International technological dynamics in production sectors: An empirical analysis

Fernando Isabella Revetria

ABSTRACT

A new methodology is proposed for evaluating the economic development opportunities associated with the different industries making up a country's economic structure. To this end, neo-Schumpeterian concepts are used to reinterpret the tools afforded by the "product space" literature in an attempt to assess the technological pervasiveness and sophistication of different production sectors. The ultimate objective is to develop a description of today's techno-productive paradigm and the differential role that the various sectors play in it. An analysis of export data from 113 countries and territories for 2005-2009 indicates that the key sectors in the world economy are: industrial machinery, scientific and medical instruments, and pharmaceuticals. The strong performance of sectors based on mature technologies suggests that key sectors originating in different stages in history can survive and overlap one another, much like geological strata, owing to the persistence of older technological systems.

KEY WORDS

Economic development, industrial production, production diversification, product quality, technological innovations, exports, Latin America

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I
Introduction

In the past few years, certain changes in a number of South American economies, such as the boom in agricultural and mining sectors and the exponential growth of their exports, have rekindled an academic and political debate about the medium- and long-term prospects for economic growth. Specifically, the discussion has focused on whether the commodity-based sectors that are leading growth will put the economies on a sustainable growth path or whether the current boom will prove to be nothing more than a fleeting windfall.

Various schools of thought characterize the agricultural and mining sectors and their industrial chains as having a very limited potential for driving economic growth over the long term. These sectors are often contrasted with manufacturing sectors that are not so closely linked to commodity production and offer greater opportunities for the application of scientific knowledge. Adherents of this view therefore feel that sectoral trends in these South American countries are a cause for concern from a long-term perspective and that proactive policies are needed to deal with the situation and to fuel the development of new, more technology-intensive production sectors (Lall, 2000; Cimoli, 2005; ECLAC, 2007).

At the regional level, economists at the Economic Commission for Latin America and the Caribbean (ECLAC) have recently been making an effort to integrate the Commission's structuralist tradition with an evolutionary microeconomic approach in order to develop what has been called an "evolutionary structuralist synthesis". This approach articulates various lines of economic thought that share a number of basic concepts, such as the intrinsic differences between different production sectors' contributions to development, the importance of knowledge and technology specificities, the frequent absence of automatic adjustment processes, the influence that disequilibria have on the development process, and the role of institutions and State action in surmounting obstacles to structural change (Peres and Primi, 2009; ECLAC, 2012).

The evolutionary neo-Schumpeterian school of thought also espouses the view that the different types of productive specialization are not neutral in terms of their implications for development and stresses the different sectors' opportunities for learning and for the application of technical progress (Pavitt, 1984; Lall, 2000; Antonelli, 2007). Special emphasis is placed on the pervasiveness of certain new technologies (radical innovations), referring to the broad array of opportunities that exist for their application not only in the sector where they were developed, but throughout the economy.

These economic schools of thought are in agreement about the important role of sectoral specialization in enhancing an economy's development potential. However, an empirical analysis is needed in order to gather evidence for use in evaluating the different production sectors. Numerous studies have drawn upon pre-established industrial taxonomies, which derive from empirical studies on specific points in time and countries, and seek to evaluate different industries' capacity to absorb innovations and generate positive spillovers or externalities (see Pavitt (1984); Hatzichronoglu (1997); Lall (2000); Katz and Stumpo (2001). The usefulness of these taxonomies has been demonstrated, and these studies' findings have generally stood up when cross-checked against current data. Nonetheless, in a constantly changing world in which production processes are continually being reorganized and rearranged, the specific conditions under which certain products were produced at one point in time and location do not necessarily inform the potential for their production under a different set of circumstances.

Therefore, the question which this paper seeks to address is how to arrive at a dynamic evaluation of different production sectors' potential to steer an economy towards a sustainable growth path.

