage changes in price due to changes in the related characteristic. An alternative approach is suggested by Bils and Klenow who use instrumental variables for estimating the rate of quality growth. They apply this approach to estimate the overall importance of unmeasured quality growth for 66 durable consumer goods (using the US Consumer Expenditure Surveys). Their instrument is based on predicting which of these 66 goods will display relatively rapid quality growth, using the slopes the quality Engel curves across the 66 goods to predict the rate of quality upgrading. The idea is for instance that richer households buy more expensive automobiles than poorer households, whereas
richer households spend only modestly more than poorer households in purchasing vacuum cleaner. Thus, as households on average become richer, they predict faster quality growth for automobiles than for vacuums.

Estimating the welfare impact of the introduction of new varieties gives rise to another methodological issue. The development of an empirical methodology to estimate the welfare change resulting from price changes can be traced to Hicks’ (1942) compensating variation measure. Historically compensating variation has been difficult to measure because it involves integration of the unobservable Hicksian compensated demand curve. However, Hausman (1981) develops a closed-form solution for measuring compensating variation under standard linear or log-linear demand functions. Hausman (1997) looks at how to value the introduction of new services in telecommunications in the US, since they can create very large gains in consumer welfare. He applies the method first introduced by Hicks (1946). The basic idea underlying the economic approach to valuing new goods or services is the recognition that until these goods actually come on the market, consumers are unable to purchase them at any price, no matter how much they would like to buy them. Thus in some sense the price of the new good or service might as well be infinite. Hausman (1997) proposes a more refined approach and calculates the “virtual” or “reservation” price that sets demand for the new good or service to zero. The actual price of the new service will usually be below the virtual price and the welfare effect of the introduction of a new product is equivalent to the welfare effect of a price drop from the product’s “virtual price”, the price that sets its demand to zero, to its current price. The quantity consumer multiplied by the difference between the virtual price and the market price (time one half) approximates the consumer surplus from the new service. For voice messaging he estimates consumer welfare gain of about $1.27 billion a year based and for cellular phones
those gains are about $50 billion a year. In addition, he also estimates that the FCC's decision to delay the introduction of two telecommunication services has reduced U.S. consumer welfare by billions of dollars a year.

Subsequently researchers have examined the welfare effects of other new products in traditional markets, using similar or more refined models. Welfare consequences of new product introductions have received increased attention from economists over the last two decades (see Bresnahan and Gordon (1997)). Papers focusing on buyer benefits from new products cover a range of goods & services, including automobiles (Feenstra (1988), Berry Levinsohn and Pakes (1993), Fershtman and Gandal (1998), computers (Bresnahan (1986), Greenstein (1994)), health care technology (Trajtenberg (1989)), breakfast cereals (Hausman 1997a), telecommunication services (Hausman 1997b). Trajtenberg (1989) uses a two stage approach whereby first the benefits from innovation are estimated by applying discrete choice models to data on the distribution of sales per brand and on their attributes and prices to estimate the parameters of the demand function and, under some restrictions, of the underlying utility function. Second, those benefits are used to construct ‘quality adjusted’ price indices. He shows that conventional indicators (hedonic price indexes and simple unadjusted price index) might be missing a great deal of the rate of decline of real price. Other examples include Nevo (2001), Goolsbee and Petrin (2001), Hausman and Leonard (2001). New products have also been the focus of economists’ attempts at revisiting the Consumer Price Index, in part because of findings of Armknecht (1984) that changes in the index are mostly due to price inflation from new products. The Stigler commission (NBER 1961) and the Boskin Commission (Boskin Commission Report 1996) conclude that the greatest flaw in the Consumer Price Index is its failure to account adequately for new goods and quality improvements in existing goods. Petrin (2001) develop a
technique useful for obtaining more precise estimates of demand and supply curves when constrained to market-level data, by augmenting the estimation routine with data on the average characteristics of consumers that purchase different products. He applies the technique to the automobile market estimating the effects of the minivan introduction. In addition, Bresnahan (1986) and Brynjolfsson (1995) have looked at welfare gains from information technology investments. Brynjolfsson et al. (2003) focus on increased product variety made available through Internet networks. With the development of the Internet book markets, he find that the increased online availability of previously hard-to-find products represents a positive impact on consumer welfare. It is also worth noting that there is a large body of marketing literature examining the relationship between perceived variety and actual assortment. Most researchers agree that consumers generally prefer more variety when given a choice (e.g., Baumol and Ide 1956 and Kahn and Lehmann 1991). More recently, researchers have shown that consumers’ perception of variety is influenced not only by the number of distinct products, but also by the repetition frequency, organization of the display, and attribute differences (e.g., Dreze, Hoch and Purk 1994; Broniarczyk, Hoyer and McAlister 1998; Hoch, Bradlow and Wansink 1999; Van Herpen and Pieters 2002).

