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Price and Quality Competitiveness across OECD countries:

An approach to quality by R&D expenditure

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Price and Quality Competitiveness across OECD countries: An approach to quality by R&D expenditure

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Abstract:
The aim of this paper is to analyze the effects of quality competitiveness based on technological innovation on the bilateral trade of goods. Our approach is based on the estimation of an import demand model using the data for 19 manufacturing sectors across 28 OECD countries over the period 1998-2012. In a first step, to identify quality from prices, the logarithm of unit value (a proxy of price) is regressed on the logarithm of private R&D expenditure (a proxy for quality). The quality-adjusted prices are derived from the difference between the unit value and its predicted value. In a second step, an import demand function is used to distinguish the effects of quality (private R&D expenditure) from the effects of other factors, such as production costs, approximated by the quality-adjusted prices. The results of the first step indicate a significant positive effect of quality on the prices of imported goods in 7 out of 19 sectors. The results of the second step highlight significant nonlinear effects of prices and quality on the import demand of goods: the higher the quality of imported goods is, the greater the marginal effect of an increase in quality on the import demand.

JEL classification: F14, O3
Key words: international trade, quality competitiveness, cost competitiveness, innovation.

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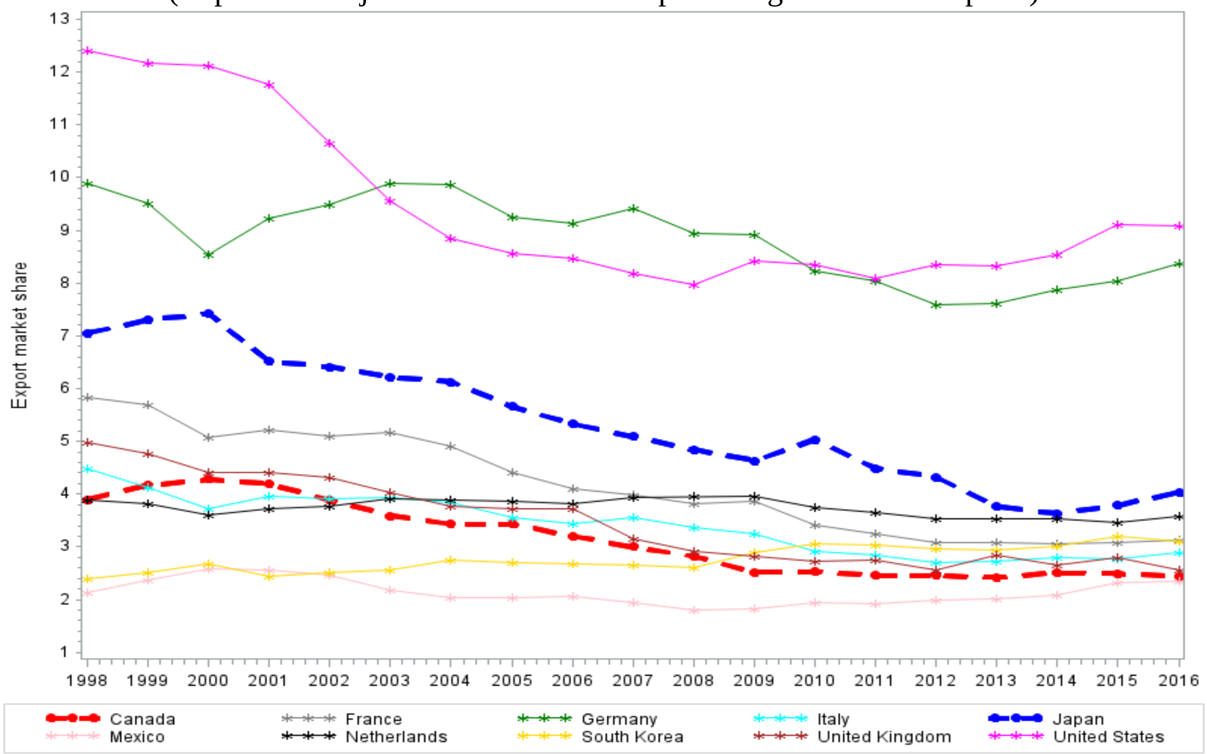
Introduction

France has always been a major exporter of goods. However, between 1998 and 2016, France's world market shares fell by almost 47% (from 5.8% to 3.1%), while by comparison, those of Germany decreased by only 15% (from 9.9% to 8.4%) (Figure 1). Only the United Kingdom, among the top 10 OECD countries contributing the most to world trade in goods, lost more market share than France (nearly 49%). Notably, countries such as Germany and South Korea, which have maintained their share of the world market, have also increased their private R&D efforts since 2000. On the other hand, France and the United Kingdom, which have lost the most market share, are also those that have experienced a relative stagnation of their private R&D expenditures (see Figure 2). Not all developed countries exert the same effort of innovation (private R&D expenditure) and consequently achieve the same quality competitiveness (Wakelin 1998). Of course, other factors also affect the competitiveness of countries. For example, Japan has seen its market share plummet, while Japanese private R&D expenditures have remained among the highest in OECD countries; this may indicate the struggle of Japanese industry to impose its technological standards, especially against the United States (Arora et al. 2013). Of course, other country-specific factors may explain the decrease in country exports. In Japan’s case, the most likely explanation is an overvalued exchange rate (OECD 2013). However, another argument often put forward is that export performance depends on cost competitiveness (Decramer et al. 2016).

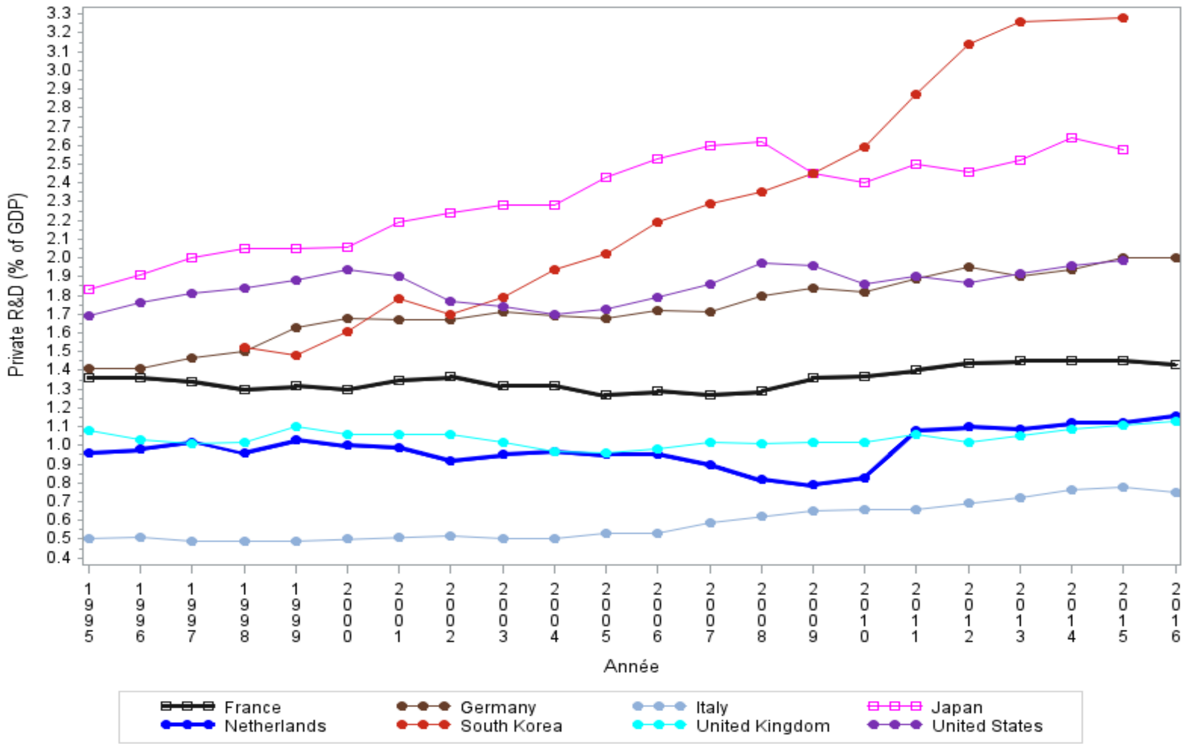
Figure 1: Evolution of export market shares of goods
(Exports of major OECD countries as percentages of world exports)



Source: WTO

From the model of Falvey and Kierzkowski (1987) based on the theory of comparative advantages, it is possible to deduce that, given their technology endowments, developed countries own a comparative advantage in the production of high-quality goods. For Bekkers et al. (2016), countries endowed with skilled labor can compete favorably in the international market by exporting products of higher quality at a high price. However, these comparative advantages are not immutable. Indeed, developed countries, such as France or Germany, need to constantly improve the quality of their products to maintain their competitiveness, particularly against the rise of emerging countries with low costs, which have also been experiencing an upgrade in the quality of their products (Khandelwal 2010; Martin and Mejean 2014).

Figure 2: Evolution of private R&D intensity



Source: OECD

The main purpose of this work is to estimate the effects of cost competitiveness and quality competitiveness in relation to technological innovation[1] on bilateral trade between OECD countries at the sector level over the period 1998-2012. In line with Hallak's theoretical approach with constant elasticity of substitution (CES) preferences and monopolistic competition, we empirically test an econometric model in which imported goods depend simultaneously on cost competitiveness and quality competitiveness. As we assume that quality is based on technological innovation, quality competitiveness is measured by private R&D expenditure (Cunéo and Mairesse 1985). However, the purpose of investment in R&D is not

[1] In the rest of the paper, the term "quality" will be used in the sense of quality related to technological innovation.

only to improve the quality of goods via product innovations but also to reduce production costs through process innovation. The potential substitutability of these two types of innovation leads to the measurement of a net effect of quality on import demand as well as on prices. The unit values (prices) of imports are used to measure cost competitiveness. However, to control for the potential positive effect of quality on prices, prices net of quality are used as a proxy for production costs.

To account for potentially low levels of bilateral trade between countries in some sectors and for some years and to correct the presence of heteroscedasticity, the Poisson pseudo-maximum likelihood estimator is used (Silva and Tenreyro 2006). The data used have several dimensions (exporting countries-importing countries-sectors-years). As usual in the gravity models, it is possible to address unobserved heterogeneity and control the correlation between random effects and regressors (Matyas 1997; Egger and Pfaffermayr 2003). However, in our case, a more specific problem must be considered since we have to address missing values of R&D expenditures (Cunéo and Mairesse, 1985).

The results show a positive and significant net effect of quality on the import demand of OECD countries, but only in some sectors. Among the 19 sectors studied, two groups can be distinguished: the first comprises the sectors where the quality rent is reflected in the prices (3 low and medium technology sectors and 4 high and medium-high technology sectors), and the second comprises sectors where quality has no effect on prices (10 sectors of low and medium technology and 2 of high and medium-high technology). Remark the very significant contribution of quality to price, exceeding 64%, in sectors of Rubber and plastic products, Electrical equipment and Machinery and equipment n.e.c.

Another contribution of this work is the finding that the effects of (logarithm) prices and quality on trade are nonlinear. It seems that the preferences of consumers considered in the import demand equation should be represented by a more flexible utility function than the CES utility function. From this finding, we can deduce that the smaller the import price is, the smaller the effect of a decrease in prices on the import demand. On the other hand, improving product quality will have a stronger positive effect on import demand, as the goods are already of high quality.

