Technological Content of Exports

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Abstract

A large body of literature claims, theoretically and empirically, that the characteristics of exports matter for economic growth and development. According to this literature some goods are better than others because their production is subject to positive externalities and increasing returns. As a consequence, for policy purposes, it is important to know whether the export basket of a country is prone to economic development or not. However, identifying the best opportunities for productive development is not an easy task. The two most influential methodologies to measure these intangible characteristics are the OECD's methodology (OECD, 1984, 1997) that uses R&D intensity data and the sophistication methodology put forward by Lall *et al.* (2006) and Hausmann and Klinger (2007) based on trade data. Building on these contributions this paper combines industry-based and product-based indicators to circumvent some of the shortcomings of the former ones, including what was known as the product-industry controversy (i.e. Are the actual activities during the production process or the product characteristics what accounts better for the technological content of exports?). Our methodology uses direct and indirect R&D spending from public and private sources in the agricultural and manufacturing sectors. It also accounts for product-level characteristics as the sophistication index does. We use Uruguayan data to contrast this methodology against existing ones in order to illustrate our contribution.

Keywords: Technological content, R&D, exports, development, methodology.

JEL classification codes: C18, F14, O25, O31, O32.

1. Introduction

A large body of literature claims, theoretically and empirically, that the characteristics of exports matter for economic growth and development. According to that literature some goods are better than others because their production is subject to positive externalities and increasing returns.

At the core of this virtuosity is the stock of knowledge associated to the production of certain goods. The more sophisticated, diverse and vast is the knowledge content, the higher the potential for knowledge spillovers within and between industries (Lall, 2000) (Griliches, 1979, 1991); the higher the economies of labour pooling (Combes & Duranton, 2006); the more likely the possibilities of producing growth-enhancing externalities of human capital formation (Silva and Teixeira, 2011); and also the faster the advance in technology to be expected with the same innovation effort (Klevorick, 1995).

As a consequence, for policy purposes, it is important to know whether the export basket of a country is prone to economic development or not. We build our methodology for measuring technological content of exports under the premise that both learning and capability building conducive to economic development are based on the interactions between science-based activities in the public sector, firms and R&D organizations. As Cimoli and Porcile (2008) discuss, developing countries' efforts to close the technological gap by merely adapting and improving developed world technology paths can lead persistent asymmetries among countries, as these efforts are only based on supply. For the demand-led mechanisms to work properly, attention should be posed also in actual demand, in particular on exports. We propose that the usual metrics for technological content of exports, based on developed countries' technology trajectories can bias the focus for innovation policy in (at least some) developing countries.

The first influential analyses trying to measure technological content of trade were produced in the United States in the early 1970s inspired by the technological gap report of the OECD (1968).[1] The US Department of Commerce created a taxonomy to classify high-technology industries based on ratios of R&D expenditures over sales (Goldin & Reinert, 2005). The same methodology was followed some years later by the OECD (OECD, 1984). The implicit assumption is that knowledge content of goods could be captured by private efforts in R&D, since firms' knowledge efforts is constructed primarily, although not exclusively, by investing in R&D (OECD, 1984).

These early studies were highly influential. They were used in numerous reports from OECD country members and other and also largely used in academic papers analyzing various aspects of the relation between trade and growth. Moreover, further taxonomies to classify trade were built from OECD (1984)'s shoulders, and they were generically called *technological content classifications*.[2]

In the mid-1990s the OECD revised its methodology to incorporate indirect spending on R&D using input-output matrices (Hatzichronoglou, 1997). This revision also incorporated a list of high-tech products based on R&D intensities, but excluding, on the basis of expert judgment, those goods that were not considered high-tech. This list

[1] See for example (Boretsky, 1971, 1975) and (Kelly, 1976).

[2] We are using knowledge content or technological content of goods indistinctly based on the definition of technology used by the OECD (1984). Technology was defined as "the stock of knowledge (technical and management) that permits the introduction of new products and processes"

was a reaction to one of the most important criticism to the OECD classification known as the product-industry controversy: early taxonomies on technological content of trade classified exports of *goods* on the basis of classifications of R&D intensity of *industries*. This implied that all products from an industry were classified in the same technology group regardless of their actual technological content (e.g. cars' tires were in the same technological group as car's motors).

Despite efforts to improve the methodology since the early studies it still suffers important shortcoming, mainly related to the fact that only R&D expenditure is used to account for knowledge content; that only private R&D efforts are considered; only in the manufacturing sectors; and using information only for developed countries.

A couple of years later, Lall (1998, 2000) reacted to the latter of this shortcoming and elaborated on the OECD product-based classification to incorporate developing countries data. However, the methodological decision of what goods were incorporated in what category remained unclear, and one of the categories (i.e. the resource based) was not very informative regarding technological content. This taxonomy was adopted by the Economic Commission for Latin America and the Caribbean (ECLAC) and therefore it is known as the ECLAC classification of technology content.

In the 2000s some other measures to capture the technological/knowledge content of goods were put forward based directly on trade data. This prominent literature sought to classify the 'technological sophistication' of goods departing from the assumption that higher-income countries tend to export higher-technology goods (see Hausmann and Klinger, 2007; Lall, Weiss and Zhang, 2006). They built an indicator of technological sophistication calculated as the trade-weighted income of countries producing each particular goods. So goods that are mostly exported by rich countries (e.g. electronics) are considered technologically more sophisticated than those exported by poor countries (e.g. soya flour).

This approach to technological content of exports overcame two important limitations of previous approaches based on R&D intensity. Firstly, the methodology is product-based, and therefore, it is more transparent than export-judgement used previously to validate the position of goods in technological content classification developed with industry-based data (see more on this below). Secondly, it is built using information from worldwide trade, so it overcomes the puzzle of having to extrapolate the industrial structure of some countries (e.g. OECD countries) to that of others involved in the analysis.

However this methodology did not go without criticism. One important limitation is that, different technologies and knowledge are involved when producing goods classified under the same product code. This criticism highlights that knowledge externalities and increasing returns arise in the *context* of production of those goods depending on the actual *tasks* involved in their production. The theoretical underpinning of *technological sophistication* methodology somehow assumes that all products, regardless of where they are produced, use the same type of knowledge and technology. This assumption does not hold anymore when tasks for producing goods could be divided across countries and production becomes fragmented. Countries with relatively low salaries would tend to perform labour intensive tasks while richer countries would perform knowledge intensive ones. In other words, this criticism suggests that the characteristics of the *industry* in the context of production also matters.[3]

In this paper we elaborate on the methodological discussions for measuring knowledge content of exports by combining industry-based and product-based indicators so as to overcome some of the limitations of the previous literature. We construct a 2 by 2 matrix by combining two groups of the R&D intensity indicator (using industry data) and two groups for the technological sophistication (corrected by quality and trade policy) indicator (using trade product data). We then defined highly dynamic goods as those in the highest group of both indicators. Thus, a highly dynamic product would be one that it is technologically sophisticated *and* that has been produced in an R&D intensive industry. We test our methodology for the Uruguayan case and compare it with the most used taxonomies.

The paper is divided as follow. Section 2 expands on current section and describes the industry-based and product-based indicators used to measure technological content of exports and explains their limitations. Section 3 presents our methodology. Section 4 estimates technological content of Uruguay exports and compares it with other available classifications. Section 5 concludes.

2. Indicators and taxonomies used to measure technological content in trade

In this section we discuss methodological aspects of the taxonomies that are currently used in the literature to measure technological content of goods.

The OECD taxonomies

The first taxonomy massively used to compare technological content of trade across countries was developed by the OECD in 1984 based on R&D intensity.

The 1984 report constructed an indicator of R&D intensity as the proportion of R&D expenditure in output (OECD, 1984: 4), weighted by industry and country, using data from 11 countries[4] and 21 industries during the period 1970-1980. This indicator was subsequently divided in three groups, to identify High, Medium and Low R&D intensity industries as showed in Table 1. They did not explain how they decided the cut-off points in the R&D intensity indicator to discriminate the three technological groups. Six industries were classified in the high and in the medium R&D intensity groups, and nine in the low-intensity group.