In international trade, a great deal of globalization takes the form of an increase in traded varieties but conventional economic statistics fail by and large to reflect them. Most economic theory starts from an implicit assumption the set of goods in an economy never changes. For instance traditional estimate of the welfare loss from protection are generally very small. Tarr and Morkre (1984) estimate the total losses from protection to be around 0.26% in the United-States. Feenstra (1992) and Romer (1994) criticize this literature for assuming the range of goods imported is not affected by the tariff. The authors suggest that a fall in the number of goods
available could add substantially to the costs of protection. Romer (1994) argues that there are fixed costs of selling a good in a country and the good will be imported only if profits cover these fixed costs. By reducing the market size for a good, a tariff reduces the profits that can be made from importing that good. A sufficiently high tariff may therefore imply not just lower imports but no imports at all for a good. Romer shows that if we assume that international trade can bring new goods into an economy, the fraction of national income lost when a tariff is imposed can be much larger. Consistent with Romer’s hypothesis, Klenow and Rodriguez-Clare (1997) find that Costa Rica’s 1986 to 1992 trade liberalization was accompanied by a surge in import variety. Using detailed data they find that a 1% larger market goes along with about .2% more variety of imported consumer and intermediate goods and a 1% lower tariff goes along with an increase in variety of about .5%. They then calibrate a general equilibrium model in order to quantify the gains from this variety expansion. They show that the estimated welfare gains from trade liberalization are 50% larger when they take into account the impact of liberalization on variety. Rutherford and Tarr (2002) develop a numerical model that quantifies the welfare effects of trade liberalization. Additional intermediate input varieties provide the engine of growth and dramatically magnify the welfare gains from trade liberalization. The crucial idea of their model is that imports of a larger variety of intermediate inputs allow producers to increase productivity through selection of intermediate inputs that more closely match their production requirements. In their central model, a 10% tariff cut leads to a 10.6% in welfare. Caballero and Lyons (1992) show that productivity increases in industries when output of its supplying industries increases. Coe et al. (1997) find that foreign research and development increases domestic total factor productivity and that the positive spill-over effect of foreign research is stronger the more open the economy is to intermediate inputs. Funke and Ruhwedel (2001) utilizing data for 19 OECD
countries they find support that a greater degree of product variety relative to the
US helps to explain relative per capita GDP levels. Their empirical work relies upon
some direct measures of product variety calculated from 6 digit OECD export and
import data. However, the model they base their study upon which draws heavily
on Feenstra (1994), does not include elasticities of substitution among varieties. If
varieties are highly substitutable then increasing the number of varieties is unlikely
to have much of an effect on unit costs of production. Using a significantly more
disaggregate and exact methodology than Funke and Ruhwedel (2001), Broda and
Weinstein (2004) document some stylized facts about the growth in global varieties
which suggest that there may have been substantial welfare gains through the
import of new varieties. They show that the average large importing countries
source imports from 50 percent more countries than they did 25 years ago.
Moreover, they calculate the impact of increased variety on import prices and find
that conventional measures of import price inflation may be dramatically biased
reconstruct the US import price index and show that the unmeasured growth in
product variety from US imports has been an important source of gains from trade
over the last three decades (1972-2001). They use Feenstra’s (1994) methodology to
estimate 30,000 elasticities and then construct an aggregate price index that is
robust to common changes in quality variation, the arbitrary splitting of categories,
the introduction of new goods, and a host of other data problems. They document
that the number of varieties imported by the US, defined as the number of import
categories multiplied by the average number of source countries for each category,
quadrupled. About half of this increase was due to increases in the number of
categories and half due to a doubling of the number of countries from which the US
imported each good. They find that the price of US imports has been falling at a rate
1.2% per year faster than one would have thought without taking new varieties into
account. In a more recent paper, shifting their focus from import prices to TFP, Broda, Greenfield and Weinstein (2006) using highly disaggregated trade data structurally estimate the impact that new imports have had on productivity in approximately 4000 markets per country. They build an exact TFP index that aggregates these micro gains and find that the typical country in the world experienced a net increase in varieties of 0.7 percent per year, France experiencing an increase of almost 1% per year\(^1\), which is much higher than the median developed country (contribution of 0.4 percent).

I. Methodology

General intuition: number of goods in a CES function

The interaction between product variety and economic growth can be simply illustrated by a model where a country produces a homogenous output good, \(Y\), using labor, \(L\), and a range of differentiated goods, \(M_g\). A Cobb-Douglas function describes the production of \(Y = L^{1-\alpha} M^\alpha\) with \(M\) being given by the aggregation of goods \(M_g\) through a standard CES function.

\[
M = \left( \sum_{g \in G} M_g^{\gamma} \right)^\frac{\gamma}{\gamma - 1}
\]

The total number of differentiated inputs add up to give what we define as total intermediate consumption, \(C\):

\[
C = \sum_{g \in G} M_g
\]

Treating intermediate inputs symmetrically in the production function, we have:

\[
M_g = \frac{C}{n}, \quad n \text{ being equal to the total number of intermediate inputs.}
\]

It is straightforward to see that:

\[
M = n^\frac{1}{\gamma - 1} C
\]

\(^1\) cf table 4 of their paper. The increase in varieties from 1994 to 2003 being computed as 1-median lambda ratio.
Therefore, within this very simple setting, the number of intermediate goods, \( n \), enters the production function and has a direct impact on total factor productivity.

\[
Y = L^{1-\alpha} n^{\frac{\alpha}{\alpha - 1}} C^\alpha
\]

Suppose we build a TFP index based on a Solow Residual without accounting for this increase in varieties: \( TFP = \frac{Y}{L^{1-\alpha} C^\alpha} \). For a given total amount of aggregate intermediate inputs, the higher the number of varieties that enter \( C \), the higher the TFP.

**I.a. Framework**

*CES production function*

To quantify the potential gains in total factor productivity from input variety, we chose a Spence-Dixit-Stiglitz framework with a CES production function. The concept of monopolistic competition is relatively old since it grounds were laid by Chamberlain (1933). Chamberlain (1955) provides a very clear and concise presentation of the main ideas of his framework. Four hypothesis can describe the monopolistic competition model. First, firms sell products of the same type but imperfectly substitutable (concept of variety). Second, each firm produce a single variety with increasing returns and set its price. Third, the number of firms in the industry is high enough in order to ensure that each firm is negligible relatively to the others\(^2\). Fourth, the free entry condition in the industry guarantee zero profit. Therefore each firm is in a monopolistic situation in her own market (where the variety she produces is sold) but given that other firms exist which produce other varieties the size of this market depends on the behaviour of other firms and some restrictions are imposed as to how freely the producer can set its price. The reason

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why the number of varities does not grow to infinity in this model exhibiting increasing returns is because fixed costs are associated to new varieties. Spence (1976) and Dixit-Stiglitz (1977) propose a way of modelling Chamberlain’s ideas that could be used in different fields of economics.