Starting from a reinterpretation of the tools developed in the literature on "product space" and drawing on neo-Schumpeterian and structuralist concepts, an empirical methodology is developed for using international trade data to assess two attributes of production sectors: technological sophistication and pervasiveness. The application of this methodology leads to the conclusion that the key sectors in the world economy are industrial machinery, scientific and medical instruments, and pharmaceuticals, while the more commodity-based production sectors are

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ranked the lowest. This corroborates the concerns about the areas of production specialization that have recently been observed in Latin America.

This study is divided into six sections. Section II introduces the conceptual framework on which the project is based. The methodology and proposed empirical strategy are discussed in section III. The fourth section reviews the data used in this analysis and the sectoral classification of the relevant products. Finally, the study's findings and conclusions are presented in section V and VI respectively.

II
Conceptual framework

1. The "product space"

In recent years, a group of Harvard researchers has developed a tool referred to as "product space", which is linked to the concept of the proximity between different goods. Product space is calculated as the conditional probability that a given country which exports product A is able to produce and export a given product B.

Hausmann and Klinger (2006a) posit that the proximity between goods *i* and *j* at a point in time *t* can be described as:

$$\phi_{i,j,t} = min\left\{P\left(x_{i,t} \mid x_{j,t}\right), P\left(x_{j,t} \mid x_{i,t}\right)\right\} \qquad (1)$$

where $P\left(x_{i,t} \mid x_{j,t}\right)$ is the conditional probability that if a country exports product *j* on the basis of a revealed comparative advantage[1] (RCA) greater than 1, it will also have an RCA for exports of product *i*.

Global trade data can be used to calculate the proximities between all the different pairs of goods, which reflect the conditions in the various countries. This is what these authors refer to as the "proximity matrix," which is basically a representation of the product space. They identify goods that are closely connected to many others because they show a high sum of proximities to the rest of the products (referred to as the "total proximity" to the product space), while other goods are more isolated. The first group can be found in the hard core of the product space, while the second group is located on the periphery of the graphic representation of the product space.

As can be seen, this is a completely empirical indicator that measures the links between goods in international markets and is independent of whatever theories may be used to interpret those links.

In terms of what determines the proximity between two products, the Harvard researchers contend that the capabilities required for the competitive production of particular goods is of central importance. The production of each product requires a specific set of skills which would be an imperfect substitute for the capabilities required for the production of any other good. If any two products tend to co-occur in countries' export baskets, this indicates that the set of capabilities required for each is a good substitute for the other. In other words, a country which develops the skills necessary for the production of one of these goods can easily develop the capability to produce the other. The concept of capabilities used by these authors is very broad and includes everything from infrastructure and institutions to physical assets and technological knowledge. However, the authors adopt an explicitly "agnostic" stance in the sense that they avoid taking a position on which of these factors may be the most important in determining a country's overall production capabilities (Hidalgo and others, 2007). This leaves ample room for a less "agnostic" interpretation which would provide a clearer theoretical basis and a more detailed interpretation of the results obtained through the use of these tools. This idea is explored further in the next section.

The foregoing considerations support the hypothesis that the probability that a country will incorporate a good that it does not yet produce into its production structure[2] will be determined by that item's proximity to the goods that already form part of that structure.

[1] Using the definition of revealed comparative advantages proposed by Balassa (1964).

[2] Given that this tool approaches the concept of production structure as based on a country's export basket and, in particular, only takes into consideration goods for which a country has an RCA>1, from this point on we will consider these concepts to be interchangeable and accept the inherent limitations.

The reason for this is that the capabilities that the economy has developed in order to produce its existing products will bear a greater or lesser similarity to the capabilities required to produce the new item. This is exactly what Hausmann and Klinger (2006a) demonstrate empirically.

Consequently, a country's existing production pattern can tell us a great deal about its possibilities for diversification.