Table 1: Taxonomy of technological content based on R&D intensity in the OECD area

High	Medium	Low
Aerospace	Automobiles	Stone, clay, glass
Office machines, computers	Chemicals	Food, beverages, tobacco
Electronics and components	Other manuf. Ind	Shipbuilding

[3] Another limitation of this approach is associated to the lack of attention to the quality dimension (i.e. two equally denominated products could be produced in very different qualities), which could be approximated by the unitary prices although that is an imperfect measure since prices are affected by other factors too.

[4] United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, the Netherlands; Sweden and Belgium

Drugs	Non-electrical machinery	Petrol refineries
Instruments	Rubber, plastics	Ferrous metals
Electrical machinery	Non-ferrous metals	Fabricated metal products
		Paper, printing
		Wood, cork, furniture
		Textiles, footwear, leather

Source: OECD (1984).

Ten years later, the OECD revised the methodology in two important ways (see Hatzichronoglou, 1997). Firstly, they included indirect R&D intensity taking into account technology flows from one sector to another through the acquisition of capital goods and intermediary inputs. Secondly, they split the medium-tech category into two: mid-high, and mid-low.

The indicator used for the classification was built with information from 22 manufacturing sectors (ISIC Rev 2) and 10 OECD countries[5] with information over the period 1980-1990. It measured overall R&D intensity defined as indirect and direct expenditures in R&D over sales. Indirect R&D intensity was calculated using the input-output coefficients from I-O matrices to capture the knowledge content embodied in intermediary products and capital goods bought domestically or imported.

To define the cut-off points they relied on three indicators: i) the overall R&D intensity, ii) direct R&D intensity measured over value added, and iii) direct R&D intensity measured over production. They then divided the 22 sectors in four groups using cut-off points that brought a stable taxonomy across indicators for the highest and lowest groups. In other words, industries classified in the higher category had a higher intensity for all indicators than industries in a lower category.

The classification currently used by the OECD, presented in Table 2, uses the same methodology as Hatzichronoglou (1997) but it updated the input data. It is now based on 12 countries with data for the period 1991-1999.

[5]United States, Japan, Germany, France, the United Kingdom, Italy, Canada, Australia, the Netherlands and Denmark

Table 2. Taxonomy of technological content based on R&D overall intensity (direct and indirect) in the OECD area

Industries	ISIC Rev. 3
High-technology industries	
Aircraft and spacecraft	353
Pharmaceuticals	2423
Office, accounting and computing machinery	30
Radio, TV and communications equipment	32
Medical, precision and optical instruments Medium-high-technology industries	33
Medium-high-technology industries	
Electrical machinery and apparatus, n.e.c.	31
Motor vehicles, trailers and semi-trailers	34
Chemicals excluding pharmaceuticals	24 excl. 2423
Railroad equipment and transport equipment, n.e.c.	352 + 359
Machinery and equipment, n.e.c. Medium-low-technology industries	29
Medium-low-technology industries	
Building and repairing of ships and boats	351
Rubber and plastics products	25
Coke, refined petroleum products and nuclear fuel	23
Other non-metallic mineral products	26
Basic metals and fabricated metal products Low-technology industries	27-28
Low-technology industries	
Manufacturing, n.e.c. Recycling	36-37
Wood, pulp, paper, paper products, printing and publishing	20-22
Food products, beverages and tobacco	15-16
Textiles, textile products, leather and footwear	17-19

Note: Based on data for 12 OECD countries: United States, Canada, Japan, Denmark, Finland, France, Germany, Ireland, Italy, Spain, Sweden, United Kingdom

Source:OECD (2003).

One criticism received by these early taxonomies on technological content of trade was that they classified exports of *goods* on the basis of classifications of R&D intensity of *industries*. Thus, all products from high-tech industries were classified as high-tech, independently of the specific characteristics of products.

This criticism led the OECD to publish in 1997 a list of **high-tech products**, based on R&D intensities, but excluding, on the basis of expert judgment, those goods that were not considered high-tech. The list corresponded to three-digit Standard International Trade Classification (SITC) Rev. 3 classification of foreign trade and was based on calculations of R&D intensity, defined as R&D expenditure over sales, by groups of products covering six countries (United States, Japan, Germany, Italy, Sweden, the Netherlands) (Hatzichronoglou, 1997: 7). From this point of departure, the OECD then opened the three-digit into four and five and confirmed with expert opinion whether those products could be considered high-tech. The list of high-tech products, includes many of the products corresponding to high-tech sectors, some of the products from medium-high tech sectors but there are no products from medium-low or low categories of the industry-based classification.

The methodology to measure R&D intensity for group of products remains unclear. Goldin and Reinert (2005: 131) stated that "all product with R&D intensities above the industry average, that is, about 3.5 percent of total sales, were considered high-tech". However, it is not clear what criteria they used to assign data informed by firms (R&D) to products. According to the above-mentioned authors, "a manual devoted to high technology was envisioned [by the OECD], but it was never written." Goldin and Reinert (2005: 131).

ECLAC classification

The classification by the Economic Commission for Latin America and the Caribbean (ECLAC) used the methodology put forward by Lall (1998, 2000). This methodology defines technology groups by three-digit SITC Rev 2 using information from developed and developing countries. Somehow inspired in Pavitt (1984)[6] taxonomy, Lall (2000) created four groups: Resource-based (RB), Low-technology (LT), Medium-technology (MT) and High-technology (HT). However, the details on the methodological decisions are totally unclear. The most relevant technical information is included in this extract, which, as will be seen, is not very informative:

> "There are many ways to categorize products by technology. A commonly used method (based on Pavitt, 1984) is to distinguish between resource-based, labour-intensive, scale-intensive, differentiated and science-based manufactures. This is difficult to use because the analytical distinctions are unclear and there are large overlaps between categories. The OECD (1994)[7] [(1996)] suggests a more detailed classification based on technological activity within each category. The scheme used here combines both, and extends them to take account of product groups or clusters of particular export interest to the developing world. Table 1 shows the scheme. Judgement is inevitably involved in assigning products to categories. The classification is based on available indicators of technological activity in manufacturing and on the author's knowledge of industrial technology. It conforms to most analysts' conception of the technological ranking of manufactured products. It differs from my earlier classification (Lall, 1998) in that the processed foods like sugar, cheese and vegetable preparations are now classified as resource-based manufactures rather than as primary products. This makes the manufactured category larger than the usual classification (which generally places all SITC items under headings 0–4 under primary products)". (Lall, 2000: 340-341)

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[6] Lall (2000) claimed that his methodology was inspired by Pavitt taxonomy, although Pavitt had classified manufacturing sectors (not products). Pavitt taxonomy created four groups of sectors: supplier dominated, scale intensive, science-based and specialized suppliers based on firms' behavior regarding knowledge sources; user-related factors and knowledge appropriability methods using information of the United Kingdom during 1945-1979. It is not clear for us what exact inputs Lall took from Pavitt to develop his technology content taxonomy.

[7] The full reference for OECD (1994) in the reference list is: OECD (1994) *Globalisation and Competitiveness: Relevant Indicators* (Paris, OECD Directorate for Science, Technology and Industry), DSTI/EAS/IND/WP9(94)19, which we found as Hatzichronoglou (1996). There is not the taxonomy of high-tech trade produced in that report.

In sum, the ECLAC classification elaborated on the OECD product-based classification since it incorporated developing countries in the analysis, they classified goods in other technological groups and not just high-tech products, and they were particularly interested to identify resource-based products from the low-tech group. However, the methodological decision of what goods were incorporated in each category remained unclear. It was based on judgment, and one important assumption to build the taxonomy was that primary products "do not need much analysis in terms of the technological basis of comparative advantage"[8] while natural resource (NR) based manufactures were treated as a separate group which is not very informative in terms of understandings their technological content.

Technological sophistication indicators

Some critical views on how accurate industrial technology classifications were to classify exports led to complementary classifications. Lall (2006) stated that differences in the aggregation level between industry classification and trade data and the different technology characteristics of goods production in different countries[9] could introduce errors when traditional industry classification was used to evaluate trade in products.

To overcome these problems Lall *et al.* (2006) and Hausmann *et al.* (2006) followed the concept of product sophistication (Kwan, 2002) which stated that countries with higher incomes would export higher value added products. Lall *et al.* (2006) explained the rationale of the sophistication measure: in the absence of trade interventions, products exported by richer countries would have characteristics that allowed high wage producers to compete in world markets. A key enabler for that was technology but there also was a role for marketing, geographical location of production, logistics, scope for production fragmentation, or infrastructure.