This paper is structured as follows. The first section is devoted to a review of the literature. The second section discusses the theoretical framework for horizontal and vertical product differentiation on which import demand is based to test the effects of cost competitiveness and quality competitiveness on bilateral trade. The third section presents the econometric strategy chosen, and the fourth section presents the data used. The next two sections present the descriptive statistics results and estimates. The paper ends with concluding remarks.

I - Literature review

Early work on the determinants of bilateral trade focused on the influence of prices (a proxy for production costs) but neglected the influence of differences in product quality. These models sought to estimate the price elasticity of trade. To avoid bias related to this estimated elasticity, these studies first focused on the measurement errors on prices (Blonigen and Wilson 1999;

Erkel-Rousse and Mirza 2002, among others). However, the omission of quality variables leads to a problem of specification in the trade equation.

In more recent work, quality has been considered without explicitly considering prices as a proxy for production costs. As in the gravity model, prices are simply accounted for by country/sector/year dummies (Hallak 2006; Chen 2013). To our knowledge, few studies have sought to combine the two approaches, with the exception of the pioneering works of Anderton (1999) and Crozet and Erkel-Rousse (2004).

One of the difficulties in assessing the effect of quality on trade is that it is not directly observable[2]. However, the literature suggests that innovation is an important factor of product quality (Hall et al. 2009), although it is clearly not the only factor. Innovation allows the introduction of new products and the quality improvement of existing products. This finding is shared by several theoretical and empirical works. For example, Kugler and Verhoogen (2012) show that, in Colombia, the elasticity of firm size with respect to price is lower (in absolute value) in the intensive R&D and marketing sectors. The authors consider R&D and marketing expenditures as vectors of vertical and horizontal differentiation that are closely related to the quality of goods and varieties (see also Sutton 1991 and 1998). Sutton (1998) postulates that R&D and marketing investments are mainly made by companies in sectors where it is possible to extract rent from the (perceived) quality through the selling price. Sutton (2007) also shows in a theoretical model that firms producing goods whose quality, linked to the R&D effort, is below a certain threshold cannot export, even with low production costs.

In fact, the theoretical literature shows that innovation can enhance the export performance of countries (Grossman and Helpman 1991 and 1995). Paradoxically, few empirical papers have tested the effects of innovation quality on the export performance of countries. Among the exceptions, Wakelin (1998) estimates a model of trade among OECD countries and emphasizes the role of innovation, measured in the usual way by several proxies (R&D expenditure, number of patents filed and number of citations). Regardless of the proxy used, the results confirm the hypothesis of a positive effect of innovation on bilateral trade. Khandelwal (2010), using US product import data for the period 1989-2001, shows that R&D expenditures have a positive effect on quality, unlike marketing expenditure, whose effect is not significant. The quality image of the products seems more difficult to acquire internationally through marketing expenditures than through R&D expenditures. Crozet and Erkel-Rousse (2004) corroborate this point. Indeed, they show that the quality of imported products perceived by consumers is highly correlated with the product innovation and that quality and product innovation have very similar effects on products sold in Europe and imported from Germany, France, Italy and the United Kingdom.

Since product quality is not based solely on innovation, other measurement strategies are used in the literature. Thus, from the estimation of import demand (and supply) functions for differentiated products, it is possible to residually identify the quality content of the traded

[2] To our knowledge, only Crozet & Erkel-Rousse (2004) provide a fairly precise measure of the quality of (imported) products through the perception of consumers. However, the scope of their analysis is limited to products sold in Europe and imported from Germany, France, Italy and the United Kingdom.

products once the price effect is controlled[3] (Khandelwal 2010; Hallak and Schott 2011; Amiti and Khandelwal, 2013; Martin and Mejean, 2014; Bas et al. 2015). The approach used in this literature limits the aggregation bias inherent to the previous analyses that used sector data rather than product data. In this kind of approach, the unit values that are used as a proxy for production costs also reflect compositional effects in the quality of imported varieties (Kravis and Lipsey 1975; Antoniades 2015). As a consequence, unit values cannot be considered "exact" prices: they are not independent of composition effects in quality (Feenstra 1994). The introduction of a quality variable into the import demand equation, without controlling for quality contained in the prices, does not fully solve the problem, even if the price elasticity of trade has more important and consistent values (Crozet and Erkel-Rousse 2004).

The econometric specification used here considers that quality is also incorporated into prices. Not addressing this issue could lead to underestimating the effect of quality and overestimating the effect of production costs. To adjust for quality in import prices, we propose an original approach that consists of estimating the quality-adjusted prices by the residuals of the regression of the logarithm of the unit values on the logarithm of the R&D expenditures[4]. After estimation, the quality-adjusted prices are introduced into the import demand equation, allowing an explicit distinction between the effects of cost competitiveness and the effects of quality competitiveness. By distinguishing between the unit values and the quality-adjusted prices, it is also possible to determine the importance of the quality rent included in prices. Thus, we can identify both the effect of quality on prices and the effect of quality competitiveness on import demand.

II - Import demand model for differentiated products

We consider an import demand model with horizontal and vertical product differentiation. Thus, as in Hallak (2006), we assume that consumers have a taste for variety and a preference for quality. Specifically, we assume that for an importing country *j*, consumer preferences are expressed by a utility function with CES across all varieties available in sector *s* for variety *h*,

$$u_s^j = \left[\sum_{h \in s} \left(\theta_h^{\gamma_s^j} q_h^j \right)^{\sigma_s - 1/\sigma_s} \right]^{\sigma_s/\sigma_s - 1} \qquad \text{with } 1 < \sigma_s \tag{1}$$

where q_h^j and θ_h are the consumed quantities and the quality of variety *h*, respectively, σ_s the elasticity of substitution and γ_s^j the intensity of preferences for the quality of varieties available in sector *s* of country *j*. This approach is quite general because allows consideration of both the

[3] Combining import supply and import demand makes it possible to consider the contradictory effects of quality on trade. For example, Feenstra and Romalis (2014) combine import supply and import demand and argue that an increase in the import demand leads to a lower quality of the goods sold on the international markets by less efficient exporters. The import supply may lead to a negative relationship between quality and bilateral trade. In the same vein, Bekkers (2016) highlights the ambiguous effect of market size. A large market encourages firms to invest in quality but at the same time favors the survival of inefficient firms.

[4] We could have also used the number of patents filed as a quality proxy. The use of either of these two proxies does not reach consensus in the literature, as it is difficult to provide a satisfactory measure of innovation. In fact, the choice of a "good" proxy is not a major issue here, referring to the results of Wakelin (1998), which suggest very similar effects on trade of R&D expenditures or the number of patents.

horizontal differentiation of products, as is usual in models of international trade (Dixit and Stiglitz 1977), and vertical differentiation (by quality) that may represent a key dimension of competitiveness (Chen 2013).

The maximization of consumer utility under budgetary constraints yields the following demand function for variety *h*:

$$q_h^j = \frac{\dfrac{p_h^{j^{-\sigma_s}}}{\theta_h^{\gamma_s^{j^{1-\sigma_s}}}}}{\sum_{r\in s}\left(\dfrac{p_r^j}{\theta_r^{\gamma_s^j}}\right)^{1-\sigma_s}} INCOME_s^j \tag{2}$$

where $INCOME_s^j$ is the consumer income allocated to sector *s* and *r* indexes all the varieties available in *s*. From these preferences, the demanded quantity of variety *h* is (q_h^j) depends on $INCOME_s^j$, the selling price of variety *h* in country *j* (p_h^j) and a sectoral price $\left(\sum_{r\in s}\left(p_r^j\right)^{1-\sigma_s}\right)$.
Note that these prices are "deflated" by their level of quality perceived by consumers. In view of expression (2), the quality of variety *h* has a positive effect on its quantity demanded or, equivalently, on the income allocated to the consumption of this variety.

Among the varieties supplied, some are produced by domestic firms, while others are imported. There are iceberg trade costs for import products. We assume that all the varieties imported from country *i* have the same quality without necessarily being sold in country *j* at the same price. We can then deduce the import demand (in volume) of country *j* for the varieties of country *i* in sector *s*.

$$import_s^{ij} = \frac{\sum_{h\in s}\dfrac{\left(p_h^i\tau_s^{ij}\right)^{-\sigma_s}}{\theta_{is}^{\gamma_s^j\,1-\sigma_s}}}{\sum_{r\in s}\left(\dfrac{p_r^j}{\theta_r^{\gamma_s^j}}\right)^{1-\sigma_s}} ICOME_s^j \tag{3}$$

where p_s^i is the net price of trade costs (free on board) of a variety of sector *s*, charged by each exporter in country *i*, and τ_s^{ij} is an iceberg cost for imports of country *j* from its partner *i*.

A logarithmic transformation applied to expression (3) yields an estimable form of the import demand function of country *j* for varieties belonging to sector *s* and produced in country *i*. So,

$$\log import_s^{ij} = -\sigma_s \log\tau_s^{ij} + \log\sum_{h\in s}\left(p_h^i\right)^{-\sigma_s} + (\sigma_s - 1)\gamma_s^j \log\theta_{is} - \log\sum_{r\in s}\left(\frac{p_r^j}{\theta_r^{\gamma_s^j}}\right)^{1-\sigma_s} + \log GDP_s^j \tag{4}$$

A common assumption in the papers using gravity models is to substitute individual country effects for price indexes (Head and Mayer 2013). This assumption is not well suited to our problematic because it does not allow us to clearly identify the effects of cost competitiveness and quality competitiveness on trade. As in Martin and Mejean (2014), we propose a proxy for import prices ($\sum_{h\in s}\left(p_h^i\right)^{-\sigma_s}$) from the unit values available in our database. The aggregate price deflated by the quality ($\sum_{r\in s}\left(\frac{p_r^j}{\theta_r^{\gamma_s^j}}\right)^{1-\sigma_s}$) is the sum of the prices of domestic products and foreign products, and it is more difficult to proxy. To allow the estimation of the model, this aggregate price is proxied through a country-importer-sector-year dummy variable (Fally 2015). Assuming that consumers allocate a fixed part of their budget to the purchase of varieties of the sector *s*, we can consider $\log GDP_s^j = \alpha_s \log GDP_j$ where GDP_j is the current income of country *j*. Trade costs are assumed to depend exclusively on the geographical distance between each pair of countries ($dist_{ij}$), i.e., $\log \tau_s^{ij} = \log dist_{ij}$. The quality of the products is a function of the innovations made by firms. This function is not necessarily log-linear for two reasons: i) the specification adopted is based on CES preferences; when the utility function representing preferences is quadratic (Melitz and Ottaviano 2008), the log-linear relationship is no longer verified (Antoniades 2015), and ii) the link between R&D expenditure and innovation is not necessarily linear. Innovation is a risky process, and a major (minor) R&D effort may lead to minor (major) innovations.

$$\log\theta_{is} = \phi_1 \log R\&D_{is} + \phi_2\left(\log R\&D_{is}\right)^2$$

From these different assumptions and considering that our data have an additional time dimension, it appears that the expression (4) can be rearranged in the following estimable form:

$$\begin{aligned}\log import_{st}^{ij} = {} & \beta_1 \log P_{ist} + \beta_2\left(\log P_{ist}\right)^2 + \beta_3 \log R\&D_{ist} + \beta_4\left(\log R\&D_{ist}\right)^2 \\ & + \beta_5 \log dist_{ij} + \beta_7 \log GDP_{jt} + DumX + DumS + DumT \\ & + DumXT + DumST + DumMST + \varepsilon_{ijst}\end{aligned} \tag{5}$$

where $import_{st}^{ij}$ is the volume of imports of country *j* from country *i* for the varieties of sector *s* in $P_{ist} = \sum_{h\in s}\left(p_{ht}^i\right)^{-\sigma_s}$, $DumX$ includes the dummies of the exporting countries, $DumS$ the sectoral dummies, $DumT$ the time dummies, $DumXT$ the exporter-year dummies, $DumST$ sector-year dummies, $DumMST$ the dummies that proxy the aggregate sector prices deflated by the quality in importing country *j* and more broadly the sectoral characteristics of that country each year, and ε_{ijst} an error term. As with R&D expenditure, the square of the log of the price of imported products is introduced in this specification (Bekkers et al. 2016). By this means, we can consider a more flexible utility function than the CES utility function.