Hausmann, Hwang and Rodrik (2005) find that some products are exported primarily by rich countries while others are exported mainly by poor countries and conclude that "you become what you export"; in other words, poor countries that specialize in products that are generally exported by rich countries gradually tend to move closer and closer to rich countries' income levels. One of the most interesting indicators that these authors have developed to measure these dimensions is the PRODY, which associates each product with the per capita incomes of the countries that specialize in exporting that good. Formally:

$$PRODY_i = \sum_c \frac{\left(x_{ci}/X_c\right)}{\sum_c \left(x_{ci}/X_c\right)} Y_c \qquad (2)$$

where x_{ci} represents the value of exports of product i by country c, X_c represents country c's total exports, and Y_c stands for country c's per capita GDP.

The PRODY is used as an indicator of a good's sophistication. It reflects the level of productivity that is associated with that good because it links the product to the per capita income of the countries that produce it. The authors statistically test the links between the level of income and the PRODY and, importantly, gauge the high level of statistical significance of the deviations between that relationship and future growth. In other words, countries that have a higher PRODY than would appear to correspond to their level of income at a given point in time tend to experience more rapid growth in subsequent periods, and they consequently move closer and closer to the corresponding income level. This is what gives rise to the idea that "you become what you export."

This approach opens up many empirical possibilities and paves the way for the development of analytical tools that do not rely on pre-established taxonomies for the classification of goods and the corresponding production sectors.

2. Interpretation

As discussed earlier, the authors adopt an "agnostic" position when it comes to the theoretical interpretation of this tool and to weighing in on the most influential factors that influence the proximity between goods and the relationship between those proximities and economic rents. This paper reinterprets these product-space tools as a basis for the development of new and effective analytical tools. This brings the concept of the technological capabilities necessary for the efficient production of a good back into the foreground. In line with the evolutionary view, technological capabilities are understood to be specific, cumulative and partially tacit. The first of these characteristics implies that a certain degree of effort is needed to adapt capabilities to meet a firm's specific requirements. These capabilities involve much more than straightforward scientific knowledge, and it is therefore not enough simply to have the appropriate manuals and handbooks. Furthermore, these skills entails sector-specific components, and technological developments designed to meet the needs of a given production sector will therefore not automatically be applicable in another. The second characteristic of technological capabilities —that they are cumulative— signals the importance of each firm's development path, which has marked implications in terms of the capabilities that the firm will acquire over time. The significance of these types of growth paths can also be a factor for wider economic systems, such as those of regions or countries. In other words, the cost (and chances of success) of adapting a technology to fit in with the specific needs of a given sector or country will depend on what types of capabilities it has built up over time. Finally, the tacit nature of technological capabilities is closely tied in with the other two attributes mentioned above. Unlike what is commonly understood as "information", a good part of applied production expertise is not codifiable; acquiring that kind of expertise is the result of practice and experience, rather than being a skill which can be learned from manuals or bought like some other asset on the markets.

This constitutes a departure from neoclassical models that depict technology as consisting of information as a free good that other firms can easily reproduce. The idea of the appropriability of innovations is also reinforced, since the benefits derived from innovation efforts can be reaped, for a time, only by the innovator because imitation is neither easy nor cost-free. Thus, the diffusion of new production technologies is not an automatic process; it requires time and learning and incurs costs. Finally, if technological capabilities are specific, cumulative and partially tacit, then the generation and accumulation of capabilities is heavily path-dependent.

Production sectors that allow for (and require) the development of certain sophisticated technological capabilities that come into widespread use (that is, sophisticated and pervasive sectors) have spillovers on the rest of the economy by driving an increase in a society's technological capabilities. These skills then provide society with more effective tools that it can bring to bear in the development of new related industries (Nelson and Winter, 1982; Pavitt, 1984; Lall, 2000; Antonelli, 2007).