The sophistication index sorted out products according to exporting countries' wealth (we refer to the formula introduced by Hausmann et al., 2006[10]). Hidalgo et al. (2007) showed that technology, institutions and skills needed to make more-sophisticated products could be easily adapted to make other high sophisticated products, and usually the contrary occurs in the case of low sophisticated products.

Subsequent studies adjusted the measure of export sophistication[11]. Xu (2007) proposed to use unit price indexes to adjust PRODY for differences in the quality of exported products (i.e. the same final product exported by a developed and developing country could involve differences in technology content, and that would be reflected in the price).

Other approaches to estimating technological content of exports at the product level focused on goods' unit values as a proxy for quality. For example, Kaplinsky and Santos Paulino (2004) suggested that the evolution of prices over time accounted for innovativeness (i.e. when new technologies are incorporated in goods, their prices increases). However, others such as Lall *et al.*, (2006) criticised this approach arguing that price changes also reflect other factors like demand changes, trade barriers or fragmentation of the value chain (More recent studies included demand models with

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[8]Lall (2000:8)

[9]Due to the growing trade fragmentation process, exports of high-tech electronic products is mostly done by low income countries, which just assemble and test final products and do not normally participate in product development or other innovations.

[10] See section 3.2

[11]See for instance, Hidalgo and Hausmann (2009).

microeconomic foundations to the estimation of quality (e.g. Khandelwal, 2010; Hallak and Schott, 2011; Feenstra and Romalis, 2012).

Limitations of the available methodologies

The main limitations of the OECD taxonomies can be grouped under the following headings.

Knowledge does not come only from R&D. The OECD taxonomy accounts for knowledge content that has been formalized in R&D expenditure, while it is a stylized fact that knowledge could also be included in the production from more informal efforts (personnel capability and training) or from external sources (licenses, inter-firm collaboration, firm-industry collaborations). The OECD was openly conscious of this limitation, but data restrictions pushed them to withdraw the attempt to include other criteria (T Hatzichronoglou, 1997: 5).

A flow variable to proxy for knowledge stock. What really matters for increasing returns and externalities is the long-term accumulation of knowledge involved in production; thus, relevant knowledge could be produced thanks to the accumulation of R&D efforts over recent history. Moreover, the intensity of R&D may be subject to firm's turnover volatility. These drawbacks may be overcome when the analysis is based over a long period of time.

Only private R&D efforts are taken into account. In many industrial sectors publicly performed R&D can be largely more important than private R&D. This is especially the case in developing countries, where the ratio public/private R&D expenditures is fairly high.

Only manufacturing industries are included in the taxonomy. This makes the taxonomy less useful to analyse developing countries' trade, which is largely based on products from *primary* sectors.

Difficult to extrapolate to non-OECD countries. The taxonomy was built using information from the industrial structure of OECD countries. The use of this tool to analyse other's countries trade requires an extrapolation of structure which is difficult to justify.

Data may become soon outdated. The data upon which current taxonomy was produced becomes fairly outdated very rapidly, especially in high-tech industries that are very dynamic.

Product-industry controversy. This means that on the one hand, all products from an industry are classified in the same technology group regardless of their actual technological content (e.g. cars' tires are in the same technological group as car's motors). But this is not only a question of aggregation; since the R&D intensity is allocated to the firm's' principal activity, it could well be the case that high proportion of R&D in one sector is dedicated to knowledge creation for another sector. This criticism led the OECD to publish in 1997 a list of high-tech products, based on R&D intensities, but excluding, on the basis of expert judgment, those goods that were not considered high-tech. Expert judgment was also used in further taxonomies (see Lall, 1998, 2000; UNCTAD, 1996, 2002).

With respect to the sophistication approach, it has the drawback of being a biased proxy of technology content. In the case of PRODY, it is argued that transportation costs, trade policy and other factors affect the composition of rich countries' exports. One of the limitations concerning the use of unit values as proxies of quality is that, even at product level, there are variations in goods composition that reveal in different unit values, and do not correspond to variation in quality.

However, the most important limitation when using product-based taxonomies is, once again, the product-industry controversy. Knowledge content differs for different tasks involved in the production produces of producing similar goods. The last assembly stage of computers or cars may not generate large spillovers or increasing returns and therefore it would have a very low impact on growth. While being involved in the whole value-chain of producing those goods could well be very growth-enhancing, being involved just in the last assembly stages is not.[12] Furthermore, the fragmentation of the global production implies that knowledge content may not be even located in the same country from where goods are exported. In other words, R&D activities in relevant fields to the production of certain good may be well located far away from the industries that assemble and export the final good. This means that for a taxonomy to properly account for the technological content of exported goods, the characteristics of the industry in the context of production also needs to be taken into account.

3 Our proposed taxonomy on exports technological content

3.1. Methodological approach

In this paper we search for an indicator of technological content of exports as a guideline for promoting innovation and economic development. Based on OECD (1984) and Mansfield (1968) we define technology content as the stock of knowledge associated to the production of (the exported) goods. We follow and complement two alternative pathways to proxy for technology content.

Firstly, we proxy the knowledge stock as the efforts done to improve the goods' features or to make the production process more efficient. Thus, at it has been done in the past by the OECD, we use the industry R&D expenditures over sales to characterize the knowledge content of all goods included in each industry class. We include both, direct and indirect R&D spending from public and private sources.

We overcome some of the problems associated to using the latest OECD taxonomy to characterize technological content of exports since:

- **We include the public sector spending**. While public enterprises' innovative activities, tax subsidies or other indirect R&D policies are already captured in the innovation surveys, we acknowledge that governments also provide knowledge accumulation through the funding of research councils or university programs. There is evidence in the literature for and against spillover effects of direct public innovation activities either on productivity (Park, 1995; Guellec and van Pottelsberg, 2004, Haskel and Wallis, 2010) and on the extent to which it is complementary to private efforts (David et al, 2000). Some of these ambiguous results might be influenced by the scope of public R&D spending considered. So we focus on public efforts that might have directly been appropriated by productive sectors (such as sectorial funds and targeted research programs).

[12] Baldwin (2006) called the 2nd unbundling to the trend of incorporating low-wage nations in value change, which at the same time heightened the international mobility of managerial and manufacturing know-how. Baldwin and Lopez González (2015:5) exemplify: *"When Toyota makes car parts in Thailand, they do not rely on local know-how; they bring Toyota technology, Toyota management, Toyota logistics and any other bits of know-how needed since the Thai-made parts have to fit seamlessly into the company's production network".*

- **We classify all sectors**. Focusing the attention just on manufacturing industries inhibits the possibility of capturing national efforts in technology investment. This is important given that knowledge accumulation patterns in developing countries could take place in other sectors where the competitive advantages are stronger (e.g. agricultural, mining, and their supporting services).
- **We use Uruguayan information.** The application of this methodology to a small, agricultural-based country sheds light on the impact of our methodological contributions to assess exports technological content for developing countries.

Secondly, we proxy the knowledge stock included in exported goods using a sophistication measure that analyses the export baskets of countries at different development stage. A good would be more sophisticated if it is normally exported by rich countries. The rationale to do so is that in the absence of trade intervention, the type of goods exported by high-income countries (presumably high-wages countries) should provide an idea of knowledge content in those goods that allows competing in world markets paying high salaries.

This index is built using product-based classifications. As it has been done previously in the literature (Xu, 2007), we adjust the index using proxies for the quality of the exported goods. We also took into account to some extent the effect of trade intervention by including Mercosur[13] preferential agreements on firms' prices.

Finally, we propose our classification of technological contents based on the combination of both, industry and product based classifications. Following the discussion in the literature, we claim that goods of higher-technology content are those that are produced in the context of knowledge intensive activities (i.e. high R&D intensity sectors) and are also sophisticated for world standards which would therefore create further development opportunities (i.e. highly sophisticated products).

3.2. Methods and data

Domestic R&D effort

The construction of our R&D effort index (total industry R&D spending in terms of total industry output or sales[14]) is analogous to that used in the OECD methodology, except for its scope. We analyze the R&D spending not only in manufacturing but also agriculture and services. In Uruguay there are innovation surveys for these three sectors. The innovation survey includes R&D spending by private businesses and public enterprises. We also take into account the public spending in R&D. This is very relevant for Uruguay, and most developing countries, since public R&D expenditure accounts for around 2/3 of the total R&D spending of the country. We surveyed the most important public research and development institutions to estimate this component of the R&D.[15]

For computing indirect efforts in R&D, private and public spending by sector was distributed according to inter-sectoral intermediate consumption as stated in the input-

[13] Mercosur is a common market agreement that has allowed preferential access to commercial partners in some products in which the block has maintained high external tariffs.