The expression (5) corresponds to the econometric model that we estimate. The two price terms reflect cost competitiveness. The R&D expenditure terms are proxies for the quality competitiveness of imported products. The other regressors of the model (GDP, distance and dummies) are control variables commonly used in the literature (Head and Mayer 2013; Fally 2015).

III - The econometric strategy

The quality linked to technological innovation of the varieties changes the terms of trade, with consumers having a higher willingness to pay for higher-quality varieties (Feenstra and Weinstein 2010; Amiti and Khandelwal 2013). The more significant the innovation effort in sector *s* of country *j*, the higher the export prices may be. However, prices may also reflect production costs. For prices to be a proxy of production costs, they must be purged of a quality effect. To this end, we propose an approach that, to our knowledge, has not yet been implemented in the literature.

In a first step, the quality-adjusted prices, reflecting production costs, are deducted from the residuals of the regression of the logarithm of aggregate sectoral unit values on the logarithm of sectoral R&D expenditures in volume. The logarithm of R&D expenditure is lagged by one year. The introduction of one lag serves a dual purpose. First, current R&D expenditures can be subject to contemporary shocks and are therefore potentially correlated with the idiosyncratic error term of the current period. Second, introducing innovation into new products can take time. Under these conditions, lagged R&D expenditure may be a better proxy for quality than current R&D expenditure. In this respect, a lag of only one year makes it quite unlikely that R&D expenditures would be transformed into innovations that will be incorporated into new products. To also control for the possible correlation between individual country/sector pair effects and country/sector R&D expenditures, the within estimator is used. The difference between the unit values and the predicted values determines the quality-adjusted prices. The latter are introduced as proxies for cost competitiveness in the import demand equation. This first step is estimated separately for the 19 manufacturing sectors in our sample (see Table 1 in Appendix 2). The estimated coefficients of the log of R&D expenditures are positive or zero. In the only case where the coefficients are positive and significantly different from zero, the quality of the products has a positive effect on the prices. However, the estimated coefficients could also be negative; such a result, which never appears in our estimates, would suggest that in some sectors, R&D expenditures are primarily used not for product innovation but for process innovation leading to lower production costs. This would imply that product innovations and process innovations are substitutable for firms. However, empirical studies show rather a complementarity between the two types of innovation, as new products often require changes in the production process (Kraft 1990; Martinez-Ros 1999; Miravete and Pernías, 2006).

The approach chosen here is simple and flexible because it does not require any particular assumptions about the value of elasticity of substitution, unlike other studies that build quality as the residual of an import demand function (Martin and Mejean 2014). This approach makes it possible to make an explicit distinction between cost competitiveness, measured through quality-adjusted prices, and quality competitiveness based on innovation. In fact, in the second step, it is possible to estimate the import demand model corresponding to equation (5). At least three problems need special attention. First, the error term of the gravity model in logarithmic form is very likely to be heteroscedastic, leading to correlation between the regressors and the error term (Silva and Tenreyro 2006). Under these conditions, the ordinary least squares method produces nonconvergent estimates for the parameters of interest of the model. Silva and Tenreyro (2006) advocate the use of the Poisson pseudo-maximum likelihood (PPML) estimator, which produces convergent estimates for positive or zero values of the explanatory variable under the assumption that the model is correctly specified[5]. In this case, the explanatory variable is measured in level, while the explained variables are expressed in logarithms. A limitation of the standard Poisson model, unlike PPML, is the hypothesis of equality between the mean and variance. This assumption does not allow us to consider the overdispersion of the exchange flows and the excess of zero trade. Given these arguments, the PPML estimator is preferable to the standard Poisson estimator, and it is therefore used here to estimate the unknown parameters of equation (5).

Second, to address unobserved heterogeneity, the multiplicity of dimensions of our data must be considered. Thus, we consider the heterogeneity between countries, sectors with different technology and years to account for the effects of the business cycle on bilateral trade. These multidimensional effects are considered through the dummies $DumX$, $DumM$, $DumS$ and $DumT$. In addition, the prices deflated by the quality of the products sold on the markets of the importing countries are accounted for through the dummies $DumMST$[6]. However, the introduction of these different dummies does not fully control the possible correlation between regressors and individual effects that is considered in the importer/exporter/sector/year dimensions. To address this correlation, it would be possible to estimate a specific effects model by introducing dummies with the importer/exporter/sector dimensions. However, such an approach raises the problem of incident parameters in nonlinear models. The presence of specific effects increases the number of parameters to be estimated to infinity with the size of the sample without providing convergent estimates, unlike the case of linear models[7]. To address the problem of incident parameters, we use an approach à la Mundlak (1978) that suggests introducing the intraindividual means of regressors to control for their possible correlation with the individual effects (Proenca et al. 2015).

Third, the model to be estimated raises problems more specific to those encountered for gravity models. Thus, depending on the sector, the value of R&D expenditure may be missing. In our case, a quarter of the observations are concerned. It can be assumed that in this case, R&D expenditures exist, but they are low. To account for the potential bias due to the missing data for R&D expenditures, we create a dummy that is 1 (an additional unknown parameter to be estimated in the model) when the observation is missing and zero otherwise, and we set the logarithm of the missing value of R&D expenditures to zero (Cunéo and Mairesse, 1985) .

[5] There may be a significant proportion of missing or zero bilateral trade flows, even at the highest level of aggregation, i.e., the country level. Thus, Helpman et al. (2008) highlight from a panel of 158 countries observed over the period 1970-1997 that almost 50% of bilateral trade flows do not exist. In our database, the zero trade flows between two countries, for a given sector, are much less present because they represent less than 4% of the entire sample. Note that our sample covers developed countries that are highly exposed to international trade. These missing data for trade and consequently for unit values are removed from the estimates because they cannot be used in the first step when we estimate the contribution of quality to prices.

[6] Cross-country effects could be introduced (Egger and Pfaffermayr 2003; Baldwin and Taglioni 2007), but in this case, it is no longer possible to identify the effect of distance, which remains constant over time.

[7] The estimate of each specific effect is non-convergent because it is based on a finite number of observations per individual. Non-linearity leads this non-convergence to "be propagated" to the estimation of the parameters of interest in the econometric model.

IV - The data

To analyze the effects of cost and quality competitiveness on bilateral trade, we use R&D data from 19 manufacturing sectors[8] (the finest disaggregation level available for this type of exercise in revision 4 of the ISIC nomenclature[9]) between pairs of 28 OECD countries[10] observed over the period 1998-2012. For the estimates, we use an unbalanced panel of 148,652 observations.

Data on trade in manufactured goods are from the CEPII BACI database. The level of disaggregation is quite fine (more than 5000 products from the 6-position harmonized nomenclature). The raw data come from the UN COMTRADE database and are treated to obtain harmonization between exports and imports. In this case, exports and imports are both expressed in free on board (FOB) rather than in insurance cost and freight (CIF). In addition, trade volumes measured in tons are available. It is therefore possible to calculate the prices/FOB unit values of imports and exports between two countries for a given product (Gaulier and Zignago 2010). Information on the geographical distances between countries is drawn from the database developed by the CEPII (Mayer and Zignago 2011). Private R&D expenditure data are drawn from the OECD STAN database. In some sectors/countries, no R&D expenditures are available for some years over the period 1998-2012. Missing R&D values represent a significant proportion (25%) of the observations of our sample. In our estimates, we kept only the sectors/countries for which at least three consecutive years were reported. The data for GDP, a measure of the income of importing countries, come from the World Bank. The data for R&D expenditures and GDP are expressed in thousands of constant dollars (base 100 in 2010) and in PPP to obtain data in volumes and with a comparable monetary unit between countries.

The price of bilateral imports by sector P_{ist} is approximated by the weighted arithmetic mean at the sector level of the prices of the varieties. The weighting used is the share of each variety in the total exports from j to i in sector s. Although the BACI database has been built very carefully, the unit values of the varieties traded are subject to such measurement errors as conventionally appear in the literature. Unit values considered as outliers were replaced by the average unit values from the previous year and the following year or were removed from the sample.

V – Descriptive statistics on cost and quality competitiveness

Statistical analysis of our three main variables of interest shows that the median bilateral trade amounts to 2669 tons and a median price per ton of nearly €5000 (see Table 1). The median R&D expenditure amounts to €65 million. Most noticeable is the strong dispersion of these three variables, which is especially marked for R&D expenditure. Thus, with an interquartile ratio of 338, it appears that 25% of the highest R&D expenditures are more than 338 times

[8] The pharmacy sector has been removed because it has a very large share of missing or non-existent trade values.
[9] The previous sector classification (ISIC rev.3) could be used to obtain additional data on some emerging countries, such as China. The major disadvantage would be the loss of data on R&D expenditures in the most recent years (2011 and 2012).
[10] The OECD countries selected for the empirical analysis are Australia, Austria, Belgium/Luxembourg, Canada, Estonia, Finland, France, Germany, Hungary, Ireland, Israel, South Korea, Spain, Italy, Japan, Mexico, Norway, New Zealand, Netherlands, Poland, Portugal, United Kingdom, Slovakia, Slovenia, Switzerland, Czech Republic and Turkey.

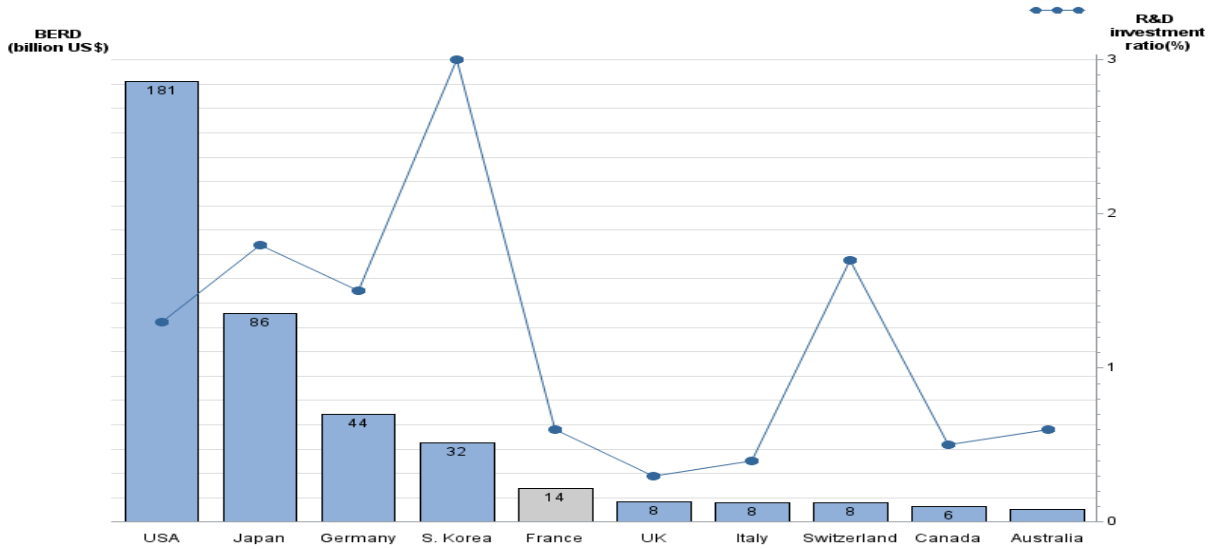
higher than the 25% lowest expenditures. For trade prices and their volumes, the dispersion is less sensitive, with interquartile ratios of 9 and 173, respectively.