The historical context determines which sectors will become pervasive. The neo-Schumpeterian view maintains that, at given points in time, a series of radical innovations will tend to cluster and strongly influence economic characteristics and trends. New methods of production and new products will have an impact on the whole of the economy and society. These innovations are extremely profitable at the outset but, because of the complexity of the technological capabilities embedded in them, only a few firms can make use of them. Little by little, their profitability drives imitation, as well as the development of new (incremental) innovations which do not alter production trends but do perfect these innovations and build on the opportunities opened up by the pioneerinnovations. Related technologies then prove to be applicable in sectors far removed from those for which they were developed. As a result, they become increasingly widespread and, as they do so, begin to modify production, consumption, distribution and other patterns. This paves the way for considerable productivity gains in a wide variety of sectors and drives economic growth.

At the same time, however, other sectors (and other technologies) are relegated to a secondary position, and these periods are therefore associated with an intensive restructuring process. The new technologies and goods require new infrastructure, worker skills and management techniques. They also usher in new consumption patterns and regulatory schemes, and all of this feeds into the formation of a new techno-productive paradigm. This branch of neo-Schumpeterian thought holds that in recent decades we have been witnessing the creation of a new paradigm in which information and communication technologies (ICTs) play a central role (Freeman and Pérez, 1988; Freeman and Louça, 2001).

Pervasive sectors will therefore be linked with goods that have a high "total proximity" to the product space, which signals the ubiquity of the associated technologies. However, goods which require very specific production capabilities do not entail an intensive use of the technologies which are pervasive in the current paradigm. They therefore do not serve as a "testing ground" for the accrual of capabilities that can then be applied in the development of new sectors and products. As a result, their role in driving growth will be much less influential, and the economies of countries that specialize in these products will tend to be much less diversified.

Many of these goods are closely linked to the basic commodities produced by an economy (Hausmann and Klinger, 2006a), which generally involve the intensive use of natural resources. While there are opportunities for applying new technologies in these industries, the associated production capabilities are focused on making a more efficient use of those resources, and the transfer of these new technologies and capabilities to sectors where those specific resources does not play a key role is more difficult.

Therefore, the diversification of production —which entails the incorporation of a wider range of sectors into a country's or region's production structure— will be more straightforward or more likely when a country has a track record of producing goods linked to the pervasive sectors of today's paradigm that are in close proximity to the product-space core, since they will then be accruing "broad spectrum" capabilities.

This interpretation should not, however, overshadow the fact that there are factors other than technological capabilities, in the strict sense of the term, that may determine the proximity between goods and their relative position in the product space. Some of these factors may fall within a broader definition of technological capabilities (regulations, infrastructure), while others fall completely outside of any possible definition of that concept (for example, the availability of natural resources).

The other fundamental concept in this approach is the technological sophistication of different production sectors, which the PRODY can be used to measure, at least in approximate terms. From a theoretical standpoint, the capability to appropriate economic rents is a very important one because the radical innovations that define a production paradigm are characterized, initially, by the ability to capture windfall profits. This is directly related to a sector's technological sophistication and the fact that a recently developed product is hard to imitate, which gives the pioneering industry or firm monopolistic power for a time. As time passes, however, and the corresponding technologies mature, imitation and the development of new incremental innovations become more possible. These technologies then become diffused and more pervasive, but lose their ability to enable a producer to capture windfall rents —in other words, they become less "sophisticated." In this paper, the PRODY (which refers to rents rather than directly to technologies) will therefore be used as a proxy for technological sophistication.

In this study, then, a high level of sophistication (high PRODY) will be interpreted as an indicator that there is a close link between the goods and the radical innovations that define the present production paradigm. These goods and the sectors that produce them are therefore also considered to hold out promising prospects for structural change.

The production sectors that exhibit the greatest combination of these characteristics will be referred to as "key sectors" because they display two fundamental aspects that are necessary for development: technological pervasiveness, which paves the way for diversification, and sophistication, which makes them profitable.

The link between sophistication and pervasiveness is not a given. At least at certain stages of innovation, a trade-off may exist between the two. This is because a high degree of pervasiveness is associated with a high degree of diffusion of the technologies in question. This would, in turn, mean that the innovators would have very little capacity to appropriate economic rents, since competition would drive down prices (towards the level of marginal costs). This subject will be explored further in a later section.

