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The quality-cost choice of
R&D in the nations' exports

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The quality-cost choice of R&D in the nations' exports [⌘]

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Abstract

Is R&D primarily directed at quality improvement or cost reduction? We use UN-Comtrade data on manufactured goods exports by 19 OECD countries in order to assess this conjecture from the endogenous growth literature. We find that, in export market competition, the demand for high-tech goods – i.e., R&D intensive goods – is less sensitive to price than the demand for low-tech goods. We also estimate exporters' quality levels in each market and find that high-tech goods have more quality, as well as their demands is the most sensitive to quality.

JEL classification: F1; F14; O3; O33.

Keywords: international trade; endogenous growth; quality of exports; R&D intensity.

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1. Introduction

From the end of the 90s on, new, more disaggregated and internationally comparable trade data became available, reviving empirical research in the area.¹ Perhaps the most representative work of this surge is Hummels and Klenow (2005), who regress the extensive margin (the range of goods), the intensive margin (quantity of each good), price and quantity indexes of countries' exports on certain characteristics of those countries, such as population size and *per capita* income. Among their findings, stand out that: (i) rich countries export more in value than poor countries, most of the difference occurring in the extensive margin; (ii) bigger countries also export a greater variety of goods; and (iii) richer countries export slightly more expensive goods.

Having in mind that rich countries perform much more Research and Development (R&D) than poor countries, we realize that some of Hummels and Klenow's (2005) stylized facts are of particular interest to empirically assess endogenous growth models' predictions. In endogenous growth models, R&D is the source of innovations, and these may take the form either of new products, as in Romer (1990); quality improvements in already existing goods, as in Grossman and Helpman (1991); or even cost reductions, as in Taylor (1993). For example, if we observe that countries' exports that overlap less with other countries' exports are particularly "R&D intensive", we may say that that Romer's (1990) "variety expansion" strategy is in action enlarging the "extensive margin" measures.

But here we are more interested in quality versus quantity type strategy models, such as Grossman and Helpman's (1991) and Taylor's (1993). Although their respective forms of innovation are not generally perceived as substantially different in macro growth models – since a higher quality good produced at a constant cost may also be seen as a good produced with lower cost per unit of the quality service – the distinction has an immediate bearing on empirical trade predictions. First, if innovation takes mainly the form of cost reduction, then highly innovative, rich countries would, other things equal, export at lower prices within each product category – which apparently is not consistent with the empirical evidence found by Hummels and Klenow (2005).² Second, if innovation takes mainly the form of cost reduction, then we would expect

¹ For example, the NBER trade dataset (described in detail by Feenstra, Romalis and Schott 2002) and the United Nations Comtrade database.

² Hummels and Klenow (2005, pg. 713) find that, within categories of goods and to a given market, countries with twice the GDP per worker export 34 percent higher quantities at 9 percent higher prices.

exported quantities to be more sensitive to export prices in high-tech, R&D intensive, than in low-tech goods – for it would not pay off to spend much in innovation targeted at cost reduction in markets where cost competitiveness is not important.³

Another way of stating this last conjecture is: looking at nations' exports, are high-tech goods more or less “quality differentiated” than low-tech goods? If they are more, then we may say that when it comes to export market competition, innovation under the form of quality improvement is more relevant than under the form of cost reduction. However, measuring the “quality of exports”, let alone “quality differentiation”, is a complicated matter in the empirical trade literature. As Hallak and Schott (2008) notice, until recently *ad hoc* proxies for quality such as observed prices (unitary values) were pervasive. Truly, in many quality ladder growth models like Grossman and Helpman's (1991), given Bertrand competition and identical production costs among innovators and followers located in different countries, a higher price indeed reflected higher quality.

Here we benefit from the recent literature on exports quality measurement, such as Hallak and Schott (2008 and 2011) and Khandelwal (2010), to perform a test of the above second conjecture. Since the conjecture involves a comparison of high-tech and low-tech goods, a natural strategy is resorting to split-sample analysis. We use Comtrade United Nations data on traded quantities and values for 19 OECD countries in their intra-trade.⁴ Using relative exported quantities as dependent variables and relative unitary values (prices) as independent variables, we estimate separated price elasticities of demand for high- and low-tech products in a panel, to examine their difference. A higher price sensitivity of high-tech industries would provide the incentive for this group to pursue cost reduction. While a lower price sensitivity to high-tech industries would provide the incentive for them to pursue quality improvement.