Table 1: Main characteristics of import prices, import volumes and R&D expenditures

	# non-missing observations	1st decile	1st quartile	median	3rd quartile	9th decile
Volume (in tons)	148 652	9.65	170.66	2 669.42	29 538.34	194 908.3
Prices (in million US$)	148 652	0.39	1.37	4.77	12.46	29.94
R&D expenditures (in million US$)	6 412	0	0.47	28.25	159.115	795.95

Figure 3 indicates the top 10 countries investing in private R&D. France is in 5th position after South Korea and before the United Kingdom when the ranking is based on the amount of R&D investment. When R&D investment is considered as a percentage of GDP, the Asian countries (South Korea and Japan) hold the two highest rankings, followed by Germany and the United States.

Figure 3: Private R&D expenditures in amount and percent of GDP
(2010 – the first ten countries by amount of private R&D expenditure)



Source: STAN OECD and authors’ calculations

VI - Analysis of econometric results

To assess the extent to which the lack of private R&D investment in OECD countries has impacted the quality competitiveness of the products exported, we adopt a two-step approach. In a first step, we estimate the contribution of quality to prices. The first term of the equation described in Appendix 2 measures the share of quality in prices when the residual term corresponds to the quality-adjusted prices. In a second step, we estimate an import demand function that considers both cost competitiveness (quality-adjusted prices) and quality competitiveness (measured by R&D expenditure), in addition to the usual variables used in gravity models (see equation 1.5).

1 - Importance of quality in prices

In sectors where the quality is significantly positive, the contribution to prices represents 47.3%, on average (Table 2[11]); in other words, quality represents, on average, almost 48% of the export price. There are, of course, important differences between the 19 sectors used for the analysis. Thus, the quality of traded products is reflected in prices in only 7 sectors (Table A.1 in Appendix 2).

Of the 13 low and medium technology sectors where R&D expenditures are lower, quality contributes positively to prices in only three of the sectors[12]. This contribution is more systematic in the high and medium-high technology sectors, concerning 4 of the 6 sectors in this category. Quality does not impact export prices in only the two sectors of "chemistry" and "computers, electrical and optical goods". The results do not indicate that the products in these sectors have low R&D input but suggest that, on average, the positive effect of R&D on quality and therefore on price (the effect of product innovation) offsets the effect of R&D on the decrease in the production cost (effect of process innovation)[13].

The results in Table 2 also indicate that the contribution of quality to prices is higher, on average, in the high and medium-high technology sectors (48.9%) than in the sectors of lower technological level (45.2%). However, there is not a systematic positive link between the level of R&D expenditure and the contribution of quality to prices. Thus, in the information technology (IT) sector, R&D expenditures are six and a half times higher than in the other sectors, while the contribution of quality to prices is zero. One possible explanation is that the strong competition in the IT sector is pushing firms to invest in both product innovation and process innovation. The effects of these two types of innovation on price may then offset each other.

A more detailed analysis allows establishing a hierarchy between countries in sectors where the contribution of quality to prices is strictly positive. Table 3 shows the average contribution of quality to prices for country-sector pairs in 2012, the last year of our observation period, and

[11] The estimates used to determine the contribution of quality to prices have been made by sector and are presented in Table A.1 of Appendix 2.
[12] This result may appear surprising. However, the extractive industry has high-quality products whose production may require the use of sophisticated technologies (Scott and Bristow 2002).
[13] It is important to point out that, for all sectors, the estimates do not indicate a negative effect of R&D expenditure on price.

the ranking of contributions in descending order between countries for a given sector[14]. Thus, for the United States, Japan and Germany, quality has a strong contribution to export prices. Of the seven sectors where quality has a positive effect on prices, the United States ranks first in five sectors (one low technology sector and four high technology sectors). For its part, France ranks second, its highest ranking, in the sector of other transport equipment, which includes aeronautical construction. In this sector, France holds the same position as Germany and is just behind the United States. France is ranked lower than Germany in 3 of the 4 high and medium-high technology sectors; however, in these sectors, the difference between the two countries in terms of the contribution of quality to price remains small (approximately 3 percentage points[15]). Thus, France does not seem so far behind its German partner in terms of quality competitiveness linked to innovation[16]. In 2012, the top five countries with the highest quality related to price innovation are the United States, Japan, Germany, Korea and France[17]. In 2010, France was in fourth place, just behind Germany, before South Korea took its place in 2011 (Table 2.4 in appendix 2).

Our ranking is quite different from that obtained by Feenstra and Romalis (2014), which classified Switzerland, Finland, Ireland and Israel among the countries with the highest share of quality in prices. These countries are not part of our own ranking due to the lack of sectoral data available on R&D expenditures. The authors also highlight the higher share of quality in prices for Austria (4th in 2007), which does not hold very high positions in our own ranking (11th from 2010 to 2012). One possible explanation for the differences in ranking is that Ireland and Finland are specialized in the "computers, electronic products and optical products" sector, while our estimates indicate no positive contribution of quality to prices in this sector. However, unlike Feenstra and Romalis (2014), who position France ahead of Germany, our results are more in line with those obtained by Bas et al. (2015).

[14] The ranking shown in Table 4 is determined from all countries in the sample. The results for all these countries are presented in Table A.2 of Appendix 2.

[15] For example, if we consider the "Automobiles, trailers and semitrailers" sector, the contribution of quality to the price is 31.2% for France and 35% for Germany, a gap of 3%.8 percentage points.

[16] By considering non-price competitiveness as a residual, Bas et al. (2015) highlight at a finer level of aggregation three sectors where France is more competitive in the non-price dimension (Aeronautics Leather goods and Wine).

[17] This ranking does not incorporate Switzerland, Estonia, Finland, Ireland, Israel, the Netherlands, New Zealand, and Slovakia, for which data on R&D expenditures are missing in some sectors where the contribution of quality to prices is significant.

Table 2: Share of prices due to quality by sector (in %)

	# obs.	Mean	Standard error	1st decile	1st quartile	Median	3rd quartile	9th decile	R&D[1]
Mining and carrying	6328	35.86	15.48	0.00	34.40	39.20	46.40	50.00	2.2
Food products, beverages and tobacco	9828	31.68	13.38	0.00	31.00	36.40	39.80	41.00	6
Rubber and plastics products	7728	68.22	8.11	56.60	62.20	70.10	73.80	78.80	4.6
Electrical equipment	8400	64.03	6.71	54.20	60.00	64.60	68.80	72.60	6.6
Machinery and equipment n.e.c.	8400	79.54	5.830	72.60	73.40	80.50	83.80	88.00	19.40
Motor vehicles, trailers and semitrailers	8400	22.71	11.17	0.00	21.80	26.40	29.20	34.20	41.20
Other transport equipment	7728	29.26	15.34	0.00	24.40	34.80	40.80	43.40	20.00
All sectors	56 812	47.31	23.95	0.00	31.8	42.6	69.20	78.40	100

[1] Share of sector R&D expenditures in the total R&D expenditures of the sectors where quality has a positive significant effect on prices.
Reading: In the automobile industry, the contribution of quality to prices is, on average, 22.71%.

Table 3: Share of quality in prices by sector for France and its main trading partners (2012, in percentages and ranking)

	France	Germany	United Kingdom	Italy	Spain	United States	Japan	Korea
Mining and carrying	40.4 12th	40.2 13th	49.6 4th	45.8 6th	43.8 8th	55.6 1rst	43.2 9th	42.8 10th
Food products, beverages and tobacco	40.6 7th	40.8 6th	41.0 5th	38.8 10th	40.2 9th	46.8 1rst	44.8 2nd	41.4 3rd
Rubber and plastics products	78.2 4th	79.2 3rd	73.2 10th	75.6 6th	74.2 7th	80.8 2nd	81.0 1rst	78.0 5th
Electrical equipment	71.6 6th	74.0 3rd	68.2 13th	70.8 7th	69.4 9th	75.6 1rst	75.2 2nd	72.8 4th
Machinery and equipment n.e.c.	85.4 6th	88.4 3rd	85.0 7th	85.6 5th	83.0 11th	89.8 1rst	89.2 2nd	86.8 4th
Motor vehicles, trailers and semitrailers	31.2 5th	35.0 2nd	31.0 6th	30.6 7th	29.4 8th	34.0 3rd	35.4 1rst	32.8 4th

	France	Germany	United Kingdom	Italy	Spain	United States	Japan	Korea
Other transport equipment	44.6 2nd	44.6 2nd	43.4 4th	42.6 5th	42.0 7th	49.4 1rst	40.4 9th	41.4 8th

Reading: In the German automotive industry, the contribution of quality to prices is 35%. Germany occupies second place, while France occupies fifth place, with 31.2%. Germany is ranked behind Japan (first place), with a difference in the contribution of quality to prices of only 0.4 percentage points.

2 - Cost competitiveness and quality competitiveness: nonlinear effects on import demand

The estimates of the import demand equation (5) are reported in Table 4. Column (1) presents the estimates obtained from the within estimator. The PPML estimates are presented in the following columns. In addition to the fact that the distance parameters are not identifiable with the within estimator, it appears that the results differ greatly depending on the estimation method used. Under these conditions, it is preferable to use the PPML to address the heteroscedasticity and endogeneity of the regressors due to the correlation with the unobserved characteristics of the exporting sector-exporting country-exporter triplets (individual effects).

Our preferred specification is presented in column (3)[18]. As expected, the results indicate a negative nonlinear effect of the quality-adjusted price. The relationship between import demand and the quality of imported products is also nonlinear. The nonlinearity highlighted in both cases indicates that the price or quality elasticities are not isoelastic. In other words, the higher the prices (R&D expenditures) of imported products are, the more price sensitive (in terms of quality) consumers are in import demand. This result challenges the assumption of CES utility for consumer preferences and argues instead for a quadratic utility function (Antoniades 2015). The nonlinear effects of price and quality lead, in both cases, to amplified movements in import demand but do not take the same direction. Thus, for the same quality-adjusted price, an exporting firm with a low selling price will see its foreign demand increase relatively less than if it set a high price. In the case of quality, exporting companies that produce high-quality goods benefit the most in terms of additional import demand from a relative increase in the quality of their products.