The way in which economies become specialized in key sectors involves an overarching restructuring process that lies at the centre of the concerns addressed by this study.

3. Pathways of structural transformation in the product space: a proposal

The structural transformation process is an ongoing one that should enable society to incorporate new capabilities at every step along the way that will lay the groundwork for further sophistication and diversification. A combination of these two facets is therefore of crucial importance in defining the profiles of key sectors. A good in a key sector not only needs to be sophisticated and to be in proximity to many other goods, but it also must be in close proximity to other sophisticated goods. This is of crucial importance for structural transformation processes in which the economy not only becomes more diversified as it incorporates new production sectors, but these new sectors also help drive it towards higher levels of income and growth.

Proximities therefore map out the road for structural change, while the degree of sophistication points out the way to go. The principal contribution that this study seeks to make is to provide a methodology for evaluating these two factors in conjunction with one another.

By the same token, the degree of pervasiveness of a given good will be determined by its proximity to many other products but, in particular, to other pervasive goods. Close proximity to any specific product is not as important in terms of structural change as close proximity to products that, in turn, are in close proximity to many others. Therefore, the central proposal being put forward in this study is that, in order to identify key sectors, all the different paths for structural change that are opened up by each product should be explored. This idea will be developed more fully in the following pages.

The product space can be defined on the basis of an inter-product proximity matrix that traces the proximity between the goods in each row and those in each column. This also provides a way of looking at the opposite dimension, i.e. the distance between different goods, which would be a measurement of their dissimilarity in terms of the skill set required to produce them on a competitive basis and, hence, the degree of difficulty involved in adapting the capabilities required to produce one of them in order to produce the other.

The next step is to define exactly what is meant by the "distance" that has to be covered in order to progress along a path of change while moving from one product to another and then another. Measuring the distance between product A and product B is fairly straightforward and can be accomplished simply by inverting the concept of proximity. But how can we measure the total distance to be covered if we start with product A, then incorporate product B and then go on to incorporate product C? This is an essential question to be answered if we are to explore the myriad paths of change that are opened up when a given good (product A) is introduced into a country's production structure. If we start from the point of product A, we can arrive at the production of good C by following any number of different paths. Some of those paths will lead us directly through good B, but others will lead us through any number of other goods.

Now, if proximity is to be defined in a probabilistic sense, then the concept of joint probability should be employed, as defined here:

$$\text{Given } \phi\,(A,B) \text{ and } \phi\,(B,C);\ \phi\,(A,C) \text{ via B is:}$$
$$\phi\,(A,B)\,.\,\phi\,(B,C)$$

This has to be interpreted within the theoretical framework developed here. If the proximity between A and B signals the degree of substitutability between the capabilities required to produce each of those goods on a competitive basis, then, when considering a path that involves three different goods, we need to think about how adaptable the capabilities associated with product A are in terms of fulfilling the technical and production requirements of the other two goods simultaneously. Thus, the fit between the capabilities associated with three different products will be lower than the fit when dealing with just two products, since the various specificities accumulate. As the concept of joint probability dictates, as we add more and more goods to the path (i.e. as we lengthen that path), the degree of proximity will diminish (because we are adding new multiplicands that are always less than 1), which is the same thing as saying that the distance increases.

One of the fundamental features of the product space when defined as we have done here is that it does not have some of the requisite features of a Euclidean space. In a Euclidean space, the shortest distance between any two points is a straight line. If we were to carry this over to the framework being discussed here, it would mean that in order to make the transition from one good to another good that is not yet being produced, the shortest distance between the two would equate with simply beginning to produce the second good using the capabilities that are already in place.

However, in the product space, it may be the case that the shortest distance between two goods entails passing through another one.[3] Hence, it is possible to find "shortcuts" along the path leading from a given production structure towards the incorporation of a series or group of goods that are seen as being desirable by virtue of their pervasiveness and sophistication. These "shortcuts" through other products reduce the total distance that has to be covered. Consequently, in order to evaluate products in terms of the opportunities for structural change that their presence in an economy creates, it becomes necessary to explore all the different possible paths that they open up —including the direct ones (proximity between the product being evaluated and each of the other products) and the indirect ones (paths that involve various other products).