Our raw data, at SITC Revision 3, 5-digit disaggregation level, comprise around 2100 different manufactured goods (SITC codes 5 to 8), which are then classified according to R&D intensities by OECD ISIC Revision 3 (2011), based on Hatzichronoglou (1997).

³ In standard classifications, like OECD's ISIC Revision 3 2011, industries and goods are ranked as to their “technological level” according to their R&D intensity, that is, R&D expenditure / production or R&D expenditure / value added. For a discussion of the classification methodology, see Hatzichronoglou (1997).

⁴ *Intratrade* means that we consider only trade flows inside the 19 countries' block.

In line with the above mentioned recent literature, we make a “micro-founded” choice of controls to be included in our regression model. In particular, we follow Hummels and Klenow (2005) in assuming a Dixit-Stiglitz-type of utility function which embodies a “love of variety” by consumers. This implies that, other things equal, country A exports a bigger quantity of good i than country B does, if A has more varieties (or “different models”) of i to offer.⁵ In order to control for non-observable or “hidden” variety, that is, variety beyond the utmost disaggregation level for which we have data (in our case, 5-digit), we follow Krugman (1980) and use country size (given by population) as a proxy.⁶

Under fairly general assumptions about the supply-side, many international trade models predict that countries with a bigger GDP will export greater quantities of each good. In particular, Armington’s (1969) and Acemoglu and Ventura’s (2002) models predict that richer countries (with a bigger GDP per worker or per capita) will also export greater quantities of each good, and thus we include countries’ GDP per capita as a control in our regression model, having already included population.⁷

Notwithstanding the importance of an appropriate choice of controls and proxies for unobservable variables, the recent literature’s chief contribution is on the identification method. Hallak and Schott (2011) conceive a two-stage method to compare countries’ exports’ quality by 2-digit industry using exports price indexes and net traded quantity figures. Closer to our own work, Khandelwal (2010) uses a nested logit structure for consumer preferences, based on Berry (1994), in order to estimate imports demand functions for several, very disaggregate goods imported by the U.S.. Exploiting the panel (temporal and cross-sectional) dimensions of his data, Khandelwal (2010) produces for each good an estimate of each exporting country’s quality extracted from the country fixed-effect.

While our basic regression relative-quantity-price setup captures relative quantities dependence on relative prices inside each export market only, given Berry’s (1994) demand system structure, Khandelwal’s (2010) quality estimates contain

⁵ A typical example involves car models. Countries A and B produce cars at the same price and quality, but if A has to offer one sedan model and one SUV model, while B has to offer only one sedan model, then A will export more cars than B.

⁶ Khandelwal (2010) follows Krugman’s (1980) model and uses country population as a proxy for variety. Hallak and Schott (2011) deal with this problem in a different manner: based on Romalis (2004), they assume a negative relationship between the price of a country’s exports (so as to say, the inverse of its “comparative advantage”) and the number of varieties.

⁷ For a good typology of trade models, presented in a unified framework, see Hummels and Klenow (2005), section I.

additional information on cross-good substitutability. Thus, we also implement a “two-step” procedure, where we first recover quality estimates from a general demand system *à la* Berry (1994), and then use this quality estimate as an additional explanatory variable in our relative-quantity-price setup. This further comparison provides another piece of evidence in testing our paper’s central conjecture.

Before moving on to this paper’s next section, it’s worth mentioning two earlier attempts at comparing price elasticities, and relating them to sectors’ characteristics. Anderton (1999) produced estimates of imports demand functions for the United Kingdom and Germany with data at 2-digit ISIC disaggregation level, using imported quantities by sector as dependent variables and relative prices (domestic / imported) as independent variables. His empirical evidence is not conclusive in terms of an average behavior of the technological groups. He finds some low-tech sectors with high price elasticity (such as wood) and others with low price elasticity (such as paper); some high-tech sectors with high price elasticity (such as transport equipment) and others with low price elasticity (such as professional and scientific goods). Also, Anderton (1999) could not benefit from the recent literature on exports quality measurement to sharpen his identification strategy. For example, he alternatively uses relative (importer country’s/exporter country’s) R&D expenditure and patenting by sector as a proxy for both product “variety” and “quality”. Although “variety” is a relevant control that should be included in the regression model, it would be desirable to have an independent proxy for variety, an attribute which we want to separate from quality by the identification method. Besides, if R&D expenditure and patenting correlations with quality are not identical across sectors, then their inclusion as proxies may generate price elasticity estimates which do not appropriately reflect sectors’ levels of quality differentiation.