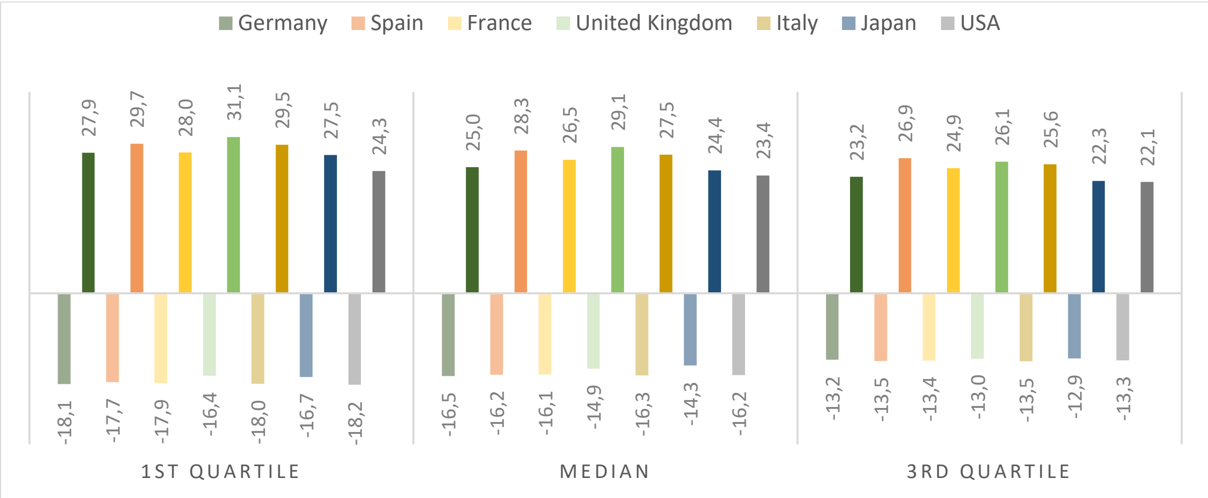
Figure 4 identifies additional R&D expenditures (or lower quality-adjusted prices) allowing for a 10% increase in (selected) country exports. For example, to increase its exports by 10%, France must, all other things being equal, increase its R&D expenditure by 28% in the low-quality sectors (1st quartile) against 24.9% in the high-quality sectors (3rd quartile), representing a decrease in effort of 3.1 percentage points. To achieve the same objective with a policy of lowering prices (cost competitiveness), France must lower the quality-adjusted prices of the least expensive products (1st quartile) by 17.9% against 13.4% for the most expensive products (3rd quartile), a decrease in effort of 4.5 percentage points. Given the nonlinear effects highlighted, the effort to improve cost competitiveness must be increasingly important, while the effort to improve quality competitiveness must be increasingly limited.

This lesser effort to increase exports by 10% from a change of specialization in product quality is also observed in the German case. Indeed, the effort to be made goes from 27.9% of additional R&D expenditure in the 1st quartile to 23.2% in the 3rd quartile, a differential of -4.7%

[18] In Table 4, we keep only the explanatory variables that are significant at the 5% level.

percentage points, while to improve cost competitiveness, this differential amounts to -4.9 percentage points (= 13.2% in the 1st quartile - 18.1% in the 3rd quartile). In fact, the gap between France and Germany is greater for quality competitiveness (-3.1 pp for France versus -4.7 pp for Germany) than for price competitiveness (-4.5 pp for France against -4.9 pp for Germany). The gap between France and Germany in the different efforts to be made in the event of a change in specialization in favor of better-quality goods confirms the need to improve the quality competitiveness of French products in order to reduce the discrepancies of these two countries in terms of foreign trade.

Figure 4: Additional R&D expenditures (in %) / decrease of quality-adjusted prices (in %) for an export increase of 10% (2009-2011)



Reading: An increase of 10% in France's exports requires, all other things being equal, an increase in R&D expenditure of 28% or a fall of 17.9%in quality-adjusted prices in sectors with low R&D intensity (1st quartile). In the R&D-intensive sectors (3rd quartile), the R&D expenditure should increase by 24.9%, or the price should decrease by 13.4%.

In column (2) of Table 4, no quality-adjusted prices are included for the estimation. It appears that the quality elasticity and the price elasticity are very close in comparison with the case where the prices are "purged" of quality (column (3)). In both cases, the lack of differences is expressed not only for the first-order terms but also for the quadratic terms. Consequently, the introduction of quality-adjusted prices does not change the effects of cost competitiveness and quality competitiveness on import demand. However, the conclusions are different when we distinguish the estimates between the sectors where the contribution of quality to prices is significantly positive and the other sectors.

Table 4: Estimates of the effects of cost and quality competitiveness on import demand in OECD countries

	(1)	(2)	(3)	(4)	(5)
	all sectors			sectors with quality-adjusted prices[1]	sectors with no quality-adjusted prices[2]
	Within	PPML		PPML	PPML
	-	no quality-adjusted prices	quality-adjusted prices	quality-adjusted prices	-
$\log P_{ist}$	-1.083*** (-72.560)	-0.598*** (-9.639)	-0.572*** (-7.432)	-0.274*** (-3.549)	-0.668*** (-20.758)
$\left(\log P_{ist}\right)^2$	0.029*** (9.431)	-0.067*** (-3.071)	-0.046** (-2.021)	- -	- -
$\log R\&D_{ist-1}$	0.041* (1.785)	- -	- -	- -	- -
$\left(\log R\&D_{ist-1}\right)^2$	-0.002** (-2.209)	0.015*** (8.301)	0.014*** (7.483)	0.011*** (3.652)	0.009*** (5.922)
$\log GDP_{jt}$	0.864*** (28.420)	0.781*** (13.825)	0.778*** (14.404)	0.858*** (9.809)	0.676*** (32.236)
$\log dist_{ij}$	- -	-1.005*** (-13.378)	-1.046*** (-18.153)	-1.202*** (-10.157)	-0.777*** (-23.558)
Dummy_ $\log R\&D_{ist}$	0.291** (2.315)	2.666*** (8.914)	2.436*** (8.291)	2.433*** (4.103)	1.273*** (5.981)
Constant	-8.410*** (-13.816)	1.627 (1.335)	1.489 (1.152)	0.763 (0.324)	2.408*** (3.735)
Sector dummies	Yes	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes	Yes
Sector-year dummies	Yes	Yes	Yes	Yes	Yes
Export country dummies	Yes	Yes	Yes	Yes	Yes
Year-export country dummies	Yes	Yes	Yes	Yes	Yes
Sector-year-import country dummies	Yes	Yes	Yes	Yes	Yes
R^2	0,439	0,781	0,777	0,852	0,752
Observations	143527	148361	148361	56718	91643

Student *t* in parentheses. The estimated standard errors are robust to heteroscedasticity. The index *i* is for the exporting country, *j* is for the importing country and *s* is for the sector. The dummy for missing values of R&D expenditures in country *j* and sector *s* is introduced in the different specifications to control the bias that may occur in the presence of missing data. Estimates are made by eliminating coefficients that are not significantly different from 0. To address the problem of incidental parameters and the potential correlation between regressors and individual effects, we introduced the intraindividual mean of the regressors into the estimates (Mundlak 1978).

[1] Mining and carrying; Food products, beverages and tobacco; Rubber and plastics products; Electrical equipment; Machinery and equipment n.e.c.; Motor vehicles, trailers and semitrailers; Other transport equipment.

[2] Agriculture, forestry and fishing; Textiles, wearing apparel, leather and related products; Wood and paper products, and printing; Coke and refined petroleum products; Chemicals and chemical products; Other nonmetallic mineral products; Basic metals; Fabricated metal products, except machinery and equipment; Computer, electronic and optical products; Furniture; Other manufacturing; Repair and installation of machinery and equipment.

The estimates in column (4) use observations from the 7 sectors where quality impacts prices, while in column (5), the estimates use a sample of the other 12 sectors where quality has no effect on prices. For the two types of sectors, the price competitiveness effect is now linear. In addition, the price elasticity is more than two times lower in absolute value for the first 7 sectors than for the other 12 sectors. These results indicate that the sectors where quality has an impact on prices are less sensitive to cost competitiveness than the other 12 sectors. On the other hand, the quality effect on import demand is relatively close between the two types of sectors. This quality effect is always nonlinear, and the parameters associated with the (significant) quadratic terms of columns (3) and (4) have very similar values. Such a result may suggest that even if quality has no effect on prices in the other 12 sectors, the quality competitiveness may still explain trade of a quality product without any increase in prices, particularly in sectors in which competition is fierce, such as the market of computers.

The estimated coefficients of the control variables usually used in gravity models are quite robust to the different specifications. Moreover, the effects obtained are close to those mentioned in the literature. Thus, the elasticity of the distance variable is negative and quite important (close to 1 in absolute value). The income of the importing country, measured by GDP, also has the expected positive effect, with elasticity values fairly close to those generally obtained in gravity models.

3 - Linder's hypothesis: first robustness test

Linder (1961) considers that trade in products of high quality will be even more important between countries when their per capita incomes are high and similar. On the demand side, countries with high per capita income spend a large fraction of this income on high-quality goods. On the supply side, countries have developed a comparative advantage in the production of goods for which domestic demand is strong. Starting from the observation that the empirical verification of Linder's theory leads to mixed results, Hallak (2010) emphasizes that this theory is difficult to verify at the aggregate level of bilateral trade insofar as the demands are not homothetic between sectors. In addition, empirical verification must take place in sectors where quality impacts price. Out of 116 differentiated product sectors traded among 64 countries in 1995, Linder's assumption is verified in more than two-thirds of the cases. To measure the (dis)similarity between countries, one can use a standard measure in the literature: the difference in the square of the income per capita of the trading partners, i.e., $\left(\log PIB\_Capita_{it} - \log PIB\_Capita_{jt}\right)^2$ [19]. For Linder's assumption to be verified, the effect of this difference on bilateral trade should be negative.

In equation (5), the Linder assumption is not explicit. This specification could therefore be subject to an omitted variable problem. To verify that this is not the case, we have added to our

[19] Per capita income is calculated by dividing a country's GDP by its population.

specification the squared difference of the per capita incomes and made estimates across all sectors. We also estimated the equation for sectors where quality is reflected in prices (see Table 5). To better control quality in the verification of Linder's assumption, we have included in our import demand specification the cross product between the logarithm of R&D expenditure of the exporting country and the squared difference of per capita incomes in logarithms. There appears to be no problem of omitted variables in our specification. The term measuring income similarity between countries has no effect on trade even when the sample is limited to sectors where quality impacts prices (column (3)). The same result is provided when controlling the level of quality on the similarity of income per capita between countries (columns (2) and (4)). Linder's hypothesis, as usually tested in the literature, seems to play no role in our import demand specification. It then appears that taking quality into account via R&D expenditure allows us to capture the effects of this assumption, given that developed countries have the highest per capita incomes and with the highest R&D expenditures (Thursby and Thursby 1987).