The development of new capabilities takes time, since they are cumulative. The longer the path (i.e. the less total proximity there is between the starting and ending points), the longer it will take to develop the necessary capabilities out of the ones already existing in the production structure and the more it will cost to do so.

[3] This happens, for example, when working with the matrix of proximities available in www.chidalgo.com, where the indirect path between cereals (SITC 0412) and other organic chemicals (SITC 5162) that passes through fertilizers (SITC 5629) entails greater total proximity (a shorter distance) than the direct transition.

III
Methodology

1. Developing the methodology

The methodology to be used in evaluating the different production sectors has to be such as to provide a straightforward way of updating the framework for that evaluation. Equation (1) —in sample terms— is therefore applied to the trade statistics that will be detailed below, recalculating the product space with updated data. These data will be the basic inputs for our study of pervasiveness in current paradigm.

The sophistication of products, as well as their pervasiveness, has to be assessed, since the combination of these two dimensions is what determines what sectors are of key importance. As explained earlier, the PRODY will be used as an indicator of sophistication.

As discussed in the section on the theoretical framework, the combined presence of sophistication and pervasiveness is of greater interest than those two features in isolation. In other words, proximity per se is not as useful as proximity to sophisticated goods. It is therefore important for the empirical strategy to be used to provide a way of assessing the combination of these features.

Finally, we want to assess products' strategic position in terms of the combined presence of pervasiveness and sophistication, both when taking the "direct route" and when taking "indirect routes". In other words, we want to explore all the possible pathways that have each products as their starting point. The following indicator, which can be thought of as a succession of steps (and will be referred to as "successive steps") is proposed here:

$$\frac{\sum_{j}\phi_{b,j,t}S_j}{n}+\frac{\sum_{j}\phi_{b,j,t}\sum_{r\neq b}\phi_{j,r,t}S_r}{n(n-1)}+\frac{\sum_{j}\phi_{b,j,t}\sum_{r\neq b}\phi_{j,r,t}\sum_{k\neq j;k\neq b}\phi_{r,k,t}S_k}{n(n-1)(n-2)}+\dots \quad (3)$$

where S is the indicator used to measure product sophistication (the PRODY in this case). This indicator is applied to all goods ("b") in the product space and is used to assess a good's potential in terms of the features that we have defined as being desirable. This is done by looking at both its direct proximity to the other goods ("j") and its proximity when indirect paths are taken: its proximity to goods "r" via goods "j" (the second addend) or to goods "k" via a pathway that starts at goods "j" and from there goes on to goods "r" and then jumps to good "k" and so on. This indicator can thus be used to try to measure the values associated with the direct and indirect (via other products) paths that lead from each good to highly sophisticated goods.[4]

This indicator therefore can be used to gauge the value of each good "b" in terms of all the possible paths that can be followed from that good to other products and from those other products to yet others and so on until all the goods in question have been covered, without "turning back" (i.e. without considering products that have already been passed on the path that is being explored).

Each term (which represents "each step") is multiplied by the product of the proximities between the goods located at earlier stages along the pathway (i.e. parts of the path that have already been travelled). Each successive step that can be taken away from the product being evaluated influences the indicator less and less, which reflects the idea that longer paths entail more complex adaptations of existing capabilities and greater investments of time and money.

Consequently, the "b" goods that have the highest values on this indicator will be signalling the key sectors in the world economy of today.

At each one of these steps, the number of addends rises. If "n" represents the number of goods in the product space, then that is the number of addends in the first term of the equation. In the second term (second step), however, for each of the possible first steps ("n" terms), the indicator reflects all the possible second steps ("n-1" terms, since the original good "b" would be a backward step and is therefore explicitly excluded). Therefore, the number of addends in the second term equals n(n-1). Likewise, the third term is going to include n(n-1)(n-2) addends, and so on, with the last term including n steps. This is because, at each step, for every good that could possibly be reached by taking that step, all the possible next steps are considered. We have decided to divide each term by the number of addends that it includes in order to avoid artificially inflating the influence of each successive step.