Aiginger (1997) was perhaps the first to put forward the idea of revealed price elasticity (REVELAST) to discriminate between price (cost) and quality competition in international trade. Basically, his idea is: if in market i (that is, for traded good i) country A has a higher unitary value (or “price”) than country B, and A is a net importer (in terms of quantity of good i) from B, then we may say that good i was revealed as one in which what matters is cost competition. If, on the contrary, for some other good j country A has a higher unitary value (or “price”) than country B, and A is a net exporter to B, then we may say that good j was revealed as one in which what matters is quality competition. Notice, however, that this classification is dependent on the particular

bilateral trade under consideration: in terms of the above example, good i might very well turn up to be revealed as a quality competition good if a different pair of countries was taken (say, bilateral trade between countries A and C, or B and C, etc.). Unfortunately, Aiginger (1997) does not pursue an attempt at overcoming this “bilateral trade dependence” limitation.

The remainder of this paper is organized as follows. In section 2, we provide a structural form econometrics rationale for the REVELAST approach. We describe the data in section 3. In section 4, we present our estimates of quasi-demand functions, which allow us to compare high- versus low-tech goods’ price and quality elasticities. Section 5 concludes.

2. The Revealed Price Elasticity Approach (REVELAST)

2. 1. The demand side

Our departure point is a Dixit-Stiglitz utility function like Hummels and Klenow’s (2005), which incorporates a “love of variety” by consumers. In an international trade context, think of the expression below as characterizing the representative consumer’s preferences over goods (and “varieties” of the same good) supplied by different exporter countries. Consumer preferences are internationally identical:

$$U = \left[\sum_{j=1}^J \sum_{i=1}^I Q_{ji} \cdot N_{ji} \cdot (x_{ji})^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad (1)$$

where j denotes the exporter country of good i ; N_{ji} is the number of symmetric varieties of good i exported by country j ; Q_{ji} is the quality of country j ’s varieties of good i ; and x_{ji} is the quantity of good i imported from country j . The $\sigma > 1$ is the single elasticity of substitution between different goods and between producer countries within each good.

The representative consumer maximizes (1) subject to:

$$\sum_{j=1}^J \sum_{i=1}^I N_{ji} \cdot p_{ji} \cdot x_{ji} \leq Y \quad (2)$$

where p_{ji} denotes the price exporter country j charges for good i (therefore we make the crude assumption that all good i varieties exported by j have the same price) and Y denotes the representative consumer's (or importing country's) income.⁸

Consider now the same good i being exported by countries j and k . Standard maximization of (1) subject to (2) yields:

$$\frac{x_{ij}}{x_{ik}} = \left(\frac{p_{ij}}{p_{ik}} \right)^{-\sigma} \cdot \left(\frac{Q_{ij}}{Q_{ik}} \right)^{\sigma} . \quad (3)$$

But the observed total quantity of good i that country j exports is actually:

$$X_{ij} \equiv x_{ij} \cdot N_{ij} . \quad (4)$$

Combining (3) and (4) we have:

$$\frac{X_{ij}}{X_{ik}} = \frac{N_{ij}}{N_{ik}} \cdot \left(\frac{p_{ij}}{p_{ik}} \right)^{-\sigma} \cdot \left(\frac{Q_{ij}}{Q_{ik}} \right)^{\sigma} \quad (5)$$

and taking logs we arrive at the fundamental relationship between the dependent variable “relative exported quantity” and the explanatory variables “relative variety”, “relative price” and “relative quality”:

$$\log \left(\frac{X_{ij}}{X_{ik}} \right) = \log \left(\frac{N_{ij}}{N_{ik}} \right) - \sigma \cdot \log \left(\frac{p_{ij}}{p_{ik}} \right) + \sigma \cdot \log \left(\frac{Q_{ij}}{Q_{ik}} \right) . \quad (6)$$

We present below a few alternative assumptions about the supply side in light of which it would make sense adding other “controls” to our basic expression (6), such as: countries' sizes, GDPs *per capita*, etc. But let's for the moment assume that all supply

⁸ “Love of variety” obtains very easily from the utility function if we consider, for example, an hypothetical situation in which the expenditure with good i from country j and p_{ij} remain constant but N_{ij} doubles (and therefore x_{ij} is reduced to one half): the net effect is an increase in the utility level.

side characteristics are summarized in prices, and use (6) above to give a micro-founded justification to the REVELAST intuitive arguments.⁹