Table 6: Import demand function and Linder's assumption

	(1)	(2)	(3)	(4)
	All sectors		Sectors with quality-adjusted prices	
$\log P_{ist}$	-0.569***	-0.575***	-0.366**	-0.370**
	(-7.428)	(-7.390)	(-2.480)	(-2.506)
$(\log P_{ist})^2$	-0.045**	-0.046**	-0.025	-0.026
	(-2.013)	(-2.055)	(-0.769)	(-0.808)
$(\log R\&D_{ist-1})^2$	0.014***	0.014***	0.010***	0.010***
	(7.688)	(7.521)	(3.724)	(3.805)
$\log GDP_{jt}$	0.790***	0.790***	0.834***	0.833***
	(13.851)	(14.004)	(8.776)	(8.799)
$\log dist_{ij}$	-1.047***	-1.046***	-1.221***	-1.221***
	(-17.967)	(-17.854)	(-12.140)	(-12.146)
Linder[1]	-0.005	-	0.009	-
	(-0.077)	-	(0.084)	-
$\log R\&D_{ist-1} \times Linder$[1]	-	0.003	-	-0.010
	-	(0.305)	-	(-0.738)
$\text{Dummy\_}\log R\&D_{ist-1}$	2.472***	2.320***	1.842***	1.847***
	(8.362)	(7.965)	(4.157)	(3.767)
Constant	1.836	1.959	-0.519	-0.152
	(1.476)	(1.569)	(-0.229)	(-0.068)
Sector dummies	Yes	Yes	Yes	Yes
Year dummies	Yes	Yes	Yes	Yes
Sector-year dummies	Yes	Yes	Yes	Yes
Export country dummies	Yes	Yes	Yes	Yes
Year-export country dummies	Yes	Yes	Yes	Yes
Sector-year-import country dummies	Yes	Yes	Yes	Yes
R^2	0.782	0.779	0.843	0.845
Observations	146626	146626	55904	55904

[1] $\left(\log PIB\_Capita_{it} - \log PIB\_Capita_{jt}\right)^2$ for Linder's assumption

Student *t* in parentheses. The estimated standard errors are robust to heteroscedasticity. The index *i* denotes the exporting country, *j* the importing country and *s* the sector. A dummy for missing values of R&D expenditure in country *j* and sector *s* is introduced in the different specifications to control the bias that may occur when data are missing.

4- The assumption of Washington apples: second test of robustness

Unlike iceberg/ad valorem costs, the specific costs (per unit exported) imply a reduction in the relative export price of products of better quality. Such products can be transported over a longer distance than those under the assumption of an iceberg cost, which is called the "Washington apples" effect (Alchian and Allen, 1964; Hummels and Skiba, 2004). To account for this effect, we add a cross-term that is the product between the log of distance and the quality of imported goods (the logarithm of the R&D expenditure of exporting countries) into the import demand equation (5). If the Washington apples effect is at work, the sign of the coefficient of this additional regressor would be positive. Indeed, for better-quality products, distance should have a less negative effect on import demand. In our specification, transport costs are iceberg/ad valorem. The problem is that with this type of cost, the (FOB) prices are unchanged regardless of the destination. To test the presence of a Washington apples effect, we introduce the distance as a variable proxy of the specific transport costs into our specification.

The estimates highlight an effect of the specific transport cost in addition to that of the ad valorem transport cost (Table 7). Indeed, distance has a negative and significant effect on import demand (column 1). If we now control for the presence of a Washington apples effect, our estimates do not indicate the presence of such an effect (column 2). The coefficient of the variable proxy of the Washington apples effect is not significant. Consequently, it seems that when proxying product quality more directly as quality based on innovation, the Washington apples mechanism is not at work. In any case, the introduction of specific transport costs and a Washington apples effect do not alter the conclusions reached previously. Price/cost and quality effects on import demand are nonlinear and have very similar magnitudes to our previous estimates.

5 - Endogeneity of prices and quality: third test of robustness

Prices and R&D expenditures may be subject to demand shocks and supply shocks as well as measurement errors. It is therefore very likely that these two regressors are endogenous in the sense that they are correlated with the idiosyncratic error term of equation (5). Remark that until now, we have addressed only the correlation between explanatory variables and individual effects, which is a source of endogeneity. Hallak and Schott (2011) use exchange rates as an instrumental variable for export prices. In our case, it is difficult to use this instrument because half of the countries in our sample, 14 out of 28, belong to the euro area. Amiti and Khandelwal (2013) use transport costs as an instrumental variable of export prices. We cannot retain this instrument because the distance variable is introduced as a regressor in equation (5). In addition, we have to provide one or more instruments for R&D expenditures. In our case, it seems more appropriate to use the temporal dimension of the panel data using the delays of at least three years of R&D expenditure and price in level and in first difference as instruments, including delays for the dummy of missing R&D expenditures. We apply the instrumental variables method to the PPML regression. In addition, to verify the validity of the instruments used, the Sargan overidentification test is implemented. We can accept hypothesis H0 that the instruments selected are not correlated with the error term at the 5% threshold.

The results of the estimates in Table 8 are qualitatively close to those obtained for our preferred specification (column 3 of Table 5). There is no change in the sign of coefficients, and the price and quality effects on import demand are still nonlinear. The quality elasticities obtained are very similar in both cases. In fact, the most notable difference is in price elasticities, which are higher in absolute terms when the instrumental variable method is used. This result confirms that not adjusting for quality in prices tends to underestimate the price elasticity (Crozet and Erkel-Rousse 2004).

Table 7: Import demand and the Washington Apples effect

	(1)	(2)
$\log P_{ist}$	-0.627***	-0.618***
	(-10.097)	(-10.100)
$\left(\log P_{ist}\right)^2$	-0.057***	-0.055***
	(-3.352)	(-3.263)
$\left(\log R\&D_{ist-1}\right)^2$	0.014***	0.015***
	(8.872)	(8.448)
$\log GDP_{jt}$	0.767***	0.764***
	(20.159)	(20.116)
$\log dist_{ij}$	-0.543***	-0.559***
	(-7.831)	(-8.582)
Specifique transport cost	-0.000***	-0.000***
	(-7.005)	(-3.550)
Washington Apples	-	-0.000
	-	(-1.207)
Dummy_ $\log R\&D_{ist-1}$	2.497***	2.434***
	(9.647)	(9.498)
Constant	-0.099	-0.031
	(-0.098)	(-0.031)
Sector dummies	Yes	Yes
Year dummies	Yes	Yes
Sector-year dummies	Yes	Yes
Export country dummies	Yes	Yes
Year-export country dummies	Yes	Yes
Sector-year-import country dummies	Yes	Yes
R^2	0.889	0.889
Observations	148361	148361

Student *t* in parentheses. The estimated standard errors are robust to heteroscedasticity. The index *i* denotes the exporting country, *j* the importing country and *s* the sector. The dummy for missing values of R&D expenditures in country *j* and sector *s* is introduced in the different specifications to control the bias that may occur when data are missing.

Table 8: Estimates of the effects of cost and quality competitiveness on import demand in OECD countries – Instrumental variables and PPML

	(1)	(2)
	Preferred specification	Instrumental variables
$\log P_{ist}$	-0.572***	-0.936***
	(-7.432)	(-16.258)
$\left(\log P_{ist}\right)^2$	-0.046**	-0.093**
	(-2.021)	(-2.228)
$\log R\&D_{ist-1}$	-	-
	-	-
$\left(\log R\&D_{ist-1}\right)^2$	0.014***	0.018***
	(7.483)	(10.096)
$\log GDP_{jt}$	0.778***	0.797***
	(14.404)	(25.957)
$\log dist_{ij}$	-1.046***	-0.890***
	(-18.153)	(-12.466)
Dummy_ $\log R\&D_{ist-1}$	2.436***	2.111***
	(8.291)	(8.902)
Constant	1.489	-1.631
	(1.152)	(-066)
Sector dummies	Yes	No
Year dummies	Yes	No
Sector-year dummies	Yes	No
Export country dummies	Yes	No
Year-export country dummies	Yes	No
Sector-year-import country dummies	Yes	No
R^2	0.777	-
Hansen test (ddl)	-	19.37(11)
P value	-	0.0542
Observations	148361	94339

Student *t* in parentheses. The instrumental variables used for the estimation in column (2) are as follows: $\log P_{ist-3}$, $\log P_{ist-4}$, $\log P_{ist-5}$, $\left(\log P_{ist-5}\right)^2$, $\log R\&D_{ist-3}$, $\log R\&D_{ist-4}$, $\log R\&D_{ist-5}$, $Dummy\_\log R\&D_{ist-3}$, $Dummy\_\log R\&D_{ist-4}$, $Dummy\_\log R\&D_{ist-5}$, $\left(\log P_{ist-4} - \log P_{ist-3}\right)\left(\log R\&D_{ist-4} - \log R\&D_{ist-3}\right)$. The estimated standard errors are robust to heteroscedasticity. The index *i* denotes the exporting country, *j* the importing country and *s* the sector. The dummy for missing values of R&D expenditures in country *j* and sector *s* is introduced in the different specifications to control the bias that may occur when data are missing.

VI – Conclusion

Price competitiveness has been claimed to be crucial for developed countries to reduce external imbalances and ensure the sustainable growth of their economies. However, in the face of increased competition from low-wage countries, market share is no longer increased only by producing at lower cost and then selling at the lowest price. More than ever, product quality is a key element in the competitiveness of developed countries.

To assess the effects of cost and quality competitiveness on trade in OECD countries, we estimate an import demand model with vertically (and horizontally) differentiated products. This model explicitly incorporates quality-adjusted prices to proxy cost competitiveness and technological innovation measured through R&D expenditure to proxy quality competitiveness.

From the determination of the quality-adjusted prices, we have estimated that quality contributes positively to export prices in only 7 of the 19 sectors selected for the analysis. However, in the 7 sectors where quality is embodied in export prices, the quality rent is relatively high (48% of the prices, on average). A comparison across countries indicates that the quality rent (the share of the quality in the prices) is regularly the highest for the US products. By way of comparison, for the 7 sectors considered where quality impacts the prices, France is ranked at least 6th in 5 sectors and Germany at least 3rd in 5 sectors. This suggests that the quality rent is easier to extract from the price of products exported by Germany and the United States than from the price of products exported by France.

One of the most important results of this paper is that the effects of cost and quality competitiveness on import demand are nonlinear. The positive impact of quality on foreign demand is all the more important because imported products have a high level of quality. In this respect, it is important to emphasize that these amplification movements are not symmetrical for cost and quality effects. Thus, for a low price level of exported goods (where price competitiveness predominates), a sharp drop in prices is necessary to increase exports.

Our results provide new insights for policymakers in understanding the impact of cost and quality competitiveness on imports. To improve cost competitiveness, many developed countries have implemented exemptions from social security contributions to reduce the labor cost of less qualified employees. The amplification movements drawn from our results indicate that these policies will likely become increasingly costly and inefficient in view of the increasing cost competitiveness of low-wage countries. It appears that it would be better to allocate more public funding to innovation in selected sectors to improve the quality competitiveness of OECD countries.

This research could be extended in two directions. First, it may be useful to extend the scope of analysis to emerging importing countries to assess the extent to which the results, including the (nonlinear) effects of cost competitiveness and quality competitiveness, remain valid. Second, the use of firm data would be useful to better control the export supply dimension, in particular by providing more precise information on innovation.

References

Alchian, A. A., & Allen, W. R. (1964). *University economics*. Belmont, Calif., Wadsworth.

Amiti, M., & Khandelwal, A. K. (2013). Import Competition and Quality Upgrading. *Review of Economics & Statistics*, *95*(2), 476–490.

Anderton, B. (1999). Innovation, product quality, variety, and trade performance: An empirical analysis of Germany and the UK. *Oxford Economic Papers*, *51*(1), 152.

Antoniades, A. (2015). Heterogeneous Firms, Quality, and Trade. *Journal of International Economics*, *95*(2), 263–273. doi:10.1016/j.jinteco.2014.10.002

Arora, A., Branstetter, L. G., & Drev, M. (2013). Going Soft: How the Rise of Software-Based Innovation Led to the Decline of Japan's It Industry and the Resurgence of Silicon Valley. *Review of Economics & Statistics*, *95*(3), 757–775. doi:10.1162/REST_a_00286

Baldwin, R., & Taglioni, D. (2007). Trade Effects of the Euro: A Comparison of Estimators. *Journal of Economic Integration*, *22*(4), 780–818.