Big countries trade larger quantities of goods (intensive margin) but also a larger set of goods (extensive margin). For instance, Hummels and Klenow (2002) using data on shipments by 110 exporters to 59 importers in 5,000 product categories find that the extensive margin accounts for two-thirds of the greater exports of larger economies, and one-third of the greater imports of larger economies. This result might appear as standing in conflict with the prediction of Krugman’s monopolistic competition model, whereby economies increase exports only through the extensive margin channel. Alternatively, in Armington (1969) model, a larger country expands only through the intensive margin (higher quantity of each variety sold at lower price). However, because of its tractability, the CES function appears by far and large as the preferred tool for specifying the productivity and welfare gains from variety in international economics, economic geography, and macroeconomics. Indeed, for instance, the work of Krugman, the Dornbush, Fisher, Samuelson models and more recent work by Eaton and Kortum (2002), Broda and Weinstein (2004, 2006) and Broda, Greenfield and Weinstein (2006) use CES production function.

**Theoretical model**

In line with Broda and Weinstein (2004, 2006) and Broda, Greenfield and Weinstein (2006), the composite imported good is defined by a two-tiered CES utility function:

$$M_t = \left( \sum_{g \in G} M_{gt} \right)^{\frac{\gamma - 1}{\gamma}}$$

Aggregation of goods $g$.

Each good $g$ comes from aggregating a set $I_g$, of varieties.
For each good $g$, it is straightforward to derive the expression for the minimum cost associated with importing one unit of good $g$:

$$M_{gt} = \left\{ \sum_{i \in I_g} \frac{1}{d_{git}} \left( m_{git} \right)^{\sigma_{g-1}} \right\}^{\sigma_g \sigma-1}$$

$$\begin{cases} \text{Min} \sum_{i \in I_g} p_{git} m_{git} \\ s.t. M_{gt} = 1 \end{cases}$$

$I_g$ = set of goods imported at time $t$. If this set is constant over time, we denote it $I_g$.

Solving the optimization problem yields the unit-costs function:

$$c(p_{gt}, I_{gt}, d_{gt}) = \left( \sum_{i \in I_g} b_{git} p_{git}^{1-\sigma_i} \right)^{-1-\sigma_i}$$

with $b_{git}$ that can be expressed in function of $d_{git}$ and $p_{git}$ being the vector of variety prices.

Differentiating the unit-cost function, we get the expenditure shares $s_{git}$.

$$s_{git} = \frac{\partial \ln c(p_{gt}, I_{gt}, d_{gt})}{\partial \ln p_{git}} = c(p_{gt}, I_{gt}, d_{gt})^{\sigma_i-1} b_{git} p_{git}^{1-\sigma_i}$$

Hence:

$$\frac{c(p_{gt}, I_{gt}, d_{gt})}{c(p_{gt}, I_{gt}, d_{gt})} = p_{git}^{s_{git}/s_{git}^{(1-\sigma_i)}}$$

for any variety $i$.

This leads us to the following definitions and properties:

Definition 1: We define the Sato-Vartia log-ideal weight $w_{git}$ of each variety $i$ in good $g$ as:

$$w_{git} = \frac{S_{git} - S_{gis}}{\ln s_{git} - \ln s_{gis}}.$$
\[ \Sigma_{gs} = \prod_{i \in I_t} \left( \frac{p_{git}}{p_{gis}} \right)^{w_{gs}} \]

With \( I_g \) being the set of varieties that are common in \( t \) and \( s \).

Definition 3: A price index is “exact” (Diewert) if this price index equals the ratio of unit-costs.

Property 1: Under the assumption of constant \( b_t \) and constant \( I_{gt} \), the Sato-Vartia price index \( \Sigma_{gs} \) is exact: \[ \Sigma_{gs} = \frac{c(p_{gt}, I_{gt}, d_{gt})}{c(p_{gt}, I_{gt}, d_{gt})} \]

Property 2: Under the assumption that \( I_{gt} \) is non constant:

\[ \Sigma = \frac{c(p_{gt}, I_{gt}, d_{gt})}{c(p_{gt}, I_{gt}, d_{gt})} \left( \frac{\hat{\lambda}_g}{\hat{\lambda}_g} \right)^{(s_t - 1)} \] with \( \hat{\lambda}_g = \frac{\sum p_{gt} m_{gits}}{\sum p_{gt} m_{gits}} \) and \( I_g = I_{gt} \cap I_{gs} \)

Definition 4: The Sato-Vatio price index relative to the composite good between period \( t \) and period \( s \) is given by:

\[ \Sigma_a = \prod_{g} \Sigma_{gs} \]

If the set of varieties imported in \( t \) and \( s \) was the same and the taste parameters \( d \) time unvarying, we hence know that the Sato-Vatia price index would be “exact” (Diewert), ie equal to the ratio of unit-costs in \( t \) and \( s \). However a bias between the Sato-Vartia price index and the ratio of unit-costs arises from the fact that the set of imported varieties in \( t \) and \( s \), \( I_{gt} \) and \( I_{gs} \), are not identical. The aggregation of goods \( g \) to get the composite imported good \( M_o \) will lead to a bias in the resulting price index equals to:

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3 We know that this weight is approximatively equal to: 1/3 arithmetic mean + 2/3 geometric mean between \( s_{t-1} \) and \( s_{t-2} \).
\[ \prod_g \left( \lambda_{tg} / \lambda_{sg} \right)^{w_{gt}} \]

With \( w_{gt} = \text{Sato-Vartia log-ideal weight of good } g \text{ in total composite intermediate good}^4 \).

Property 3: \( \prod_g \left( \lambda_{tg} / \lambda_{sg} \right)^{w_{gt}} \) gives the bias in estimating the unit costs and, by the same token, total factor productivity, by price indices that are based on common varieties only.

Let us expand the expression for this bias and detail how it is determined:

\[
\prod_g \left( \lambda_{tg} / \lambda_{sg} \right)^{w_{gt}} = \prod_g \left( \frac{\sum_{i \in I_{ts}} p_{gis} m_{giv}}{\sum_{i \in I_{ts}} p_{gis} m_{giv}} \right)^{w_{gt}}
\]

First we observe evidently that if the set of varieties is constant for each good, this bias boils down to 1. If \( I_{tg} \) is small compared to \( I_{sg} \), lots of new i’s appeared between time s and time t, varieties creation was strong and \( \lambda_{tg} \) is low and so is the lambda ratio. However, if new i’s that appeared between s and t account for a small proportion of good g; the downward impact of these new varieties on the lambda ratio will not be so big. Symmetrically, if many i’s were in \( I_{gs} \) but not in \( I_{tg} \), it means that the process of variety destruction was strong. \( \lambda_{tg} \) will be high, driving up the lambda ratio and moderating the effect of variety creation reflected by a low \( \lambda_{tg} \).