In (6), suppose that total exported quantities (left-hand side variables), numbers of varieties and prices are directly observable, but relative quality is not.¹⁰ Then one approach would be using proxies for quality, like observed price itself or industry's i R&D intensity in country j as Anderton (1999) does. The other, alternative approach is relying on econometric identification, and treating Q_{ij}/Q_{ik} as an omitted variable. Whence basically two things may happen:

- 1) If good i is not characterized by much “quality differentiation”, that is if $Q_{ij}/Q_{ik} \cong 1$, then omitting this variable will not have effect on the coefficient associated with the relative price.
- 2) Conversely, if good i is characterized by “quality differentiation”, that is if Q_{ij}/Q_{ik} is substantially different from 1, and besides there exists a positive correlation between p_{ij} and Q_{ij} , then omitting the relative quality will bias the coefficient associated with the relative price, making it “less negative”.

This is what lies at the bottom of REVELAST arguments: in quality differentiated goods or markets, demanded quantity seems to be less sensitive to price.

2.2. The supply side and further controls

Hummels and Klenow (2005) summarize variety across and within goods categories as $V_j = N_j \cdot I_j$, where I_j is the number of different goods produced by exporter country j and N_j is j 's number of varieties per good. But since we are concerned here with export market performance within a certain good market (say, good i as in expression 6 above), we adopt the normalization $I_j = 1, \forall j$, so that variety is simply summarized by N . Then a reasonable functional form for the production function is:

$$x_j = \frac{L_j^\delta}{N_j^\alpha}, \quad \alpha > 1 \quad \text{and} \quad 0 < \delta < 1, \quad (7)$$

⁹ REVELAST intuitive arguments like Aiginger's (1997) and Anderton's (1999) mentioned in the introduction.

¹⁰ As we shall see below, this is only partially true for the number of varieties.

from which we dropped the subscript i for simplicity, given the normalization $I_j = 1$. L_j is country j 's labor endowment. Given that $0 < \delta < 1$, expression (7) assumes decreasing returns to labor (due, for example, to an omitted stock of capital). Given that $\alpha > 1$, (7) assumes a cost of producing variety: the amount produced of each variety (x) is reduced more than proportionally when the number of varieties (N) increases.

Now, country j 's GDP is given by:

$$Y_j = p_j \cdot x_j \cdot N_j, \quad (8)$$

and per capita GDP is thus:

$$y_j = p_j \cdot x_j \cdot N_j \cdot L_j^{-1}. \quad (9)$$

Substituting (7) in (9) and solving for the price we arrive at:

$$p_j = y_j \cdot N_j^{\alpha-1} \cdot L_j^{1-\delta}. \quad (10)$$

Next, consider expression (5) above when country k is Hummels and Klenow's (2005) "reference country", for which Q , N , x , y and p are all normalized to 1:

$$X_j = N_j \cdot p_j^{-\sigma} \cdot Q_j^\sigma, \quad (11)$$

from which we also removed subscript i . Substituting (10) in (11) and after a little algebraic manipulation, we finally arrive at:

$$X_j = y_j \cdot N_j^\alpha \cdot L_j^{1-\delta} \cdot p_j^{-(\sigma+1)} \cdot Q_j^\sigma, \quad (12)$$

or, taking logs:

$$\log(X_j) = \log(y_j) + \alpha \cdot \log(N_j) + (1 - \delta) \cdot \log(L_j) - (\sigma + 1) \cdot \log(p_j) + \sigma \cdot \log(Q_j). \quad (13)$$

We should not make much ado about expression (13), understood as a structural form. Essentially, it is only expression (6) above with GDP *per capita* and population appearing as controls. These controls are widely used in the literature when it comes to explaining export market performance.

3. The data and variables construction

Our primary data source is United Nations' Comtrade, from which we extract information on exported quantities (in physical units of measure) and values (that is, total nominal revenue from exports) for manufactured goods (SITC Revision 3, codes 5 to 8) at 4 and 5-digit disaggregation levels. Instead of examining the imports made by a single country, like Anderton (1999) or Khandelwal (2010) do, here we look at the exports of 19 OECD countries in their intra-trade (that is, we consider only trade flows inside the 19 countries block).¹¹

To obtain the exports data, we actually start with imports figures, since these latter are more reliable due to Customs controls. So, in order to obtain the quantity of good i exported by country j , we sum over the quantities of good i imported from j by all the other countries different from j – in Comtrade terminology, this amounts to taking the other countries as “reporters” and j as “partner”. Although OECD countries usually report their imported quantities in the same unit of measure (say, kilograms for good i), for a few manufactured goods it does not happen, and we have thus removed such goods from our sample.