Bas, M., Fontagne, L., Martin, P., & Mayer, T. (2015). À la recherche des parts de marché perdues, *Notes du Conseil d'Analyse Economique*, *23*(4), 1–12.

Bekkers, E. (2016). Firm Heterogeneity, Endogenous Quality, and Traded Goods Prices. *World Economy*, *39*(1), 72–96. doi:10.1111/twec.12244

Bekkers, E., Francois, J., & Manchin, M. (2016). Trade costs, quality and the skill premium. *Canadian Journal of Economics*, *49*(3), 1153–1178. doi:10.1111/caje.12228

Blonigen, B. A., & Wilson, W. W. (1999). Explaining Armington: What determines substitutability between home and foreign goods? *Canadian Journal of Economics*, *32*(1), 1.

Chen, W.-C. (2013). The Extensive and Intensive Margins of Exports: The Role of Innovation. *World Economy*, *36*(5), 607–635. doi:10.1111/twec.12032

Crozet, M., & Erkel-Rousse, H. (2004). Trade Performances, Product Quality Perceptions, and the Estimation of Trade Price Elasticities. *Review of International Economics*, *12*(1), 108–129. doi:10.1111/j.1467-9396.2004.00434.x

Cunéo, P., & Mairesse, J. (1985). Recherche-développement et performances des entreprises : une étude économétrique sur données individuelles. *Revue économique*, *36*(5), 1001–1042. doi:10.2307/3501563

Decramer, S., Fuss, C., & Konings, J. (2016). How Do Exporters React to Changes in Cost Competitiveness? *World Economy*, *39*(10), 1558–1583. doi:10.1111/twec.12412

Dixit, A. K., & Stiglitz, J. E. (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, *67*(3), 297–308.

Egger, P., & Pfaffermayr, M. (2003). The proper panel econometric specification of the gravity equation: A three-way model with bilateral interaction effects. *Empirical Economics*, *28*(3), 571.

Erkel-Rousse, H., & Mirza, D. (2002). Import price elasticities: reconsidering the evidence. *Canadian Journal of Economics*, *35*(2), 282.

Fally, T. (2015). Structural gravity and fixed effects. *Journal of International Economics*, *97*(1), 76–85. doi:10.1016/j.jinteco.2015.05.005

Feenstra, R. C. (1994). New Product Varieties and the Measurement of International Prices. (cover story). *American Economic Review*, *84*(1), 157–177.

Feenstra, R. C., & Romalis, J. (2014). International Prices and Endogenous Quality. *Quarterly Journal of Economics*, *129*(2), 477–527.

Feenstra, R. C., & Weinstein, D. E. (2010). *Globalization, Markups and U.S. Welfare* (Working Paper No. 15749). National Bureau of Economic Research. http://www.nber.org/papers/w15749. Accessed 6 February 2015

Gaulier, G., & Zignago, S. (2010). BACI: International Trade Database at the Product-Level. The 1994-2007 Version.

Grossman, G. M., & Helpman, E. (1991). *Innovation and growth in the global economy*. Cambridge, Mass. and London:

Grossman, G. M., & Helpman, E. (1995). Technology and Trade. In G. M. Grossman & K. Rogoff (Eds.), *Handbook of international economics. Volume 3* (pp. 1279–1337). Handbooks in Economics, vol. 3.

Hall, B. H., Lotti, F., & Mairesse, J. (2009). Innovation and Productivity in SMEs: Empirical Evidence for Italy. *Small Business Economics*, *33*(1), 13–33.

Hallak, J. C. (2006). Product quality and the direction of trade. *Journal of International Economics*, *68*(1), 238–265. doi:10.1016/j.jinteco.2005.04.001

Hallak, J. C. (2010). A Product-Quality View of the Linder Hypothesis. *Review of Economics & Statistics*, *92*(3), 453–466.

Hallak, J. C., & Schott, P. K. (2011). Estimating Cross-Country Differences in Product Quality. *Quarterly Journal of Economics*, *126*(1), 417–474.

Head, K., & Mayer, T. (2014). Chapter 3 - Gravity Equations: Workhorse,Toolkit, and Cookbook. In G. Gopinath, E. Helpman, & K. Rogoff (Eds.), *Handbook of International Economics* (Vol. 4, pp. 131–195). Elsevier. doi:10.1016/B978-0-444-54314-1.00003-3

Helpman, E., Melitz, M., & Rubinstein, Y. (2008). Estimating Trade Flows: Trading Partners and Trading Volumes. *Quarterly Journal of Economics*, *123*(2), 441–487.

Hummels, D., & Skiba, A. (2004). Shipping the Good Apples Out? An Empirical Confirmation of the Alchian-Allen Conjecture. *Journal of Political Economy*, *112*(6), 1384–1402.

Khandelwal, A. (2010). The Long and Short (of) Quality Ladders. *Review of Economic Studies*, *77*(4), 1450–1476. doi:10.1111/j.1467-937X.2010.00602.x

Kraft, K. (1990). Are product and Process Innovations Independent of Each Other? *Applied Economics*, *22*(8), 1029–1038. doi:10.1080/00036849000000132

Kravis, I. B., & Lipsey, R. E. (1975). *International Trade Prices and Price Proxies* (NBER Chapters) (pp. 253–268). National Bureau of Economic Research, Inc. https://ideas.repec.org/h/nbr/nberch/3776.html. Accessed 17 February 2015

Kugler, M., & Verhoogen, E. (2012). Prices, Plant Size, and Product Quality. *Review of Economic Studies*, *79*(1), 307–339.

Linder, S. B. (1961). *An Essay on Trade and Transformation* (First Edition edition.). Stockholm : Almqvist & Wiksell.

Martin, J., & Mejean, I. (2014). Low-wage country competition and the quality content of high-wage country exports. *Journal of International Economics*, *93*(1), 140–152. doi:10.1016/j.jinteco.2014.02.002

Martinez-Ros, E. (1999). Explaining the decisions to carry out product and process innovations: The Spanish case. *The Journal of High Technology Management Research*, *10*(2), 223–242. doi:10.1016/S1047-8310(99)00016-4

Matyas, L. (1997). Proper econometric specification of the gravity model. *World Economy*, *20*(3), 363.

Mayer, T., & Zignago, S. (2011). Notes on CEPII's distances measures: The GeoDist database.

Melitz, M. J., & Ottaviano, G. I. P. (2008). Market Size, Trade, and Productivity. *Review of Economic Studies*, *75*(1), 295–316. doi:10.1111/j.1467-937X.2007.00463.x

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. *Econometrica*, *46*(1), 69–85. doi:10.2307/1913646

OECD. (2013). Economic Surveys: Japan 2013. https://www.oecd-ilibrary.org/fr/economics/oecd-economic-surveys-japan-2013_eco_surveys-jpn-2013-en. Accessed 6 May 2019

Proenca, I., Sperlich, S., & Savasci, D. (2015). Semi-mixed effects gravity models for bilateral trade. *Empirical Economics*, *48*(1), 361–387. doi:10.1007/s00181-014-0891-x

Scott, P. W., & Bristow. (2002). *Industrial Minerals and Extractive Industry Geology* (GSL Miscellaneous Titles.).

Silva, J. M. C. S., & Tenreyro, S. (2006). The Log of Gravity. *Review of Economics & Statistics*, *88*(4), 641–658.

Sutton, J. (1991). *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration*. MIT Press.

Sutton, J. (1998). *Technology and Market Structure: Theory and History*. MIT Press. https://mitpress.mit.edu/books/technology-and-market-structure.

Sutton, J. (2007). Quality, Trade and the Moving Window: The Globalisation Process. *Economic Journal*, *117*(524), F469–F498. doi:10.1111/j.1468-0297.2007.02119.x

Thursby, J. G., & Thursby, M. C. (1987). Bilateral Trade Flows, the Linder Hypothesis, and Exchange Risk. *Review of Economics & Statistics*, *69*(3), 488.

Wakelin, K. (1998). The role of innovation in bilateral OECD trade performance. *Applied Economics*, *30*(10), 1335–1346. doi:10.1080/000368498324959

Appendix 1

Classification of sectors (ISIC rev. 4) by technological level

ISIC code	Sectors	Technology level
01-03	Agriculture, forestry and fishing	Non manufacturer
05-09	Mining and carrying	Non manufacturer
10-12	Food products, beverages and tobacco	Low or medium-low
13-15	Textiles, wearing apparel, leather and related products	Low or medium-low
16-18	Wood and paper products, and printing	Low or medium-low
19	Coke and refined petroleum products	Low or medium-low
20	Chemicals and chemical products	High or medium-high
22	Rubber and plastics products	Low or medium-low
23	Other nonmetallic mineral products	Low or medium-low
24	Basic metals	Low or medium-low
25	Fabricated metal products, except machinery and equipment	Low or medium-low
26	Computer, electronic and optical products	High or medium-high
27	Electrical equipment	High or medium-high
28	Machinery and equipment n.e.c.	High or medium-high
29	Motor vehicles, trailers and semitrailers	High or medium-high
30	Other transport equipment	High or medium-high
31	Furniture	Low or medium-low
32	Other manufacturing	Low or medium-low
33	Repair and installation of machinery and equipment	Low or medium-low

Appendix 2

The estimates in Table A.1 are based on the assumption that the price of traded products depends on their quality related to innovation. Quality is proxied by the R&D expenditure of countries/sectors. Therefore, we have the following equation:

$$LogP_{ijst} = \alpha_2 \log R\&D_{ist-1} + \alpha_1 Dummy\_\log R\&D_{ist-1} + \alpha_0 + f_{is} + \omega_{ist}$$

where $LogP_{ist}$ is the logarithm of the price of a product belonging to sector *s* and exported from country *i* to a given trading partner *j* at time *t*, $\log R\&D_{ist-1}$, the logarithm of the R&D expenditure of country *i* in sector *s* at time *t-1*, $Dummy\_\log R\&D_{ist-1}$, a dummy that takes the value of 1 when the R&D expenditure is missing, f_{is}, a combined specific effect for countries *i* and *j* and sector *s*, and ω_{ist}, an idiosyncratic term. To estimate these equations of quality, we used the intraindividual estimator considering that there is an unobserved individual heterogeneity in each price that is potentially correlated with the proxy of innovation. For example, consumers in different countries may not all have the same willingness to pay for the innovations embodied in imported products. We also assume that R&D expenditures are potentially correlated with contemporary shocks embedded in the idiosyncratic component of the error term. For this reason, this variable is introduced into the quality model with a delay of one year. The introduction of other, higher order delays could alter the accuracy of the estimates due to the increasing loss of available observations. In the absence of bilateral trade, as export prices are not reported, the associated observations are not used in the estimations. On the other hand, to limit potential estimation bias, missing data on R&D expenditure are kept in the sample. This is why indicator variables for missing R&D expenditure data are introduced. In the end, we considered that the contribution of quality was effective when the price elasticity to R&D expenditure was positive and significantly different from 0 at the 5% significance threshold. To construct net quality prices or complement the price resulting from quality, we also considered that the missing indicators for R&D expenditure and the constant were not always significantly different from 0.

Even if the medium and low technology sectors are more numerous (13 sectors) than the high and medium-high technology sectors (6 sectors), we have less sectors for which quality contributes to prices in the medium and low technology sectors (3 sectors) than in the medium-high technology sectors (4 sectors). The contribution of quality to price is significant in the 7 sectors highlighted even though the estimated price/quality elasticities are generally quite low (0.0937 on average).