Hence the lambda ratio can be interpreted as a measure of net increase in varieties.

\[ w_{gt} = \frac{g_{tg} - g_{tg-1}}{\ln(\ln(g_{tg}) - \ln(g_{tg-1}))} \]

\[
\sum_{g \in I_{tg}} \frac{g_{tg} - g_{tg-1}}{\ln(\ln(g_{tg}) - \ln(g_{tg-1}))}
\]
The lower the lambda ratio, the more intense variety creation. The effect of variety creation on the lambda ratio will be high only to the extent that new varieties account for a large proportion of the imported good. The lambda ratios are calculated at the level of each good $g$. Aggregating these good-level biases gives the total bias related to the composite intermediate good. The weight of each good in the aggregate bias will naturally increase with its Sato-Vartia log-ideal weight together with the elasticity of substitution of the good. Indeed, clearly, if a good exhibits new varieties but is highly substitutable, the impact of these new varieties on the composite intermediate good will not be so large.
II. Dataset and variable construction

We work on database including information on French importing firms and resulting from the matching of two databases. The first database comes from custom declarations. It contains the amount of importations of all importing firms (identified with an identification code “SIREN”) for each year between 1993 and 2003, for each product at a 4 digit level classification and by origins of imports. This file is similar to the one used in Biscourp and Kramarz (2004) but they work on the period 1986-1992. We match this custom database with a subpart of the “FIBEN” database (Banque de France balance sheet dataset). Clerks in the different local subsidiaries of the Bank de France contact firm to complete a survey. The Fiben database comes from the collection and the cleaning of these surveys, includes all businesses with more than 50 employees and a fraction of smaller firms. Its coverage ratio (in terms of number of employees) is 57% but is smaller for service sectors. The Banque de France uses these data (plus information from banks including payment incidents) for computing the firm score, which is massively used by commercial banks for evaluating the financial risk for each firm (see Bardos, 1998). Consequently, firms that are interested in the credit market are incited to provide these data. The database includes the different variables of a standard firm tax forms plus a set of complementary variables. In particular we have information about total wage bill, number of employees, intermediate consumption and capital stock (gross and net) for each year and each firm.

Two measures of the increase in varieties

1) A first option: variety as the combination of a 4 digit product and an origin country

For each firm we have the breakdown of her imports at the 4 digit level together with the origin country of imports. A first option is to define a good as the 3 digit category the imported product belongs to. A variety is defined as a pair: (4 digit
category, origin country). We have data for years: 1993, 1999, 2000, 2001, 2002, 2003. The goal of this paper is to concentrate on the effects of increase in varieties on total factor productivity (TFP). We do not integrate imports of new goods in our measure of varieties increase but limit ourselves to the integration of new varieties within the same set of imported goods. Therefore, for each firm, we keep goods that are continuously imported on our sample, discarding goods which appear or disappear in the firm production function. In table 8, the total number of goods is therefore constant over time (122 goods) whereas we can observe that the average number of imported varieties within this set of continuing goods is increasing from 16 to 20 between 1993 and 2003. This increase stems both from an increase in 4 digit product (from 8.6 to 10.2) and from an increase in the number of origin countries of each 4 digit product: from 36.5 to 45.1

2) A preferred option: A variety as an origin country

An alternative definition of variety exploits only the origin country dimension of our dataset. We assume that firms import as many varieties as we observe origin countries in their custom declarations. This alternative definition may appear as strongly limitative. However, several strong rationales are behind this one sector assumption. First, we need this assumption to treat goods that are produced in France and goods that are produced abroad symmetrically in the CES production function. Indeed we do not have a breakdown of domestically produced intermediate consumptions by types of goods. Second, this assumption increases the time period of our dataset since years 1994-1998 are now in our dataset. Third, treating the 4-digit dimension and the country dimension in a symmetric way may be rather unrealistic given strong evidence that varieties are more similar within a country and that country specific comparative advantage tend to make a country’s varieties more alike. For instance Berry, Levinshon and Pakes (2004) report survey results according to which consumers that buy a Japanese car tend to report a
Japanese car as their second preferred car as well while consumers that buy an
American car report as their second preferred car.

Construction of increase in varieties:

One way to look at the increase in the number of varieties would be to do a simple
count for each firm and each good. As we saw in a previous section, in a simple
framework assuming symmetry across varieties, the number of varieties appears as
a determinant of TFP which the simple neoclassical growth model made no attempt
to explain. However, two problems arise from using $n$ as a direct measure of
varieties (cf. Broda and Weinstein 2006). First, if new varieties represent only a
small (large) share of total expenditure in a good, then a simple count of varieties
will grossly overestimate (underestimate) the true impact of new varieties. Secondly,
if new varieties are arbitrarily introduced due to some “administrative” changes in
the statistical classification, then a simple count artificially increases biasing the
increase in product variety upwards.

The Broda, Greenfield and Weinstein (BGW) index of increase in varieties number
measure is defined by: $-\frac{W_{gt}}{\sigma_g-1} \ln \left( \frac{\lambda_{gt}}{\lambda_{gw}} \right)$. With the assumptions of elasticities of
substitution, $\sigma_g$, for France come from Broda, Greenfield and Weinstein (2006).

In the one sector case (increase in varieties stems only from increase in origin
countries), this index boils down to: $-\ln \left( \frac{\lambda_{gt}}{\lambda_{gw}} \right)$

Similarly, increase in varieties can be computed in the same way at the sector level.
According to this measure, a variety will be considered as a new variety if it is
imported at time $t+1$ by at least one firm in the sector but was not imported at time
$t$ at all. A variety that disappears is counted exactly in the opposite way.
Total Factor Productivity computation

One major problem we faced in computing TFP is the calculation of real capital stock, since FIBEN includes balance sheet data only. To be more specific, working on balance sheet data, the value of physical assets that is reported in FIBEN is given at historical costs. For instance, if the 1993 capital stock of firm $i$ was entirely purchased in 1970, the value of this capital stock that appears in firm $i$’s balance sheet is the amount in 1970 euros that firm $i$ paid for it in 1970. Thus we would need to deflate by 1970 price level to infer the corresponding volume of capital stock. An estimation of the average age of capital allows adjusting for this price effect and constructing accurate measure of capital stocks in volume.