The same procedure was used to obtain total exported values, say, country j 's total revenue with good i exports. The primary data supplied by individual countries to Comtrade consists of imported current values denominated in local currencies, which are then converted to dollars by Comtrade using the appropriated current exchange rates. Because the data available from Comtrade are thus denominated in current dollars and we will consider a panel of 5 years (1990, 1995, 2000, 2005 and 2010), we convert current values in real, comparable values using the dollar GDP deflator.

¹¹ This choice is not harmless. Although there is a gain in the number of importing countries considered, we lose important instruments (like tariffs, for prices) which are available for U.S. imports only, in Feenstra, Romalis and Schott (2002), the database used by Khandelwal (2010).

So thus far we have two variables, which we will call QT_{ij} , which is the quantity of good i exported by country j to the other 18 countries in our OECD block; and V_{ij} , which is the total value of good i exports from j to the other 18 countries in our OECD block. With these two variables, we construct a third one called UV , or unitary value, that is pervasive in the empirical trade literature:

$$UV_{ij} = V_{ij}/QT_{ij} , \quad (14)$$

with the intuition of average price at which j exports good i inside the block of countries.

Next we adapt variables QT and UV to “structural form” expressions (6) or (13) above. Recall that in order to arrive at (13), we used Hummels and Klenow’s (2005) “reference country” concept. Here we take this country to be the block total for quantities and the block average for prices:

$$RQT_{ij} = \frac{QT_{ij}}{\sum_{k=1}^{19} QT_{ik}} , \quad (15)$$

where k denotes a country in the block. The relative quantity RQT_{ij} is thus our empirical counterpart of X_{ij}/X_{ik} in (6), or of X_j in (13). We define the unitary value of country j relative to the cross-country average unitary value, in market i as:

$$RUV_{ij} = \frac{UV_{ij}}{\sum_{k=1}^{19} UV_{ik} / 19} , \quad (16)$$

such that RUV_{ij} is thus the empirical counterpart of p_{ij}/p_{ik} in (6) or of p_j in (13).

Because reported values by Comtrade are already in c.i.f. prices, which incorporate freight or transportation costs, we do not use these latter (or the distance between countries) as regressor. We cannot use tariffs data because – unlike Khandelwal (2010) who looks at U.S. imports from both OECD and non-OECD – all 19 countries in our import-export block are OECD members and tariffs on manufactured goods are negligible among them in the period considered (1990-2010).

Because we do not have data on number of good i varieties exported by country j , like Krugman (1980), we use country j 's population as a proxy for this unobservable variety. Although we do not explicitly model how the number of varieties N_{ij} might depend on L_j , notice that our treatment of the supply-side in subsection 2.2 above has already led us to include L_j as a right-hand side variable. This variable is extracted from Penn World Table 7.0.

Another control appearing in equation (13) is *per capita* income. This variable is also extracted from Penn World Table 7.0. As we did when defined RQT above, here we take the reference country's per capita income as the 19 countries-block total:

$$\text{relgdp}_j = \frac{y_j}{\sum_{k=1}^{19} y_k} . \quad (17)$$

An important issue for our split-sample analysis strategy (described in the introduction) is the classification of SITC goods as to their technological level. However, technological level classifications (based on R&D intensities, such as Hatzichronoglou's (1997) or OECD ISIC Revision 3 (2011)) apply to industries, not to goods. To overcome this problem, we use the SITC-ISIC "correspondence table" developed by M. Aendy, Sim Yee and Satoru's (MPRA 2010). Then, our variable "tech level" is a binary variable which classifies each of the approximately 2100 5-digit goods as "high-tech" or "low-tech".

Finally, a note is due on the choice of OECD countries that constitute our 19-countries "intra-trade block". Here, our criterion was basically the World Bank's R&D expenditure/GDP indicator – we took those OECD countries which perform more R&D, with what relevant international trade partners such as Spain were left out. In the end, our sample consists of: Belgium (including Luxembourg), Canada, Finland, France, Germany, Ireland, Israel, Italy, Japan, Korea, Taiwan, Netherlands, Norway, Singapore, Sweden, Switzerland, the United Kingdom, and the United States. Sometimes, in our regressions below, we further restrict attention to the 11 countries which are more diversified in international trade (that is, which export a wider set of goods): Belgium (including Luxembourg), Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, the United Kingdom, and the United States.