[14] ISIC Rev.4 from two to four digit level. Innovation surveys for the period 2007-2009.

[15] A description of the methodology used to estimate public R&D effort can be found in Appendix.

output matrix. We used the 2005 input-output (I-O) matrix[16] -the last I-O matrix that makes a distinction between imported and domestic intermediate inputs.

Sophistication

The sophistication index is constructed using the PRODY indicator, which calculates a weighted sum of the per capita GDP of countries (Y_c) exporting each product at 6 digits of the Harmonized Standard (HS) classification. The weights account for the share of exports of each country in total exports (s_{ic}).

$$PRODY_i = \sum_c \left[\frac{s_{ic}}{\sum_c s_{ic}} Y_c \right]$$

This measure is corrected for a relative price index proposed by Xu (2007), QPRODY, to capture differences in quality within the same product for different countries, using the trade unit value base from Centre d' Études Prospectives et d' Informations Internationales (CEPII). A relative price index for the Uruguayan exported goods (q_{i_ury}) is computed as:

$$q_{i\_ury} = \frac{p_{i\_ury}}{\sum_c (\mu_{ic} p_{ic})}$$

Where p_{ic} accounts for prices of a certain good i exported by a country c, and μ_{ic} is the share of exports of country c in the world exports of good i.

P_{i_ury} is also adjusted by the impact of Mercosur preferential agreements on firms' prices, assuming that those goods protected by high common external tariff would be overpriced by firms for up-to the total tariff protection[17]. For each product at the 6 digits of HS we computed the ratio of Mercosur exports to global exports, and set the benchmark at 90%, above which the price was estimated as *(1+tariff).p*[18].

Finally the quality adjusted PRODY is computed as

$$QPRODY_{i\_uryt} = q_{i\_ury}{}^{\theta} \times PRODY_i ,$$

With θ being de adjustment coefficient (θ=0.2, as in Xu, 2007).

Combining industry and product based taxonomy

In order to overcome the product-industry controversy we propose a methodology that combines both taxonomies.

To that end, we sorted the scores for the R&D index and the Sophistication index. These indicators were constructed using different classifications, since the former was industry-based while the latter was product-based. The R&D index used the ISIC classification at four-digit codes disaggregation level; while the Sophistication index used the HS classification disaggregated at 6-digit codes level. We used an equivalence table available in World Integrated Trade Solution (WITS) to assign each of the ISIC 4-digit to each HS 6-digit codes.

[16]The matrix was constructed by the Central Bank of Uruguay in occasion of national accounts revision of the base year in 2005.

[17] The 2010 tariff base was used.

[18] The number of products whose prices were modified ascended to 773 at 6 digits of the HS, and represented approximately 16% of total export value of the country in the years 2010- 2012.

We divided both indexes by the median of number of codes (ISIC 4-digit and HS 6-digit).

The criterion of using the median of number of codes as a cut-off point was, of course, arbitrary. As we discussed above, the methods to decide cut-off points remained quite obscure in the literature. Using the median, although arbitrary, is at least, easy to interpret and could work for illustrative purposes.

We finally organized both indexes using a two dimensional Cartesian system whose axes were the median for each index. Four regions were defined. Quadrant I includes highly sophisticated products (i.e. those normally exported by rich countries) that were produced in knowledge intensive contexts (i.e. their production activities are within the top 50% in terms of R&D intensity in Uruguay). So, products included in this quadrant are called, in our classification, of "highly dynamic" sectors or products, depending on whether we use industry-based or product-based classifications. The opposite situation is that of quadrant III. In that case, the products and the activities involved in their production are "non-dynamic" (products or sectors). These two regions are the most relevant in terms of comparability to other existing taxonomies.

Quadrant II and IV represent the product-industry controversy. Quadrant II includes products that were considered sophisticated worldwide, but in Uruguay they were produced in the context of low R&D intensity, we call it "potentially dynamic" sectors or products. This means that Uruguayan production tasks to produce these sophisticated products did not involve much knowledge (e.g. last assembly stages). These can be goods for which improving in the frontier is still very expensive, so Uruguayan producers brought technology from abroad. For some of these goods policy intervention might be needed in order to generate the basic conditions for competitive production.

Quadrant IV instead includes products that belonged to highly intensity domestic R&D sectors but were not highly sophisticated (these goods are not produced in high-income economies); we call it "locally dynamic" sectors or products. Why would one expect products/sectors to be located in Quadrant IV? This could either be explained for methodological or economic reasons. In the first case, goods produced in each sector might be fairly heterogeneous in knowledge content (e.g. is in car's motor and car's tires) and/or diversified firms could produce different types of goods (more or less sophisticated) –even some that belong to different sectors- although they are classified in one single sector. In the second case, it could be good economic reasons why Uruguay actors decide to invest heavily in improving knowledge content of (worldwide) non-sophisticated goods (e.g. the country has comparative advantages in these goods). To what extent would it be convenient to continue intensifying the R&D investment in these goods? We need further information to say so. For example, we may need to know whether there are comparative advantages involved; whether these are static or dynamic; what actors (private, public) invest in R&D; whether new markets or niches have opened up for the country in these products; etc..

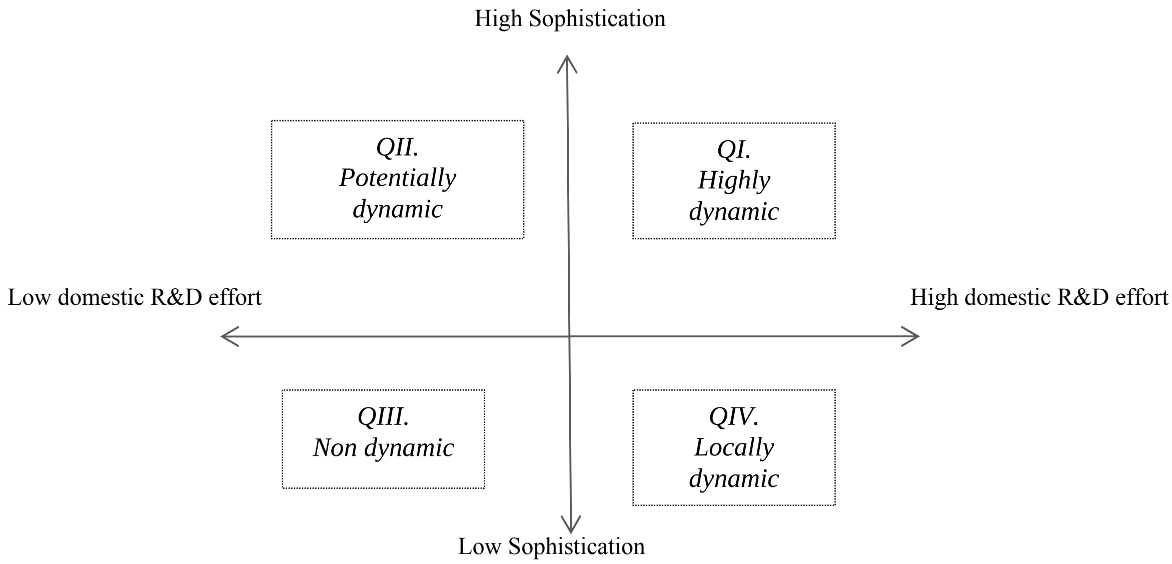


Figure 1: Classification of products according to R&D intensity and sophistication. Four regions: I: highly dynamic; II: potentially dynamic; III: locally dynamic; IV: non-dynamic

In sum, our methodology to measure technological content of exports overcomes some of the shortcomings of previous attempts:

1. It allows to classify all products (manufacturing, services, agriculture),
2. It does not use judgment to classify products and therefore it can be replicated elsewhere without losing relevance,
3. It includes knowledge (R&D) produced by public organisations in specific programmes that could be more or less directly appropriated by private actors in different sectors. This is very relevant for developing countries where most of the R&D is done in these institutions,
4. It overcomes the product-industry controversy, since it uses global trade product-based data to classify worldwide sophisticated products combined with industry-based domestic data on R&D intensity, which characterizes the local context in which those goods are actually produced.
5. The taxonomy is produced using a product-based classification which facilitates the analysis on exports
6. Four groups of products are identified, which are informative for policy perspectives: highly dynamic; non-dynamic; potentially dynamic; locally dynamic, products.