Using two alternative methods, we estimate two different measures of capital stocks in volume that account for differences in the average age of capital. Capital stocks were first estimated by the perpetual inventory method, assuming geometric depreciation\(^5\). Basically this method assumes that past investments were all done in the same year ($t_0$). A firm enters the database at year $t_e$. Of course, $t_e$ and $t_0$ are firms specifics and they satisfy the relationship (see appendix 3):

$$ t_0 = t_e - \left( A - \frac{\text{net value of physical capital stock}}{\text{depreciation}} \right) $$

$A$ is the average asset life. To compute $A$, we consider the subgroup of “New firms” which includes firms that enter the database less than 5 years after their date of creation. For those firms, we can have a proxy for $t_0$ since since the whole sequence of investments is observed and thus we can infer a value for $A$.

The initial quantity of capital stock ($K_{te}$) for a given firm at its date of entry is thus given by:

$$ K_{te} = \text{net value of physical capital stock in } t_e / \text{investment price in } t_0 $$
Each $K_t$ is calculated with the permanent inventory method:

$$K_t = K_{t-1} + I_t / p_h - \text{depreciation}_t$$

For this method we require gross investment (acquisitions nets des cessions) for each asset together with an estimate of the real value of the capital stock in the base year for each firm. Gross investments by asset were derived from data on asset values and depreciation.

The second method is implemented in various works by Mairesse. The idea is the following. Let $K_{HC}$ be the capital stock, at historical cost, observed from balance sheet data and $K_{CP}$ the capital stock at current price (unobserved). $T$ is the asset life. We have:

$$K_{HC_t} = p_t I_t + \ldots + p_{t-T} I_{t-T}$$

$$K_{CP_t} = p_t I_t + \ldots + p_{t-T} I_{t-T}$$

Total depreciation assuming a linear depreciation rate is observed from balance sheet data:

$$D_t = \frac{p_t I_t + \ldots + T p_{t-T} I_{t-T}}{T}$$

The capital stock at constant price can be rewritten as:

$$K_{CP_t} \approx p_t I_t + (1 + \hat{p}) p_{t-1} I_{t-1} + \ldots + (1 + \hat{p})^T p_{t-T} I_{t-T}$$

with $\hat{p}$ being some estimate for the average inflation rate of the investment deflator between $T-t$ and $t$.

Hence:

$$K_{CP_t} \approx K_{HC_t} + \hat{p} (p_{t-1} I_{t-1} + \ldots + T p_{t-T} I_{t-T})$$

and

$$K_{CP_t} \approx K_{HC_t} \left(1 + \hat{p} \frac{T \times D_t}{K_{HC_t}}\right)$$

We define:

$$a = \frac{T \times D_t}{K_{HC_t}}$$

which can be interpreted as the average age of the capital stock. The stronger the depreciation-capital ratio, the stronger this age is. $a$ can be

---

5 I am extremely thankful to Nicholas Oulton for suggesting this method
estimated using the variables available in our database assuming asset life equal to 9, which is in line with INSEE assumptions. Therefore we have:

\[ K_{C_{PT}} \approx K_{HC_{t}} \frac{P_t}{P_{t-a}} \]

Once we have estimated capital stocks, TFP for firm \( j \) at time \( t \) is computed as a Solow Residual:

\[ TFP_{j,t} = \frac{Y_{j,t}}{K_{j,t}^\beta L_{j,t}^\alpha C_{j,t}^{1-\alpha-\beta}} \]

\( \alpha_j \) and \( 1-\beta_j-\alpha_j \) are taken respectively as the shares of intermediate consumption and of wage bill in total production. The parameter for capital stock, \( \beta_j \), is computed as a residual. These parameters are calculated as a time average of the firm level relevant ratios assuming that the production function varies across firms but is constant over time.

III. Econometrics and results

We want to empirically investigate how TFP growth between time \( s \) and time \( t \) relates to the increase in variety between these two periods. The baseline equation is the following:

\[ \ln(TFP_{t,s} \_j) - \ln(TFP_{s,i} \_j) = \theta \text{increase in varieties}_{t,s,j} + c + e_{t,s,j} \]

We first select the geographical way of defining varieties: one variety is associated with one origin country. The TFP measure we use is based on the permanent inventory method. Tables 2 and 3 provide general summary statistics about the dataset. We can see that the average number of origin country per firm increases from 1.3 to 1.5 between 1993 and 2003 with a peak at 2.0 in 1998. According to these figures, a globalization process was strongly at work in the 1990s and seems to have been declining or at least decelerating after 1998. Table 3 shows descriptive statistics for the BGW index of increase in varieties. On average, the contribution of
import varieties to productivity is 0.06 which is comparable to Broda, Greenfield and Weinstein estimate for France (0.09). At the firm level, the distribution seems pretty widespread with some firms having an increase in varieties by more than 800% and some firms exhibiting string decrease in varieties. However a eightfold increase does not seem unrealistic at the firm level and these observations are not treated as outliers. The magnitude of the distribution reflects a problem that we face in the econometric estimations: firms with outstandingly large variety creation/destruction are little likely to show the same patterns for TFP. Working at the sector level, we can compute the variety creation/destruction of the whole sector and the maximum and minimum values are less extreme. At the sector level, it is worth noting that the mean contribution of varieties evolves in line with the average number of origin countries per firm. Particularly large variations are observed in two different years: 1994 (11% increase) and 1999 (-9%) Table 4 gives the estimation results. The impact of import varieties on TFP growth is strongly significant (5% level with RE regression) but the elasticity of $TFP$ to the BGW index of variety increase is estimated at 0.002 only whereas theory predicts an unit elasticity.