Besides the REVELAST approach (based on 6 and 13 above), we use Khandelwal's (2010) "demand system" method to extract exporter countries' quality estimates. For this, we need two more variables:

$$share_{ij} = \frac{V_{ij}}{\sum_{k=1}^{19} \sum_{h \in I} V_{hk}}, \quad (18)$$

where k denotes country k and h denotes good h . I is the set of all manufactured exported goods, including good i of course. So $share_{ij}$ is the share of good i exported by country j in total 19 countries-block exports of all goods, and:

$$nest_{ij} = \frac{V_{ij}}{\sum_{k=1}^{19} V_{ik}}, \quad (19)$$

is the share which country j has in the nest of export market i . Notice that $share_{ij}$ may diminish, either because $nest_{ij}$ has been reduced (country j has lost competitiveness in market i), or because good i has been replaced by other goods in the representative consumer's bundle.

Descriptive statistics of the series used in this paper are presented in Table 1.

Table 1: Series Descriptive Statistics

	Relative quantity (lrqt)	Relative unit value (lruv)	Relative GDP per (lrelgdp)	Population (lpop)	Market share (lshare)	Unit value (uv)	Nest share (lnest)	Quality estimate (quality)
mean	-3.64	-0.62	-3.11	10.53	-12.05	2380.34	-3.39	-0.21
median	-3.27	-0.33	-2.80	10.96	-11.85	16.10	-3.11	-0.24
minimum	-20.91	-12.94	-4.69	8.83	-26.54	0.01	-16.71	-49.90
1st quarter	-4.60	-0.98	-4.42	9.25	-13.40	4.66	-4.25	-3.38
3rd quarter	-2.28	0.05	-2.45	11.31	-10.50	56.58	-2.22	3.05
maximum	-0.03	2.89	-0.89	12.63	-4.40	6417512.00	-0.08	57.14

Correlation matrix								
	lrqt	lruv	lrelgdp	lpop	lshare	uv	lnest	quality
lrqt	1							
lruv	-0.24	1						
lrelgdp	0.32	0.01	1					
lpop	0.33	0.00	0.99	1				
lshare	0.67	0.01	0.29	0.29	1			
uv	-0.07	0.05	-0.02	-0.02	0.00	1		
lnest	0.87	0.00	0.39	0.39	0.76	0.00	1	
quality	0.14	-0.02	-0.10	-0.10	0.13	0.01	0.15	1

Notes: lrqt, lruv, lrelgdp, lpop, lshare and lnest are the natural logarithms of the original series as used in the following regressions. Each series has 91960 observations, the product of 11 countries, during 5 periods, in 1672 industries. Quality is estimated from equation (15) from Khandelwal (2010).

4. Results

Based on expression (13) above, we propose the following reduced form to test price elasticity differences in our split-sample:

$$\ln RQT_{ijt} = \beta_0 + \beta_t + \beta_j + \beta_{1(low)} \cdot D_{low}(i) \cdot \ln RUV_{ijt} + \beta_{1(high)} \cdot D_{high}(i) \cdot \ln RUV_{ijt} + \beta_2 \cdot \ln relgdp_{jt} + \beta_3 \cdot \ln L_{jt} + \varepsilon_{ijt}, \quad (20)$$

where: i denotes a good; j denotes an exporter country; t denotes time, with $t = 1990, 1995, 2000, 2005, 2010$; $D_{low}(i)$ is a dummy variable which assumes value 1 if i is a low-tech good and 0 otherwise; $D_{high}(i)$ is a dummy variable which assumes value 1 if i is a high-tech good and 0 otherwise; β_t is a time fixed-effect; and β_j is a product-country fixed-effect.

In Table 2, Columns 1 to 4 present the estimates for equation (20). The data frequency is quinquennial. Pooled cross-sectional Ordinary Least Square (OLS) in column (1), including common-time effect (TE-OLS) in (2), country-industry effects

(CE-OLS) in columns (3), and time and country-industry effects (LSDV) in columns (4), with robust standard errors clustered by country-industry in parentheses.

We note that the relative unit value is negative and significant as expected in a price-quantity demand relationship. Although common-time and country-product fixed effects have shown to be significant, they do not change the price sensitivity significantly.

We are aware that the simultaneous definition of the price quantity in a demand-supply context creates some endogeneity problems (that we intend to address in following versions of this paper). However, the Comtrade database does not contain other variables, like transportation costs, that could be used as instruments for the relative unit value. For the while, our controls are summed up to the inclusion of the relative GDP and population, in addition to the time and country-product effects.