4. Results

Domestic R&D efforts

In Uruguay, the biggest share of both private and public spending on sectors' sales is concentrated in agricultural-based activities (see Table 4) as in: i) primary activities such as agriculture (ISICs 0111 0112 0113)[19] and cattle raising (ISICs 0121 0122); ii) their manufactures (ISIC 15) and iii) other associated activities in their value chain (e.g. especially within the chemical industry ISIC 2423, 2421, 2412). These goods, in turn, explain the lion share of Uruguay exports (68%).

Indirect R&D in the NR sector accounts for only 11% of total R&D in that sector. This indirect R&D is provided mostly by national inputs from the same sector and also from service and manufacturing inputs. NR-based manufactures have the biggest share of indirect R&D, mostly explained by the big share of local R&D content from NR inputs. In general, the service sector seems to be quite relevant in explaining indirect R&D in most sectors.

Table 3. Impact of indirect R&D on R&D effort index by sector aggregates

Sector aggregates	**Natural Resources (NRs)**	**NR-based manufactures**	**Other Manufactures**	**Services**
Share of indirect R&D in Total R&D				
Total share of indirect R&D in each sector	11%	72%	40%	46%
Contribution by each sector i (row) to indirect R&D intensity of sector j (column)				
Natural Resources (NRs)	58%	75%	4%	6%
NR-based manufactures	5%	4%	4%	6%
Other Manufactures	14%	4%	30%	9%
(Machinery and transport)	*3%*	*1%*	*19%*	*4%*
Services	23%	17%	62%	79%
(Business Services)	*19%*	*15%*	*56%*	*68%*

Non-manufacturing sectors are not included in OECD taxonomy. This means that if we were to classify Uruguayan trade using that taxonomy, an important share (26.7%) would go to a residual category. More importantly, as said above, those primary sectors in Uruguay are those where local actors have decided to spend on R&D more intensively in Uruguay, presumably because there are incentives to do so. A great proportion of R&D spending in agricultural sector is funded by public sources (these sources represent 61% of total R&D spending in these sectors, while they are 37% for the rest according to our estimates), and it is spent by several public institutes including

[19] We use ISIC Rev 3 to show the results

University of the Republic, National Agricultural Research Institute and National Innovation and Research Agency.

Moreover, the second group of highly intensive domestic R&D spending includes agricultural-based manufacturing sectors and they explain more than 38% of Uruguayan trade. These are classified as low-tech by OECD taxonomy; which again highlights the importance of building a taxonomy using national data.

Finally, agrochemical products (ISIC 2421) and plastic products (ISIC 2413)[20], which are part of the primary and food-products value chain, are more closely classified by both taxonomies (medium-high intensive domestic R&D index and high-tech with the OECD taxonomy). However, the participation in total exports of these products is rather low (1.6%). Similarly, the only sector classified as high-tech in both taxonomies corresponds to pharmaceutical products, which are negligible in terms of exports (1.7%).

On the contrary, other sectors classified as high-tech by OECD are not particularly dynamic in terms of local efforts (e.g. office, accounting and computing machinery (ISIC 30); radio, TV and communications equipment (ISIC 32); medical, precision and optical instruments (ISIC 33) and aircraft and spacecraft (ISIC 353)) and certainly have no importance in terms of exports.

Table 4. ISIC 3 sectors classified by local R&D intensity in Uruguay and by OECD taxonomy. Average shares for 2012-2013 are shown between brackets and in grand-totals

		OECD taxonomy					
		High-technology industries	Medium-high-technology industries	Medium-low-technology industries	Low-technology industries	Not classified	**Total**
Local R&D efforts taxonomy	High local R&D effort	2423 (1,7%)	2412, 2421 (1,6%)		1511, 1520, 1531, 1541, 1544, 1552, 191 (38,1%)	0111, 0112, 0113, 0121, 0122, (26,7%)	**68%**
	Medium - High local R&D effort	30, 32, 33 (0,3%)	29, 31 (1,3%)	27, 28 (2,2%)	0200, 1532, 1533, 1553, 173, 192, 22 (6,1%)	0500 (0,0%)	**10%**
	Medium - Low local R&D effort		2411, 2413, 2422, 2424, 2429, 2430 (2,5%)	2511, 2519, 2520 (4,6%)	1512, 1513, 171, 172, 18, 20, 36 (9,7%)		**17%**
	Low local R&D effort	353 (0,0%)	34, 352, 359 (2,4%)	2320, 26, 351 (1,0%)	1542, 1543, 1549, 16, 21 (2,0%)	92 (0,0%)	**5%**
	Total	**2%**	**8%**	**8%**	**56%**	**27%**	**100%**

Source: Own calculation

Export sophistication

[20] Mostly food containers.

Our next exercise is to classify Uruguayan exported products by their degree of sophistication (see Table 5). Differently to our findings when analyzing domestic efforts, the lion share of Uruguayan exports fall into the low end of the sophistication index (59%). This shows that Uruguay exports are mostly exported by less developed countries.

The products with a bigger share in Uruguayan exports among those classified as highly sophisticated are Printed paper and in rolls; Meat of sheep, boneless, frozen; Chemical contraceptive preparations based on hormones; Other orthopaedic appliances; Other polyesters and resins; Other colouring matter.[21] Together, these products account for 1% of Uruguayan exports.

It can be seen in Table 5 that while the extreme classes of the OECD and sophistication taxonomies coincides in terms of trade shares for Uruguay (i.e. more than fifty percent of trade value falls into low technology/sophistication and 2% falls into high technology/sophistication), the distribution within categories does not match. For instance, near half of highly sophisticated exports are classified as low technology in the OECD taxonomy and something similar can be said about the medium-high sophisticated exports.

Table 5: Cross classification of Uruguayan exports by Sophistication index adjusted by prices and tariffs and by OECD taxonomy. Average shares of 2012-2013 of Uruguayan trade

		OECD taxonomy					
		High-technology industries	Medium-high-technology industries	Medium-low-technology industries	Low-technology industries	NO CLASSIF	Total
Sophistication	**High Sophistication**	0,3%	0,4%	0,1%	0,9%	0,0%	**2%**
	Medium - High Sophistication	1,2%	3,8%	1,1%	13,1%	0,6%	**20%**
	Medium - Low Sophistication	0,4%	2,4%	2,6%	8,7%	4,7%	**19%**
	Low Sophistication	0,0%	1,0%	3,9%	33,1%	21,3%	**59%**
	Total	**2%**	**8%**	**8%**	**56%**	**27%**	**100%**

Note: sophistication index corresponds to our adjusted method (by prices and tariffs)

Source: own calculation.

[21] HS codes: 481019, 020443, 300660, 481013, 902190, 390799, 320649

Our proposed taxonomy

Our final exercise is to combine the industry-base taxonomy (domestic R&D index) with the product base (sophistication index). Results are illustrated in Graph 1.

The value of the exports in Quadrant I "highly dynamic products" represents 15% of total exports in the case of Uruguay. These goods are theoretically the most dynamic because they are traded by developed countries and are produced in knowledge intensive contexts. Ten products explain 12% of exports in this quadrant[22], most of them are food and fiber products which are classified as low-tech products by the OECD taxonomy.

On the opposite side, we have the least interesting quadrant from a policy perspective (Quadrant III). These are the "non-dynamic products", which score poorly in both dimensions. Altogether, products in this quadrant represent 15% of Uruguayan exports, and among them, the ten most important products in terms of the value of exports, account for 9% of the country total. They include an heterogeneous set of goods: bottles and similar articles, wool carded or combed, compounded rubber, nonconiferous wood, fish frozen, margarine, petroleum oils, plywood or similar, motor vehicles for the transport of goods, organic surface-active agents: anionic[23]. Except for the last two of them, OECD classification would also classify them, using industry-product correspondence tables such as those mentioned in Table A.2, as low or medium-low tech products. So in this case there is no disagreement among taxonomies: these products are non-dynamic in Uruguay and in OECD countries.