Table A.1: Price equation depending on quality by sector
(ISIC rev, 4 Classification)

	Agriculture, forestry and fishing	Mining and carrying	Food products, beverages and tobacco	Textiles, wearing apparel, leather and related products	Wood and paper products, and printing	Coke and refined petroleum products	Chemicals and chemical products
$\log R\&D_{t-1}$ [1]	0,031*	0,086**	0,088**	0,041*	0,032	0,040	0,006
	(1,830)	(2,283)	(2,282)	(1,775)	(0,859)	(1,023)	(0,206)
Dummy_ $\log R\&D_{t-1}$ [2]	-0,108	0,367	0,535	0,092	-0,018	-0,455	-0,407
	(-0,666)	(0,890)	(1,226)	(0,423)	(-0,044)	(-1,059)	(-1,218)
Constant	0,214	-2,036***	-0,313	1,895***	0,046	-0,890**	0,819**
	(1,366)	(-5,452)	(-0,723)	(8,063)	(0,121)	(-2,185)	(2,347)
# Observations	7512	6066	9776	9071	7074	4529	7726
R^2	0,025	0,033	0,069	0,020	0,027	0,063	0,093

	Rubber and plastics products	Other nonmetallic mineral products	Basic metals	Fabricated metal products, except machinery and equipment	Computer, electronic and optical products	Electrical equipment
$\log R\&D_{t-1}$ [1]	0,114**	0,046	0,095	0,071	0,034	0,094**
	(2,592)	(0,981)	(1,541)	(1,491)	(0,702)	(2,444)
Dummy_ $\log R\&D_{t-1}$ [2]	0,833*	0,139	0,235	0,271	0,039	0,783*
	(1,981)	(0,286)	(0,373)	(0,514)	(0,062)	(1,786)
Constant	0,325	-0,334	-0,365	1,112**	3,090***	1,523***
	(0,684)	(-0,673)	(-0,542)	(2,079)	(4,915)	(3,394)
# Observations	7665	8678	7719	7318	9758	8322
R^2	0,048	0,012	0,071	0,028	0,018	0,028

	Machinery and equipment n.e.c.	Motor vehicles, trailers and semitrailers	Other transport equipment	Furniture	Other manufacturing	Repair and installation of machinery and equipment
$\log R\&D_{t-1}$ [1]	0,139***	0,047**	0,088**	-0,012	0,001	-0,014
	(3,404)	(2,153)	(2,135)	(-0,410)	(0,055)	(-0,677)
$\text{Dummy\_}\log R\&D_{t-1}$ [2]	1,298***	0,254	0,604	-0,471	-0,459**	-0,539**
	(2,908)	(1,087)	(1,315)	(-1,630)	(-2,461)	(-2,627)
Constant	0,331	1,716***	1,503***	2,581***	3,793***	2,401***
	(0,678)	(6,402)	(3,262)	(8,962)	(20,545)	(11,689)
# Observations	8384	8364	7606	5161	8285	4788
R^2	0,049	0,034	0,033	0,062	0,156	0,169

Student t in parentheses, standard errors robust to heteroskedasticity. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

[1] For each sector, the logarithm of import prices of country *j* is regressed on the logarithm of R&D expenditures of country *i* (exporter). [2] For $\log R\&D_{t-1}$, the dummy for missing R&D expenditures ($\text{Dummy\_}\log R\&D_{t-1}$) is delayed by one year.

Table A.2.1: Share of quality in prices by sector/country for the year 2012
(in percentages and ranking)

	Australia	Austria	Belgium	Canada	Switzerland	Czech Republic	Germany	Spain	Estonia
Mining and carrying	55.6	38.2	38.4	52.6	-	32.6	40.2	43.8	-
	1rst	18th	17th	3th	-	22th	13th	8th	-
Food products, beverages and tobacco	40.6	34.4	38.2	38.2	37.2	33.6	40.8	40.2	26.8
	7th	21th	12th	12th	14th	23th	6th	9th	26th
Rubber and plastics products	71.2	73.8	72.6	73.4	-	70.4	79.2	74.2	55.8
	13th	8th	12th	9th	-	15th	3rd	7th	24th
Electrical equipment	65.2	72.0	68.4	66.2	-	66.2	74.0	69.4	55.8
	19th	5th	12th	15th	-	15th	3rd	9th	25th
Machinery and equipment n.e.c.	81.6	84.6	82.0	83.6	-	81.4	88.4	83.0	62.4
	14th	9th	13th	10th	-	15th	3rd	11th	25th
Motor vehicles, trailers and semitrailers	28.2	28.4	26.0	26.4	-	27.6	35.0	29.4	18.6
	11th	10th	16th	14th	-	12th	2nd	8th	25th
Other transport equipment	36.6	37.2	37.4	42.4	-	37.4	44.6	42.0	-
	15th	13th	11th	6th	-	11th	2nd	7th	-

Table A.2.2: Share of quality in prices by sector/country for the year 2012
(in percentages and ranking)

	Finland	France	UK	Hungary	Ireland	Israel	Italy	Japan	Korea	Mexico
Mining and carrying	39.0	40.4	49.6	34.4	-	36.0	45.8	43.2	42.8	44.2
	16th	12th	4th	21th	-	20th	6th	9th	10th	7th
Food products, beverages and tobacco	36.4	40.6	41.0	34.4	-	33.4	38.8	44.8	41.4	38.4
	17th	7th	5th	21th	-	24th	10th	2nd	3rd	11th
Rubber and plastics products	-	78.2	73.2	66.0	65.2	-	75.6	81.0	78.0	68.8
	-	4th	10th	20th	21th	-	6th	1rst	5th	17th
Electrical equipment	68.8	71.6	68.2	62.8	58.8	-	70.8	75.2	72.8	67.4
	10th	6th	13th	21th	24th	-	7th	2nd	4th	14th
Machinery and equipment n.e.c.	83.0	85.4	85.0	78.6	76.0	-	85.6	89.2	86.8	77.8
	11th	6th	7th	19th	22th	-	5th	2nd	4th	20th
Motor vehicles, trailers and semitrailers	22.4	31.2	31.0	26.0	19.6	-	30.6	35.4	32.8	27.4
	23th	5th	6th	16th	24th	-	7th	1rst	4th	13th
Other transport equipment	34.6	44.6	43.4	25.0	25.8	-	42.6	40.4	41.4	32.6
	17th	2nd	4th	24th	21th	-	5th	9th	8th	19th

Table A.2.3: Share of quality in prices by sector/country for the year 2012
(in percentages and ranking)

	Netherlands	Norway	New Zealand	Poland	Portugal	Slovakia	Slovenia	Turkey	USA
Mining and carrying	-	48.8	-	39.4	37.8	-	39.4	41.2	55.6
	-	5th	-	14th	19th	-	14th	11th	1rst
Food products, beverages and tobacco	41.2	37.0	36.6	34.4	36.2	26.6	29.8	36.2	46.8
	4th	15th	16th	21th	18th	27th	25th	18th	1rst
Rubber and plastics products	72.8	64.6	-	70.4	68.8	64.6	66.4	71.2	80.8
	11th	22th	-	15th	17th	22th	19th	13th	2nd
Electrical equipment	70.8	62.6	-	66.0	64.4	62.0	66.0	68.8	75.6
	7th	22th	-	17th	20th	23th	17th	10th	1rst
Machinery and equipment n.e.c.	85.0	79.2	-	79.0	75.0	74.8	77.6	81.4	89.8
	7th	17th	-	18th	23th	24th	21th	15th	1rst
Motor vehicles, trailers and semitrailers	26.4	22.8	-	25.4	24.2	23.8	25.0	28.8	34.0
	14th	22th	-	18th	20th	21th	19th	9th	3rd
Other transport equipment	36.8	34.4	-	36.0	29.0	30.0	30.2	38.4	49.4
	14th	18th	-	16th	22th	21th	20th	10th	1rst

Table A.2.4: Share of quality in prices, on average, by country
(in percentages and ranking)

Countries	2010		2011		2012	
	Share of quality in prices	Ranking	Share of quality in prices	Ranking	Share of quality in prices	Ranking
USA	61.69	1	61.54	1	61.71	1
Japan	58.97	2	58.94	2	58.46	2
Germany	57.40	3	57.40	3	57.46	3
Korea	56.09	5	56.34	4	56.57	4
France	56.11	4	56.09	5	56.00	5
UK	55.57	7	55.69	7	55.91	6
Italy	55.91	6	55.71	6	55.69	7
Canada	55.00	8	54.83	8	54.69	8
Spain	54.31	9	54.43	9	54.57	9
Australia	54.03	10	54.26	10	54.14	10
Austria	52.43	11	52.60	11	52.66	11
Turkey	51.69	13	51.83	12	52.29	12
Belgium	50.83	14	51.49	13	51.86	13
Mexico	52.06	12	50.51	14	50.94	14
Poland	47.69	18	48.11	17	50.09	15
Norway	50.11	15	49.86	16	49.91	16
Czech Republic	49.91	16	50.09	15	49.89	17
Portugal	47.71	17	47.46	18	47.91	18
Slovenia	46.40	20	47.00	19	47.77	19
Hungary	46.83	19	46.46	20	46.74	20
Mean	53.04	-	53.03	-	53.26	-
SE	4.09	-	4.07	-	3.84	-

Reading: considering an average export price of $100 for an American product in 2012, quality contributes €61.71, and quality-adjusted price contributes €38.29.

Note: The results in this table are based on the sectors with a significant contribution of quality in prices. Moreover, to avoid introducing a ranking bias, countries with missing data from at least one sector were deleted. The ranking is based on the year 2012.

Tableau A.2.5: Share of quality in prices by sector (in %)

	# obs.	Mean	Standard-error	1rst decile	1rst quartile	Median	3th quartile	9th decile	R&D[1]
Agriculture, forestry and fishing	7700	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Mining and carrying	6328	35.86	15.48	0.00	34.40	39.20	46.40	50.00	1.00
Food products, beverages and tobacco	9828	31.68	13.38	0.00	31.00	36.40	39.80	41.00	2.80
Textiles, wearing apparel, leather and related products	9100	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
Wood and paper products, and printing	7084	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.40
Coke and refined petroleum products	5712	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
Chemicals and chemical products	7728	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.20
Rubber and plastics products	7728	68.22	8.11	56.60	62.20	70.10	73.80	78.80	2.2
Other nonmetallic mineral products	9016	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.20
Basic metals	7728	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Fabricated metal products, except machinery and equipment	8400	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
Computer, electronic and optical products	9828	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.40
Electrical equipment	8400	64.03	6.71	54.20	60	64.60	68.80	72.60	3.20
Machinery and equipment n.e.c.	8400	79.54	5.830	72.60	73.40	80.50	83.80	88.00	9.20
Motor vehicles, trailers and semitrailers	8400	22.71	11.17	0.00	21.80	26.40	29.20	34.20	19.40
Other transport equipment	7728	29.26	15.34	0.00	24.40	34.80	40.80	43.40	9.40
Furniture	6468	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
Other manufacturing	8288	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40
Repair and installation of machinery and equipment	4788	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20
All the sectors	148 652	18.08	27.35	0.00	0.00	0.00	36.20	68.40	100

[1] R&D expenditures by sector over the total R&D expenditures in percentages.