Table 2 - Relative Quantities Demand for Exports (1990-2010)

	OLS (1)	TE-OLS (2)	CE-OLS (3)	LSDV (4)	LSDV (5)	LSDV (6)
Relative unit value	-.359*** (0.007)	-.359*** (0.007)	-.35*** (0.006)	-.356*** (0.006)	-.359*** (0.006)	
Relative unit value - high tech						-.33*** (0.006)
Relative unit value - low tech						-.448*** (0.011)
Quality					.646*** (0.007)	
Quality - high tech						.675*** (0.011)
Quality - low tech						.614*** (0.009)
Relative GDP	-.956*** (0.069)	-1.26*** (0.088)	.847*** (0.073)	.64*** (0.105)	.641*** (0.096)	.637*** (0.096)
Population	1.51*** (0.071)	1.81*** (0.090)	1.31*** (0.119)	2.4*** (0.255)	2.39*** (0.236)	2.36*** (0.235)
Year-effects	no	yes	no	yes	yes	yes
Country-prod. effects	no	no	yes	yes	yes	yes
Observations	91960	91960	91960	91960	91960	91960
Adj. R2	0.17	0.18	0.14	0.14	0.35	0.35
Equal RUV sensitivities test					F(1, 18391) = Prob > F =	84.67 0.00
Equal Qualities sensitivities test					F(1, 18391) = Prob > F =	19.82 0.00

Notes: The data frequency is quinquennial. Pooled cross-sectional OLS (OLS) in column (1), including time-variable effect (TE-OLS) in (2), country-industry effects (CE-OLS) in columns (3), and time and country-industry effects (LSDV) in columns (4)-(6), with robust standard errors clustered by country-industry in parentheses. *, ** and *** indicate the significance level of 10%, 5%, and 1%, respectively. F-tests for equal sensitivity between technological levels are for column (6) only.

Given that one objective with equation (20) is to detect different price sensitivities between low- and high-tech goods – goods that are assumed different in nature – but prices might reflect quality, we should be concerned that any detected difference does not spuriously reflect different degrees of price-quality relation. A trivial way of treating that would be to directly include a quality variable in equation (20). By including a quality variable, we could additionally test for different sensitivities of high- and low-tech demands to quality, thus inferring whether the high-tech demand conditions motivate: (i) a Grossman and Helpman (1991) quality improvement policy, in the case where high-tech goods present a lower price and higher quality sensitivity than the low-techs; or (ii) a Taylor (1993) cost reduction policy, in

the case where high-tech goods present a higher price and lower quality sensitivity than the low-techs.

However, quality is usually a non-observable characteristic. According to Hallak and Schott (2008), in different contexts, the literature has overcome this problem by using ad hoc proxies for quality. Here instead, as Khandelwal (2010), we take the less usual approach to measure the country-product quality from the market share equation:

$$\ln share_{ijt} = \lambda_{it} + \lambda_{ij} + \lambda_1 \cdot \ln UV_{ijt} + \lambda_2 \cdot \ln nest_{ijt} + \lambda_3 \cdot \ln L_{jt} + u_{ijt} \quad (21)$$

where: λ_{ij} is a product-country fixed-effect; λ_{it} is a product-specific time-effect; and UV_{ijt} is the unitary value country j charges for good i at time t .

The estimated quality of product-country ij is defined using equation (21) estimated parameters:

$$quality_{ijt} = \hat{\lambda}_{it} + \hat{\lambda}_{ij} + \hat{u}_{ijt} . \quad (22)$$

Equation (21) is a Berry's (1994) "demand system". By an increase in λ_{ij} country j alone increases its share in good i , whereas by an increase in λ_{it} all countries increase their good i shares at other goods' expense. Unlike (20) where RQT_{ij} can only increase if some other country k 's relative quantity RQT_{ik} is reduced, (21) is a "demand system" which gives room for cross-good substitution: country j 's share in good i may increase either because j became more competitive inside market i (that is, $nest_{ij}$ increased) and/or because good i 's share increased for all countries at other goods' expense.

Like Khandelwal (2010), we estimate (21) separately for each industry i , with standard-errors clustered by exporting country, and summarize the results in Table 3.