In practice, given the difficulties involved in making these calculations and the exponentially downward trend in the value of each term,[5] only the first three steps have been computed for this indicator. However, in view of that trend, it can confidently be assumed that the amount of information lost by excluding the rest of the steps is trivial.

Finally, after having calculated the product space for the years covered by this study and have computed the indicator for all the goods concerned, all that remains to be done is to group them into sectors so that a clearer picture of the results can be obtained (this point will be discussed in more detail later on). The sectors in which the highest average values are found will be the key sectors in today's economy.

In order to arrive at a fuller interpretation of the results, they can be broken down into their component attributes (pervasiveness and sophistication).

2. Limitations

This methodology does suffer from certain limitations that should be taken into account when interpreting the results that it generates.

[4] The first term of the "successive steps" indicator is similar to the strategic value indicator of Hausmann and Klinger (2006b), except that the $\Sigma\phi_{ij}$ (sum of the proximities of all the goods in the product space to good "b") quotient has been removed, since this introduces an element of relativity to the value assigned to the product that is unsuitable for our purposes.

[5] Each term provides a result equivalent, on average, to 20% of the result provided by the preceding term. Thus, the result from the third step is equivalent to only 4% of the derived from the first; if a fourth step were to be computed, the resultt would be equivalent to no more than 0.8% of that of the first step.

First of all, although the methodology can theoretically be applied both to trade in goods and trade in services, given the high level of disaggregation required in order to apply it correctly, its application is actually restricted to trade in goods (this will be explained more fully in the next section). This is a highly significant constraint, since many of the sectors in today's production systems are service sectors. Examples cited by Freeman and Pérez (1988) include software, databanks and information services.

An additional consideration is that the observation of production sectors on the basis of international trade data alone fails to pick up a number of factors or processes. This is especially true of sectors whose output is used as inputs for other sectors in the same country, since their products will not be measured directly because they are not being traded internationally. Consequently, their contribution to an economy's total output is not going to be fully reflected in the figures.

The classifications of goods (and sectors) that are used also impose certain limitations. This is partly because any product classification introduces a degree of rigidity, since it will inevitably place different types of goods under the same code. In addition, in this study we are making use of an older classification (SITC Rev. 2), which cannot properly describe new products that are just being developed and which employs a substantial degree of aggregation.

This methodology may also suffer from some weaknesses in capturing the attributes being used to identify key sectors. The PRODY is an imperfect indicator of products' sophistication, since it actually measures profits, and high profits are not always associated with high levels of sophistication (owing to the influence of protectionist policies, for example). What is more, this indicator uses the income level of the country in which a given good is produced rather than the income level of the industry that produces it. At a time when offshoring is such a common practice, the PRODY may therefore not provide a good estimate of a product's sophistication. This may also be the case for the indicator of pervasiveness used in this study.

IV
Data and sectors

The Commodity Trade Statistics Database (COMTRADE) compiles international trade statistics from all reporting countries and is the main source of the data used in this study, which covers the period 2005-2009 for 182 countries and territories. A cut-off point of a population of no less than 3 million was set, however, in order to avoid distortions due to highly specialized economies or ones that have very little influence on the global economy, and this study therefore covers 113 countries and territories. Export statistics on 765 products are reported at the four-digit level of the Standard International Trade Classification (SITC Rev. 2). In order to assess areas of productive specialization while preventing atypical figures from distorting the computations, five-year averages were used.

Information on the gross domestic product (GDP) and per capita GDP and demographic data were drawn from Penn World Table 7.0. The per capita GDP data have been adjusted on the basis of purchasing power parities (PPP) using the Geary-Khamis method at current prices. Five-year averages have been used in this case as well.