The increase in variety growth might be thought as not totally exogenous with respect to $TFP$ growth. Two effects are likely to occur at the same time. First, due to the fixed costs of imports, only the most productive firms might be able to increase the number of imported varieties. Second; due to the fixed costs of setting up an affiliate abroad, only the most productive firms might be able to shift their production in a remote foreign country, which may imply stopping importing from other closer countries. In the first case, a high TFP may entail a high number of imported varieties, in the second case, a high TFP may lead to lower number of imported varieties, by switching some strand of the production process to an unique foreign country (eg China, India) and thus cut off imports from several other
countries (e.g., Western European countries). In order to cope with these endogeneity issues, we use the sectoral increase in varieties as an instrument for firm level product varieties. The regression estimates are given in table 5 of the appendix. Controlling for endogeneity and measurement errors with sector level instruments significantly improve the quality of our results. The coefficient of BGW index is still significant (10% level) a 1% increase in variety such as measured by the BGW index gives rise to a 0.9% increase in TFP.

Two control variables are introduced in the regressions. First, we include a dummy which equals 1 if the firm reported positive R&D expenditures. As it is generally down in the literature we also control for mean reversion and catch-up effects introducing the past position of the firm in the sector productivity distribution (lagged percentile variable). As shown in the following table, the coefficient of variety increase is significant, when running the fixed effect regression and very close to 1, which strongly validates the theoretical model again.

| Table 1 |
|---|---|
| **Endogenous variance** | **TFP** |
| Estimation method | IV Fixed effects | Random effects | IV Fixed effects | Random effects |
| Impact of varieties | 8.93 E-01 7.31 E-01 | 6.78 E-01 4.54 E-01 | -8.93 E-01 (5.33 E-01)* | 7.63E-01 4.76E-01 |
| Control variables | no no no yes yes yes |
| Constant | -1.06 E-04 -7.63 E-04 | 7.96 E-05 -5.26 E-04 | -1.06 E-04 (6.21 E-04)*** | 2.14E-02 (1.35 E-03)*** |
| Observations | 189725 28592 | 189725 28592 | 189725 28592 |
| Number of firms | 189725 28592 | 189725 28592 | 189795 28592 |
| R2 | 0.00 0.23 | 0.00 0.00 | 7.63E-01 1.11E+00 |

Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1% Instruments: increase in the number of varieties, measured at the sectoral level
These results prove two points. First, working at the firm level, the increase of the number of varieties that are used as intermediate inputs does significantly improve TFP. Second, a simple theoretical framework based on a CES production function predicts an elasticity of TFP to variety increase that is equal to 1. These estimations strongly validate this theoretical prediction since, controlling for endogeneity and measurement issues, the coefficient is very close to 1.

In order to test for the robustness of our results, we investigate whether these two conclusions are still valid whether we change the TFP measure and/or the increase in variety measure. Working with the measure of TFP a la Mairesse does not change the results at all. An alternative way of viewing variety is to see it as a combination of an origin country and a 4 digit product. Table 8 shows that the average number of 4 digit products per firm increases from 9.6 in 1993 to 11.5 in 2000 and seems almost stable over 2000-2003. Similarly, the average number of origin countries per 4 digit categories increases from 1993 to 2001 (29.8 to 37.8) and seem stable over the last two years. These results seem to point to a subdued increase in imported varieties after 2000 and 2001 as if the peak of globalization process had taken place after the launch of the European Union. This deceleration in the increase in imported varieties might be related to the decrease in average tfp in our sample with is consistent with various macro-economic diagnoses for France. Table 9 gives some summary statistics of the contribution of varieties. The contribution of varieties is around .97% on average on 1993-1999 and of .40% on 1993-2003. These number are consistent with those in Broda, Greenfield and Weinstein (2006). Table 10 and following show outcomes of regression of tfp growth on variety increase. Without using instrumental variables, the impact of varieties is significant but relatively weak. The elasticity is around 0.05 whereas the theory predicts an elasticity equal
to 1. In line with the previous results, the use of instrumental variables leads to a coefficient of 0.9 which strongly corroborates the first set of results.

**Conclusion**

Shifting the level of analysis from the country level to the firm level, we are able to demonstrate that the Broda, Greenfield and Weinstein index of expanded varieties is correlated with firm level TFP with the right coefficient of correlation (1). We show that this result is robust to alternative definitions of TFP and of varieties.
References


Broda C and D. Weinstein (2006), „Globalization and the Gains from variety“, forthcoming QJE


Hummels, David and Klenow, Peter J. (2002), “The Variety and Quality of a Nation’s Trade”, NBER WP #8712


Klenow, Peter J. and Rodriguez-Clare, Andres (1997), “Quantifying Variety Gains from Trade Liberalization”, mimeo


Appendix 1:

Varieties defined as the increase in the number of origin countries

Table 2

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>nb of firms</td>
<td>18492</td>
<td>19137</td>
<td>20557</td>
<td>21249</td>
<td>21406</td>
<td>17849</td>
<td>19102</td>
<td>19862</td>
<td>21039</td>
<td>21328</td>
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<tr>
<td>Average number of origin countries per firm</td>
<td>1.536</td>
<td>1.542</td>
<td>1.570</td>
<td>1.611</td>
<td>1.583</td>
<td>2.082</td>
<td>2.050</td>
<td>1.989</td>
<td>1.929</td>
<td>1.843</td>
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<td></td>
<td>1993</td>
<td></td>
<td></td>
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Contribution of varieties