Table 3: Descriptive statistics of the quality estimate results

	Price coefficient	Nest coefficient	Population coefficient	Quality estimate	Quality est. - high tech	Quality est. - low tech
Mean	1.96E-08	1.00	-2.05E-07	-0.21	-0.09	-0.34
Standard Error	1.74E-09	1.61E-09	3.16E-08	0.02	0.03	0.04
Median	-3.92E-13	1.00	6.39E-08	-0.24	-0.21	-0.30
Mode	1.90E-08	1.00	-1.03E-05	-1.71	-4.88	-1.87
Standard Deviation	5.28E-07	4.88E-07	9.59E-06	7.43	7.27	7.59
Kurtosis	1114.09	3.04	0.30	4.39	5.64	3.19
Skewness	30.77	0.59	-0.01	-0.09	-0.02	-0.15
Minimum	-2.13E-06	1.00	-3.52E-05	-49.90	-49.90	-44.27
Maximum	1.95E-05	1.00	3.83E-05	57.14	57.14	46.98
Confidence L. (95%)	3.41E-09	3.15E-09	6.20E-08	0.05	0.06	0.07
Observations	91960	91960	91960	91960	48290	43670

Notes: The table reports estimation statistics of running Khandelwal's (2010) equation (15) separately for each of the 1672 industries. The Least Square regressions used country-fixed and common time effects.

Notice that the mean and median estimated qualities of high-tech goods are indeed higher than the low-techs', in the two last columns. There remains to check the correlation between UV (or price) and quality, what we do by estimating:¹²

$$UV_{ijt} = \gamma_0 + \gamma_t + \gamma_j + \gamma_1 \cdot quality_{ijt} + v_{ijt} . \quad (23)$$

In table 4, we see that the correlation between price and quality is positive in general, but for high-tech goods it is almost 9 times the one for low-tech goods. The F-test strongly rejects the hypothesis of equal sensitivity price-to-quality of the high- and low-tech products. The conclusion is that price reflects quality much more closely in high-tech goods.

¹² This correlation is important in the rationale we gave for the REVELAST approach at the end of section 2.1.

Table 4 - Relationship between Quality and Prices (1990-2010)

	OLS (1)	TE-OLS (2)	CE-OLS (3)	LSDV (4)	LSDV (5)
Quality	52.1* (27.4)	57.2** (27.5)	56.3** (27.6)	61.5** (27.7)	
Quality - high tech					110** (54.3)
Quality - low tech					12.3*** (4.8)
Year-effects	no	yes	no	yes	yes
Country effects	no	no	yes	yes	yes
Observations	91960	91960	91960	91960	91960
Adj. R2	0.00	0.00	0.05	0.05	0.05
Equal Qualities sensitivities test				F(1, 1671) = Prob > F =	3.24 0.0721

Notes: The data frequency is quinquennial. Pooled cross-sectional OLS (OLS) in column (1), including time-variable effect (TE-OLS) in (2), country effects (CE-OLS) in columns (3), and time and country effects (LSDV) in columns (4)-(5), with robust standard errors clustered by country in parentheses. *, ** and *** indicate the significance level of 10%, 5%, and 1%, respectively. F-tests for equal sensitivity between technological levels are for column (6) only.

Back to Table 2, in Columns (5) and (6), we include the “quality” as a further explanatory in equation (20).

In column (5), we observe that the quality variable coefficient is positive and significant as expected from the demand theory¹³.

In column (6), we finally present our desired test of Grossman and Helpman (1991) versus Taylor (1993) demand incentives for R&D investments.

Both price and quality sensitivities are different between high- and low-tech products, with F-tests strongly rejecting equalities. High-tech goods demands are on average less sensitive to price and more sensitive to quality, thus providing the incentives for the respective industries to focus the R&D effort on quality improvement. Something consistent with the results got in the two last columns of Table 3.

¹³ We are aware the standard-errors have to be corrected for the fact that quality has been estimated and will do this soon.

5. Conclusions

Models in trade theory alternatively choose to focus on quality improvement or cost reduction, with obvious implications for the participants' R&D optimal policy. But which one is a better description of the actual R&D effort is an empirical matter, revealed by the demand incentives and products resulting qualities.

In this draft, we used UN-Comtrade data on manufactured goods exports by 19 OECD countries to show that the demand for R&D intensive goods is less sensitive to price and more sensitive to quality than the demand for low-tech goods. We also estimated exporters' quality levels that are on average higher for high-tech goods, which, taken together with the first evidence, seems to provide a consistent evidence for the dominance of the quality improvement aspect.

In future drafts, we intend to explore other databases that allow IV estimation, as well as costs considerations. Another interesting point that could be made, now in the spirit of Romer's (1990) model, is comparing high tech and low tech goods as to the importance of variety for export market competition.

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