In contrast, Quadrant II contains goods that are interesting from a policy perspective. These "potentially dynamic products" are positively related to economic development (high sophistication) but which run relatively short in terms of domestic efforts in knowledge creation. They explain a tiny share of Uruguayan export basket (7%). The products with higher weight are: parts of seats, motor vehicles, fish fillets, shorn wool, paper and paperboard (not paper pulp), wood sawn or chipped.[24] In some of these cases technology is mostly imported by multinational companies producing them (i.e. motor vehicles and paper) and Uruguayan tasks are confined to routine-based activities or those located in the last assembly. Yet, these are products in which the country already has some competitive presence in the external market (i.e. paper, motor vehicles, parts of seats -leather seats-). It might be space for improvement in terms of knowledge spillovers and other growth-enhancement mechanisms, including accelerating trade, if more local R&D efforts were devoted to the production of these goods.

Finally, 63% of Uruguayan exports are classified as "locally dynamic"; they score high in technological content based on domestic R&D efforts and low technological content based on the sophistication index (Quadrant IV). In fact, five products from this quadrant (soybeans and its products, meat, milk derivatives and rice)[25] account for 40% of Uruguayan export value. The misalignment in taxonomy based on R&D efforts and

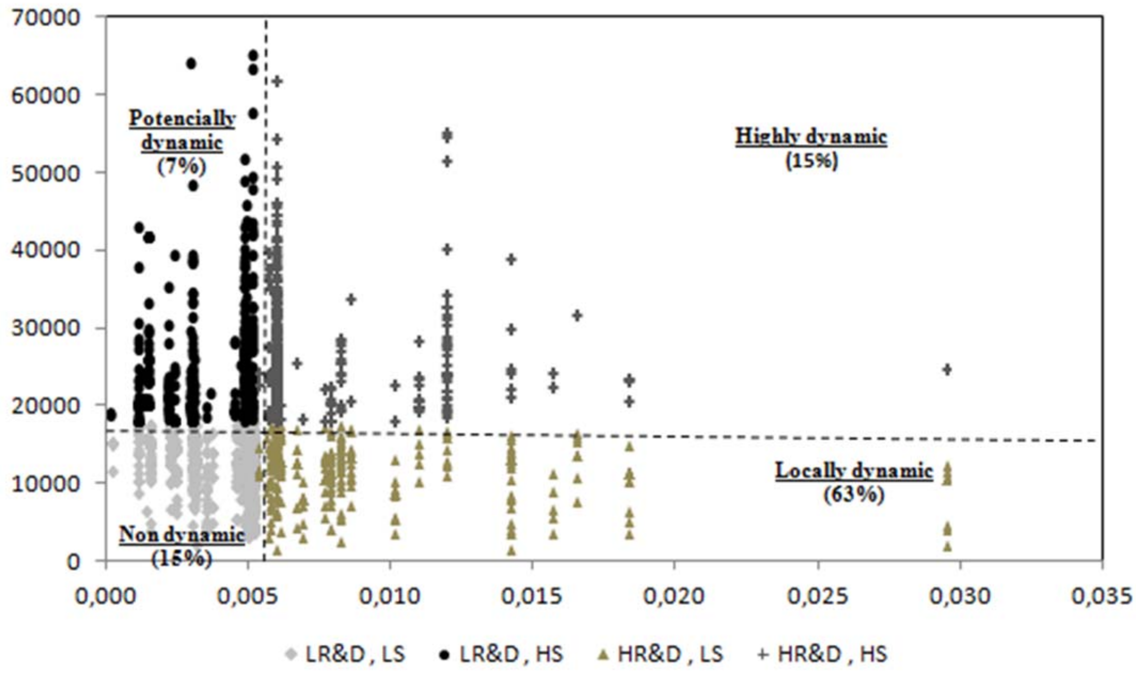
[22] HS codes: 040221: Milk and cream not containing added sugar or other sweetening matter, 040690:Cheese, Milk and cream containing added sugar (in powder), 040210: Butter and other fat, 040510: Fungicides,, 380820:Other tubes pipes of steel, 730640: welded, of circular cross-section, of stainless steel,, 300490: Other medicaments, 150200: Fats of bovine animals, sheep or goats, 510111: Shorn wool,, 20442: Meat of sheep or goats, fresh, chilled or frozen (other cuts with bone)

[23] HS codes: 392330, 510529, 400510, 440122, 030379, 151790, 271011, 441219, 870421, 340211

[24] HS codes: 940190, 870323, 030420, 870120, 510121, 481019, 440710.

[25] HS codes: 120100, 20230, 100630, 20130, 100190, 440399

in sophistication does not seem to be explained by the methodological reasons mentioned above (i.e. industrial activities including heterogeneous goods -some more sophisticated than others- or multi-product firms, which are classified high-tech for their main activity while they export other unrelated low-tech goods). In fact, this finding provides evidence of the extent to which the experience of more developed countries is decoupled from local knowledge accumulation. Uruguay is specialized in low sophisticated exports, but much of the national innovative effort has been purposively dedicated to producing (and exporting) those goods.



Graph 1. HS 6 digit exports classified in the R&D dimension (horizontal axis) and Sophistication (vertical axis). In parenthesis the share of Uruguayan exports mean value in 2012-2013

Our proposed taxonomy vs. other taxonomies

Our final exercise is to contrast our proposed taxonomy to the ones most commonly used in the literature.

Graphs 2, 3 and 4 show how ECLAC and OECD would classify exports in our four quadrants.

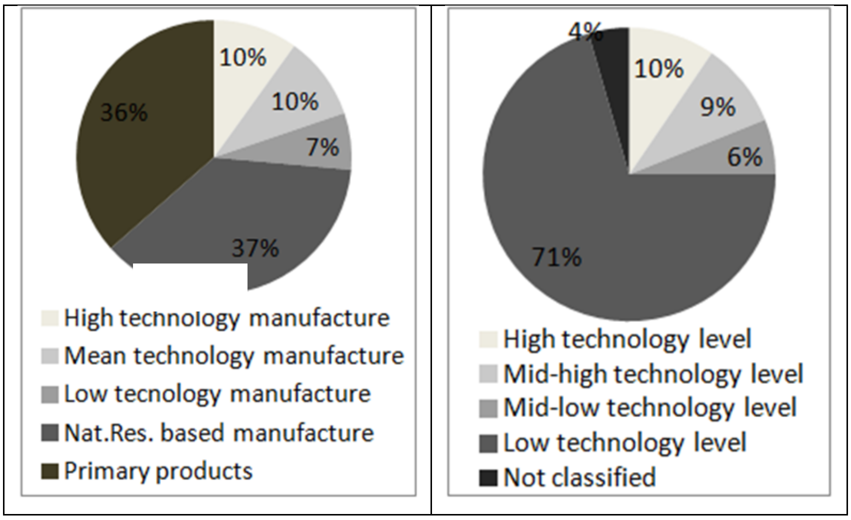
Graph 2 shows how our Quadrant I “highly dynamic products” are classified according to the alternative classifications available. ECLAC classify 37% of them as primary products and other 37% as resources-based products. These categories are uninformative about the technological content of these goods, but if something they suggest that they are low-tech or even non-tech products. Another 7% is classified as low-tech.

In turn, the OECD classification informs that 71% of our “highly dynamic products” are classified as low-tech; which shows the bias against NR-based products that have low R&D in relative terms to other industries in developed countries. Some of these goods (4%) are not even classified in the OECD classification, since OECD classification accounts only for the manufacturing sector.

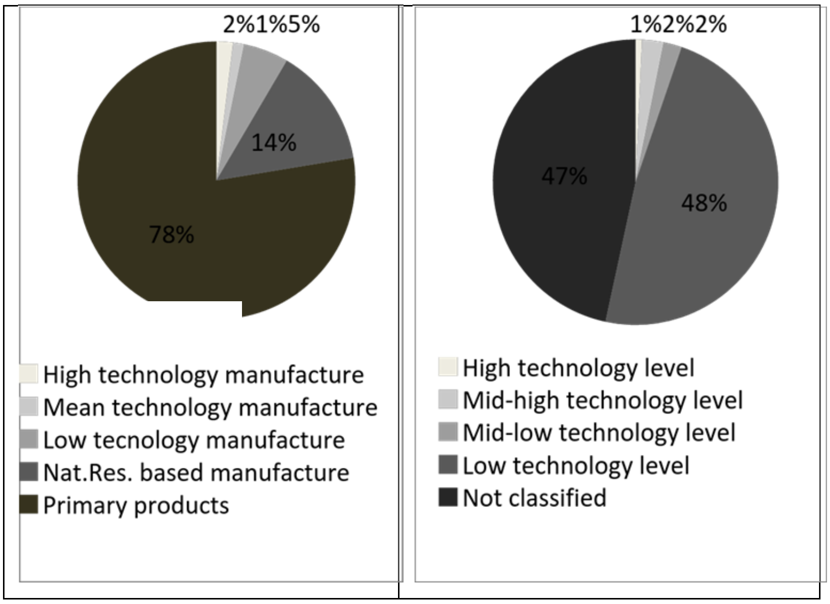
All in all, three quarters of exports considered *highly dynamic* in our framework are either not classified or classified as low-tech in ECLAC and OECD taxonomies. This share would increase further if we included services in the analysis.