Table 3

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<tr>
<th>Year</th>
<th>Mean</th>
<th>Std dev</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Std dev</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>1994</td>
<td>-1.61%</td>
<td>32.8</td>
<td>-547.1</td>
<td>815.6</td>
<td>11.05</td>
<td>345.0</td>
<td>-218.4</td>
<td>265.1</td>
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<tr>
<td>1995</td>
<td>-0.15%</td>
<td>9.5</td>
<td>-616.9</td>
<td>457.8</td>
<td>0.8</td>
<td>145.6</td>
<td>-156.0</td>
<td>126.6</td>
</tr>
<tr>
<td>1996</td>
<td>0.087%</td>
<td>9.0</td>
<td>-310.9</td>
<td>608.7</td>
<td>1.57</td>
<td>9.71</td>
<td>-866.0</td>
<td>144.4</td>
</tr>
<tr>
<td>1997</td>
<td>0.37%</td>
<td>8.16</td>
<td>-379.6</td>
<td>192.8</td>
<td>.83</td>
<td>14.1</td>
<td>-145.4</td>
<td>970.4</td>
</tr>
<tr>
<td>1998</td>
<td>0.14%</td>
<td>9.41</td>
<td>-382.9</td>
<td>380.2</td>
<td>1.63</td>
<td>14.1</td>
<td>-806.6</td>
<td>147.9</td>
</tr>
<tr>
<td>1999</td>
<td>1.90%</td>
<td>35.2</td>
<td>-827.4</td>
<td>515.9</td>
<td>-9.42</td>
<td>36.8</td>
<td>-160.0</td>
<td>336.3</td>
</tr>
<tr>
<td>2000</td>
<td>0.12%</td>
<td>11.4</td>
<td>-338.03</td>
<td>827.4</td>
<td>2.21</td>
<td>16.9</td>
<td>-229.3</td>
<td>830.6</td>
</tr>
<tr>
<td>2001</td>
<td>-0.30%</td>
<td>8.20</td>
<td>-290.0</td>
<td>281.9</td>
<td>-0.87</td>
<td>14.2</td>
<td>-127.1</td>
<td>216.3</td>
</tr>
<tr>
<td>2002</td>
<td>-0.028%</td>
<td>8.69</td>
<td>-393.02</td>
<td>283.3</td>
<td>1.1</td>
<td>16.7</td>
<td>-169.0</td>
<td>230.4</td>
</tr>
<tr>
<td>2003</td>
<td>0.12%</td>
<td>8.60</td>
<td>-567.96</td>
<td>300.0</td>
<td>0.12</td>
<td>8.60</td>
<td>-568.0</td>
<td>300.0</td>
</tr>
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</table>

Table 4: Estimation results impact of import varieties on tfp growth (whole sample)

Dependent variable TFP (solow residual) growth

<table>
<thead>
<tr>
<th>Period</th>
<th>OLS</th>
<th>Fixed effects</th>
<th>Random effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>impact of varieties</td>
<td>-2.48E-03</td>
<td>-2.34E-03</td>
<td>-2.46E-03</td>
</tr>
<tr>
<td></td>
<td>(1.19e-03)**</td>
<td>(1.26e-03)*</td>
<td>(1.19 e-03)**</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.03E-03</td>
<td>-1.03E-03</td>
<td>-2.04E-03</td>
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<tr>
<td></td>
<td>(2.04e-04)**</td>
<td>(2.05e-04)**</td>
<td>(3.23e-04)***</td>
</tr>
<tr>
<td>Observations</td>
<td>208806</td>
<td>208806</td>
<td>208806</td>
</tr>
<tr>
<td>Number of firms</td>
<td>29716</td>
<td>29716</td>
<td>29716</td>
</tr>
<tr>
<td>R2</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Hausman test FE vs. RE; chi square=0.08; Prob&gt;chisquare=78.32%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Robust standard errors in parentheses;* significant at 10%; ** significant at 5%; *** significant at 1%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Estimation results impact of import varieties on tfp growth (whole sample)

Dependent variable TFP (solow residual) growth. Linear model with endogenous covariates.

<table>
<thead>
<tr>
<th>Estimation method</th>
<th>IV</th>
<th>Fixed effects</th>
<th>Random effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>impact of varieties</td>
<td>8.93 E-01</td>
<td>6.78 E-01</td>
<td>-8.93 E-01</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.06 E-04</td>
<td>7.96 E-05</td>
<td>-1.06 E-04</td>
</tr>
<tr>
<td>Observations</td>
<td>189725</td>
<td>189725</td>
<td>189725</td>
</tr>
<tr>
<td>Number of firms</td>
<td>28592</td>
<td>28592</td>
<td>28592</td>
</tr>
<tr>
<td>R2</td>
<td>0.00</td>
<td>0.23</td>
<td>0.00</td>
</tr>
<tr>
<td>Hausman test OLS vs. IV (fe); chi square=2.22; Prob&gt;chisquare=13.64%</td>
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<tr>
<td>Hausman test OLS vs. IV (re); chi square=2.78 ;Prob&gt;chisquare=9.52%</td>
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<tr>
<td>Robust standard errors in parentheses;* significant at 10%; ** significant at 5%; *** significant at 1%</td>
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Table 6: Estimation results impact of import varieties on tfp growth. Controlling for R&D and catch-up effects (whole sample)
Dependent variable TFP (solow residual) growth

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<thead>
<tr>
<th>Period</th>
<th>BGW index of increase in varieties number</th>
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<tr>
<td></td>
<td>OLS</td>
</tr>
<tr>
<td>impact of varieties</td>
<td>-2.30E-03</td>
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<td></td>
<td>(1.21005e-03)*</td>
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<tr>
<td>R&amp;D indicator (lagged)</td>
<td>3.97E-04</td>
</tr>
<tr>
<td></td>
<td>(-9.21E-04)</td>
</tr>
<tr>
<td>Percentile (lagged)</td>
<td>-3.81E-04</td>
</tr>
<tr>
<td></td>
<td>(1.32431e-05)***</td>
</tr>
<tr>
<td>Interaction R&amp;D/percentile</td>
<td>-6.20E-05</td>
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<td></td>
<td>(1.59217e-05)***</td>
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<tr>
<td>Constant</td>
<td>2.17E-02</td>
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<td></td>
<td>(7.64456e-04)***</td>
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<td>Observations</td>
<td>189795</td>
</tr>
<tr>
<td>Number of firms</td>
<td>28592</td>
</tr>
<tr>
<td>R2</td>
<td>0.02</td>
</tr>
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Hausman test FE vs. RE : chi square=20,519; Prob>chi square 0.00%
Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Estimation results impact of import varieties on tfp growth. Controlling for R&D and catch-up effects (whole sample). Instrumental variables
Dependent variable TFP (solow residual) growth