The size of informative categories if one were to measure technology content of Uruguayan exports using OECD or the ECLAC classifications gets even worse for our "locally dynamic" products (Quadrant IV). As can be seen in Graph 3 almost half of these exports are not classified while the other half is classified as low-tech products in the OECD classification, while in ECLAC 74% are classified as "primary products" and an additional 14% are considered low-tech. Yet, Uruguayan actors have intensively invested in knowledge creation activities for these products. This may suggest that its production may be somehow beneficial for Uruguay otherwise few incentives would have existed to invest in R&D for those sectors.

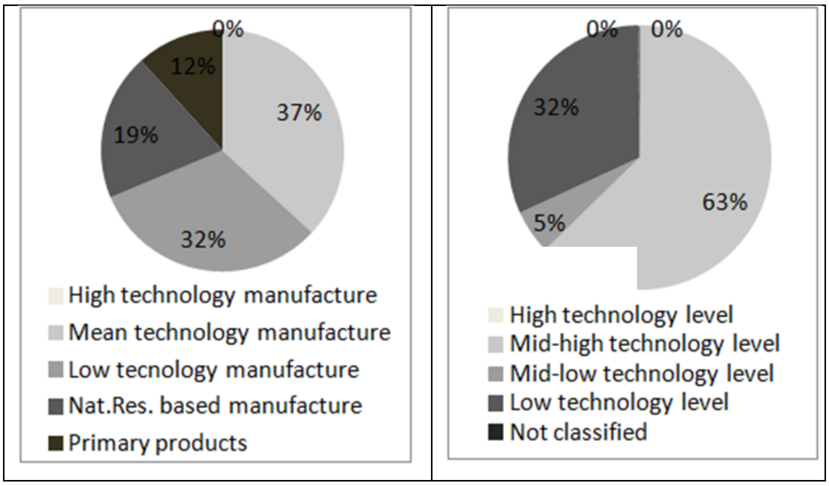
Finally, in Graph 4 we present how the "potentially dynamic exports" (Quadrant II) are classified by OECD and ECLAC classifications. As would have been expected since these are products generally exported by rich countries (i.e. they are more sophisticated), 63% of them are classified as mid-high-tech products. ECLAC classification instead distributes this group mainly into two categories high-tech (37%) and med-tech (32%).



Graph 2. ECLAC and OECD classification of Uruguayan exported value of our "highly dynamic products" (Quadrant 1 of Figure 1: High R&D and High Sophistication)



Graph 3. ECLAC and OECD classification of Uruguayan exported value of our "locally dynamic" products (Quadrant IV of Figure 1: High R&D and Low Sophistication)



Graph 4. ECLAC and OECD classification of Uruguayan exported value of our "potentially dynamic products" (Quadrant II of Figure 1: Low R&D and High Sophistication)

5. Conclusions

The more sophisticated, diverse and vast is the knowledge included in the production process or embodied in the goods that account for the lion share of the economic structure, the higher the potential for innovation and development. This premise has led international organizations and statistic offices to develop taxonomies that classify the knowledge content of goods produced or exported by different countries. Unfortunately the classifications that are generally used worldwide suffer from a series of shortcomings that make them very unreliable, particularly for developing countries.

Three prominent classifications are currently used in the literature:

1. OECD taxonomy (Hatzichronoglou, 1997), which classifies manufacturing *industries* in four ordinal groups according to the OECD countries' R&D intensity, including direct and indirect spending. This taxonomy also presents a list of high-tech *products* which are those produced by high-tech sectors, excluding some discarded by export judgment;
2. ECLAC taxonomy (Lall, 1998, 2000) which classifies manufacturing *products* in three ordinal groups plus a fourth category called resource-based. Methodological decisions to classify products into the four categories are not very transparent.
3. Sophistication taxonomy (Hausmann and Klinger, 2007; Lall, Weiss, and Zhang, 2006), which builds an indicator of technological sophistication calculated as the trade-weighted income of countries exporting each particular good.

These methodologies are subject to a series of criticism that are highly relevant when using them to measure technology content of developing countries' export or production activities:

Firstly, only private R&D efforts are taken into account, while in developing countries public efforts tend to be at least as important as private efforts -in many industrial sectors publicly performed R&D is definitely more important than private R&D.

Secondly, only manufacturing industries are included in the first and second of the taxonomies mentioned above, which makes them less useful to analyze developing countries' trade -largely based on products from primary products.

Thirdly, the OECD taxonomy was built using information from the industrial structure of developed countries, which makes it unsuitable to analyze the technological content of developing countries. The ECLAC classification tried overcoming this weakness by including information from developing countries in its construction, but the categories included in the taxonomy are not very informative for policy purposes -all NR-based products were grouped together in single taxonomy.

Finally, all the above-mentioned taxonomies are subject to the product-industry controversy. This means that, on the one hand, all products from an industry are classified in the same technology group, regardless of their actual technological content at product level (e.g. cars' tires are in the same technological group as car's motors). On the other hand, product-based categories account at best for the knowledge content embodied in goods, regardless of the specific knowledge activities taking place in different countries -i.e. not all countries participate in the knowledge intensive phases of producing sophisticated goods.

This paper proposed a new methodology to classify products using information both at industry and at product level. The methodology used information on direct and indirect R&D spending from public and private sources in service, agricultural and manufacturing sectors. We combined this information with the sophistication index, corrected for product quality and for tariffs, built using trade (product-level) data. We divided R&D intensity and the sophistication index by the median values, to build a four-category taxonomy: "highly dynamic products" (high R&D intensity activities and highly sophisticated products); "potentially dynamic products" (low R&D intensity activities and highly sophisticated products); "locally dynamic products" (high R&D intensity activities and lowly sophisticated products); and "non-dynamic products" (low R&D intensity activities and lowly sophisticated products).

We believe our methodology circumvents some of the limitations of currently used technology content taxonomies. In particular, our methodology allows to classify products from all sectors; it does not use *ad-hoc* judgment to classify products and therefore it can be replicated elsewhere without losing relevance; it includes knowledge (R&D) produced by public institutions; it overcomes the product-industry controversy, since it uses global trade product-based data to classified worldwide sophisticated products combined with industry-based domestic data on R&D intensity, which characterize the local context in which those goods are actually produced; it produces a product-based classification which facilitates the analysis on exports.

We illustrated our taxonomy using Uruguayan trade data: we found that 15% of Uruguayan trade in 2012 and 2013 are highly dynamic; 7% are potentially dynamic; 15% are non-dynamic; and 63% are locally dynamic products.

All in all this means that Uruguay is specialized in low sophisticated exports, but much of the national innovative effort has been placed in producing (and exporting) those goods. Forty percentage points from the above mentioned 63% are explained by just five products (soybeans and its products, meat, milk derivatives and rice).[26] Uruguay has (static) comparative advantages in those sectors, and consequently has invested in knowledge creation activities to support them. Actually, as we mentioned already, much of R&D efforts in these sectors are originated from public sources. It could be claimed that some degree of endogeneity may be present here: static comparative advantage may explain why the lion share of Uruguayan exports is placed in this quadrant: those advantages triggered both, exports and (especially public) domestic R&D.

We cannot follow the trail of crumbs here; however we believe that the important question is whether this high specialisation in “locally dynamic sectors” has created dynamic advantages. Are there higher technological opportunities in Uruguay than in other countries to produce this type of goods? Are we challenging Chang’s[27] idea that static comparative advantages should be challenged? There are several authors that have studied the development opportunities opened up by the production of NRs, both in terms of the possibilities of creating value added downstream (i.e. industrialisation of primary goods) (e.g. Velho and Velho 2008) or by pulling technological upgrade upstream (e.g. new machinery needed for zero-tillage agriculture) (e.g Lengyel and Bottino 2011) but also in terms of the demand for new knowledge to make NRs production more efficient or environmentally friendly (Marin et al., 2015; Pérez, 2010; Arza et al 2014).

We do not really know whether dynamic advantages have been created in Uruguay. What we do know is that these activities have pulled high level of R&D investment. We also know that Uruguay has been increasingly and successfully expanding exports and markets for these goods. However, it would be interesting to explore whether these successful exporting experience coupled with high investment in R&D have also created dynamic comparative advantages.

Finally, we analyze how these findings would have changed had we used the available taxonomies. Unsurprisingly we found that most of Uruguayan exports would have been included in a residual category or classified as low-tech products, lowly sophisticated products or primary goods products, which do not seem to be very informative for policy purposes. The weight of the residual category (27% would be not classified when using OECD taxonomy) is particularly illuminating of how irrelevant those classifications are to account for the technology content of Uruguayan exports.

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[26]HS codes: 120100, 20230, 100630, 20130, 100190, 440399

[27] Lin and Chang (2009)

In sum, we believe our methodology has done a good job in overcoming some of the shortcomings of existing taxonomies. Yet there are many possible avenues for improvement. Efforts can be made to go beyond R&D and include all the innovation activities. Moreover, rather than investment in innovation one could attempt to rank goods according to the opportunities that exist to transform that investment into innovation outcomes (i.e. the elasticity of innovation to innovation investment). In addition, trade data for services could be included in the analysis. We found that local R&D efforts in services have an important role on the indirect R&D of all other sectors, although not that much in the case of NR and NR-based sectors.

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Appendix. Data sources

In this appendix we synthesize the main sources of information used in the analysis and the correspondence table needed to compare different data sets.

<u>Local R&D effort index</u>:
To calculate private R&D spending we used the Innovation Surveys on Manufacturing, Agriculture and Services available for Uruguay for the period 2007-2009. This survey was coordinated by the National Agency for Research and Innovation (ANII) and executed by the National Statistics Agency (INE). Sectors covered by this survey are (ISIC 4th Revision): Agro based activities (10 sectors at four-digit level), Manufacturing Industries (31 sectors at three-digit levels and 7 sectors at two-digit), Service activities (9 sectors at four-digits, one sector at three-digits and 25 sectors at two digits level). In terms of ISIC Divisions these sectors correspond to: 01, 02, 10-33 , 35, 36 , 38, 49-53 , 55-56 , 58-63 , 69-75 , 77-82 and 86.
To calculate public R&D we carried on a field research based on interviews and survey to the most representative agencies. In the past decade Uruguay launched a reform of its innovation system (2005) covering three fundamental aspects: the creation of ANII, the development of the National Science, Technology and Innovation Strategic Plan (PENCTI) in 2010, and the implementation of a set of policy instruments to promote innovation and knowledge generation country-wide. This process came along with the creation of new institutions such as the Pasteur Institute and the Science and Technology Park, as well as strengthening existing institutions including the National Agricultural Research Institute (INIA) and the Technological Laboratory of Uruguay (LATU).As a result of this process an increase in public spending on science and technology activities took place, rising from 0.2% of GDP in 2005 to 0.45% at the end of 2011. We considered previous estimates of the share of different institutions on public R&D total spending to select the most representative institutions (Table A.1). Based on this information, we surveyed public R&D spending by the public University, INIA, LATU, Clemente Estable Biology Research Institute (IIBCE) and ANII, as well as other activities financed by public institutions in partnership with the public University. Each institution informed the spending in innovations that could directly or potentially impact the productive sector, using ISIC classification codes. In cases where the organization had not classified de data by ISIC codes, we asked to name the project and when possible we assigned them to ISIC codes. Data covered the period 2008-2010 as we found many missing values in the year 2007.

Table A.1 Share of main institution on total public spending in R&D (2011)

Institution	Share
Public University	26.3%
INIA	18.8%
LATU	5.3%
IIBCE	2.3%
PEDECIBA	0.8%
ANII	13.7%
Institut Pasteur	2.8%
Other public institutions	30.0%
Total	100.0%

Source: Rubianes (2013)

To obtain the "local R&D effort" we estimated not only the direct effort but also the indirect effort through production inputs. To calculate the indirect effort we used the last official input-output matrix (built in 2005) reported by national accounts classification (based on ISIC Rev. 3). We calculated the input-output technical coefficients and multiply this matrix by both vectors of private and public R&D effort. The results were added to the direct effort. We use the correspondence tables mentioned in Table A.2. to convert private R&D spending originally calculated in ISIC Rev.4 to the ISIC Rev.3 used in Uruguayan national accounts and in the input-output matrix.

Sophistication index:

We used three sets of data, all of them classified at six digits disaggregation level of the HS covering 115 countries.

Trade data for the period 2010 to 2012 was extracted from WITS (2581 products effectively exported by the country in the period).

We used the Trade Unit Values database from CEPII, at six-digits disaggregation level of the HS (1385 products). We used the last available data for Uruguay corresponding to year 2009.The missing values in this database (1196 products exported according to WITS and not available in CEPII account for only 1,2% of the exported value in the period) so we don´t lose much information.

The GDP data for the period 2010 to 2012 was extracted from the World Economic Outlook.

Finally, to adjust product unit values by the Common External Tariff (CET) we used a tariff basis provided by the Trade Advice Unit at the Economic and Finance Ministry. This database corresponds to the year 2010 and is based on Mercosur Common Nomenclature 2007.Since the tariff base is defined to 10 digits, while trade data (values and unit prices) in international databases are presented to 6 digits, the CET is calculated as an average within tariff sub-heading. In addition, as TUV is only available in HS 2002 we used correspondence tables to assign the tariff rates to each product. In those cases where there was a division of products between the two reviews (i.e. HS2002 code split into several HS2007 codes) an additional average was made between codes 2007 corresponding to one code in 2002´s nomenclature.

Correspondence used for Graphs 2 to 4:

For exports classification in these graphs we used the European Union classification of exports, which is based on the OECD taxonomy. The index is the Eurostat aggregation of the manufacturing industry according to technological intensity, which is based on NACE Rev. 2 at 2 or 3-digit level. The NACE classification is derived from the ISIC,

being defined either to be identical to, or to form subsets of individual categories of ISIC. The first level and the second level of ISIC Rev. 4 (sections and divisions) are identical to sections and divisions of NACE Rev. 2. As we intended to classify exported products at 6 digit HS aggregation, we correlated each good code into ISIC Rev. 3 code, this with NACE Rev. 2 code, and this last one with a technological content grouping.
In the case of ECLAC's classification by technological content, their classification is based in that of Lall (2000), according to the SITC Rev.2 export nomenclature. We used WITS' correspondence tables between 6-digit HS 2002 and SITC to classify the Uruguayan exported products and then assigned the technological content according to ECLAC.

In next table we show all information sources and correspondence used.

Table A.2 Data sources and correspondence tables used

	Source	Sources for correspondence
Trade data	World Integrated Trade Solution (WITS)	
Trade Unit Value	CEPII	
GDP data	International Monetary Fund. World Economic Outlook database	
Tariff data	Economy and Finance Ministry	Comtrade correspondence table: HS 2007 to HS 2002
R&D	Innovation Surveys 2007-2009 (ANII) Input-output matrix 2005 (Central Bank of Uruguay) Own collection of Public R&D data spending	-Comtrade correspondence table: ISIC Rev.3 - ISIC. Rev. 4 -Ad-hoc correspondence between ISIC Rev. 3 and Input-Output table -To assign R&D index from sectors to trade products WITS correspondence tables: HS2002-ISIC Rev. 3
OECD Classification	Eurostat indicators of High-tech industry and Knowledge - intensive services. Annex 3 – High-tech aggregation by NACE Rev. 2.	WITS correspondence tables: HS2002 - ISIC Rev.3. Comtrade correspondence table: ISIC Rev.3 - ISIC. Rev. 4
ECLAC Classification	Technological Intensity of trade in Central America and Dominican Republic. Aggregation by SITC Rev.2	WITS correspondence tables: HS2002 - SITC Rev.2