<table>
<thead>
<tr>
<th>Estimation method</th>
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<tr>
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<td>R&amp;D indicator (lagged)</td>
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<td>1.81E-03</td>
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<td>Percentile (lagged)</td>
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<td>(2.34475e-05)***</td>
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<td>Interaction R&amp;D/percentile</td>
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<td>(2.83406e-05)*</td>
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<td>(1.35388e-03)***</td>
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<td>Number of firms</td>
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<tr>
<td>R2</td>
<td>-7.63E-01</td>
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</table>

Hausman test FS vs. RE ; chi square=20,519 ; Prob>chi square=0.00%
Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%
Instruments: increase in the number of varieties, measured at the sector level
Appendix 2:
Varieties defined as the increase in number of 4 digit goods and the increase in the number of origin countries

Graph 1: Distribution. Year 2002-2003

<table>
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<th>Increase in number of varieties</th>
<th>BW index of increase in varieties number</th>
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<tr>
<td><img src="image1.png" alt="Graph" /></td>
<td><img src="image2.png" alt="Graph" /></td>
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</table>

Graph 2: average TFP

![Graph](image3.png)

Table 8: Descriptive statistics

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<td>number of firms</td>
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<td>7741</td>
<td>7741</td>
<td>7741</td>
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<tr>
<td>average number of</td>
<td>19.05</td>
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<td>19.44</td>
<td>19.41</td>
<td>18.79</td>
<td>15.87</td>
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<tr>
<td>average number of</td>
<td>11.54</td>
<td>11.75</td>
<td>11.70</td>
<td>11.70</td>
<td>11.41</td>
<td>9.64</td>
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<td>122</td>
<td>122</td>
<td>122</td>
<td>122</td>
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<td>average number of</td>
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<td>38.67</td>
<td>37.79</td>
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<td></td>
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### Table 9 Contribution of varieties

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Std dev</th>
<th>Min</th>
<th>Max</th>
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<td>1993-1999 (yearly average)</td>
<td>0.97%</td>
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<td>1999-2000</td>
<td>-0.81%</td>
<td>6.9</td>
<td>-96.5</td>
<td>49.3</td>
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<td>2000-2001</td>
<td>0.55%</td>
<td>7.0</td>
<td>-98.3</td>
<td>95.7</td>
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<tr>
<td>2001-2002</td>
<td>0.54%</td>
<td>7.1</td>
<td>-73.3</td>
<td>96.2</td>
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<tr>
<td>2002-2003</td>
<td>0.77%</td>
<td>7.9</td>
<td>-96.8</td>
<td>99.7</td>
</tr>
<tr>
<td>1993-2002 (yearly average)</td>
<td>0.40%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 10: Estimation results impact of import varieties on tfp growth (whole sample)

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable TFP (solow residual) growth</th>
<th>BGW index of increase in varieties number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period</td>
<td>OLS</td>
<td>Fixed effects</td>
</tr>
<tr>
<td>impact of varieties</td>
<td>4.96E-02</td>
<td>5.44E-02</td>
</tr>
<tr>
<td></td>
<td>(5.04E-03)***</td>
<td>(5.77E-03)***</td>
</tr>
<tr>
<td>Constant</td>
<td>1.16E-02</td>
<td>1.15E-02</td>
</tr>
<tr>
<td></td>
<td>(5.41e-04)***</td>
<td>(5.66e-04)***</td>
</tr>
<tr>
<td>Observations</td>
<td>26685</td>
<td>26685</td>
</tr>
<tr>
<td>Number of firms</td>
<td>5337</td>
<td>5337</td>
</tr>
<tr>
<td>R2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Hausman test FS vs. RE; chi square=3.02; Prob>chi square=8.21%
Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%

### Table 11: Estimation results impact of import varieties on tfp growth. Instrumental variables

<table>
<thead>
<tr>
<th></th>
<th>Dependent variable TFP (solow residual) growth</th>
<th>[to be completed]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimation method</td>
<td>OLS</td>
<td>Fixed effects</td>
</tr>
<tr>
<td>impact of varieties</td>
<td>9.02 E-01</td>
<td>7.38 E-01</td>
</tr>
<tr>
<td></td>
<td>7.31 E-01</td>
<td>4.12 E-01</td>
</tr>
<tr>
<td>Constant</td>
<td>1.16 E-02</td>
<td>1.15 E-02</td>
</tr>
<tr>
<td></td>
<td>(7.63 E-04)***</td>
<td>(5.26 E-04)***</td>
</tr>
<tr>
<td>Observations</td>
<td>26685</td>
<td>26685</td>
</tr>
<tr>
<td>Number of firms</td>
<td>5337</td>
<td>5337</td>
</tr>
<tr>
<td>R2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Robust Standard errors in parentheses. * significant at 10%; ** significant at 5%; *** significant at 1%
Instruments: increase in varieties at the sectoral level
Appendix 3. Total Factor Productivity

Permanent inventory method

The net value of physical capital stock is observed from balance sheet data and can be expressed as:

\[
\sum_{i=1}^{A} \left( p_{t-i} I_{t-i} - \left( \frac{i}{A} \right) p_{t-i} I_{t-i} \right)
\]

The total depreciation on the stock of this asset during \( t \) is also observed from balance sheet data and can be expressed as:

\[
flowD_i = \frac{1}{A} \sum_{i=1}^{A} p_{t-i} I_{t-i}
\]

So

\[
\frac{\text{net value of } K \text{ stock}}{\text{depreciation}} = \sum_{i=1}^{A} p_{t-i} I_{t-i} - (1/A) \sum_{i=1}^{A} ip_{t-i} I_{t-i} \\
(1/A) \sum_{i=1}^{A} p_{t-i} I_{t-i} \\
= A - \sum_{i=1}^{A} ip_{t-i} I_{t-i} \\
\sum_{i=1}^{A} p_{t-i} I_{t-i}
\]

= \( A - \text{Average age of capital stock} \)

Correlation matrix between TFP (Perpetual Inventory method) and TFP (Mairesse method)

\[
\begin{bmatrix}
1.0000 & 0.9405 \\
0.9405 & 1.0000
\end{bmatrix}
\]