The data have been grouped into sectors in order to make it easier to interpret the results intuitively, since a list of the results for these indicators for all 765 goods would be unmanageable. It is important to bear in mind, however, that this analysis has focused on individual products rather than sectors; the classification of products by sector has been done only for the purpose of presenting the results of that analysis. Accordingly, we will refer back to products when appropriate in order to interpret the results more accurately.

An attempt was therefore made to arrive at the most "aseptic" sector classification possible (i.e. one that would have the least possible impact on the final results). To achieve this, we tried to define sectors that conform to the sections and divisions used in the SITC classification. We departed from that approach only when a somewhat different category would make it easier to understand the results.

The result was the definition of the 12 sectors shown in table 1:

TABLE 1

Sectors

No.	Sector	SITC goods included
1	Food, beverages and tobacco	Up to and including Division 12
2	Unprocessed or semi-processed raw materials	Divisions 21-43
3	Basic chemicals	Divisions 51-53
4	Pharmaceuticals	Division 54
5	Other chemicals	Divisions 55-59
6	Basic manufactures	Divisions 61-59
7	Industrial machinery	Divisions 71-74 and, at the 3-digit level, 771, 772, 773
8	Transport equipment	Divisions 78 and 79
9	Electronics	Divisions 75-77, except the products included in sectors 7 and 10
10	Scientific and medical instruments	Division 87 and, at the 3-digit level, 774
11	Armaments	Division 95
12	Miscellaneous unsophisticated manufactures	Divisions 81-85, 88 and 89, and section 9 with the exception of Division 95

Source: prepared by the author.

V

Results

The results obtained for the “successive steps” indicator, with the different products being grouped into sectors, are shown in table 2. While this classification was developed on the basis of the average values of the indicator for the goods in each sector, that figure was nearly identical to the figure obtained by ranking the sectors by the average decile for the goods making up each sector, with the first decile corresponding to the 10% of the goods with the lowest value for the indicator and the tenth decile corresponding to the highest-ranking products. Only the latter are shown in the following table in order to simplify the interpretation of the results. The key sectors, then, are those that are ranked the highest in table 2:

TABLE 2

Classification of key sectors based on the “successive steps” indicator

Sector	Average decile
Industrial machinery	7.7
Scientific and medical instruments	7.0
Pharmaceuticals	6.4
Transport equipment	6.3
Other chemicals	6.4
Basic manufactures	6.3
Basic chemicals	5.7
Miscellaneous unsophisticated manufactures	5.5
Armaments	5.0
Food, beverages and tobacco	4.6
Electronics	4.2
Unprocessed or semi-processed raw materials	3.3

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

It is not surprising that industrial machinery, scientific and medical instruments, and pharmaceuticals are the sectors exhibiting the greatest combined presence of sophistication and pervasiveness. To continue on with the interpretation of the results, table 3 shows the different sectors’ rankings in terms of the basic indicators used to gauge pervasiveness (total proximity to the product space) and sophistication (the PRODY).[6]

TABLE 3

Sophistication and pervasiveness (PRODY and total proximity to the product space)

(Averages, by sector)

Sector	Ranking by sophistication	Ranking by pervasiveness
Pharmaceuticals	1	7
Scientific and medical instruments	2	9
Industrial machinery	3	1
Basic chemicals	4	8
Electronics	5	11
Other chemicals	6	5
Armaments	7	10
Transport equipment	8	3
Basic manufactures	9	2
Miscellaneous unsophisticated manufactures	10	4
Food, beverages and tobacco	11	6
Unprocessed or semi-processed raw materials	12	12

Source: prepared by the author on the basis of the Commodity Trade Statistics Database (COMTRADE).

[6] Actually, looking at these attributes separately provides no more than an approximation of the breakdown for the results for the aggregate indicator since, as noted earlier, the “successive steps” indicator yields results for the combination of pervasiveness and sophistication. There may therefore be slight departures from what the aggregate indicator shows and what the individual observations of these attributes indicate.

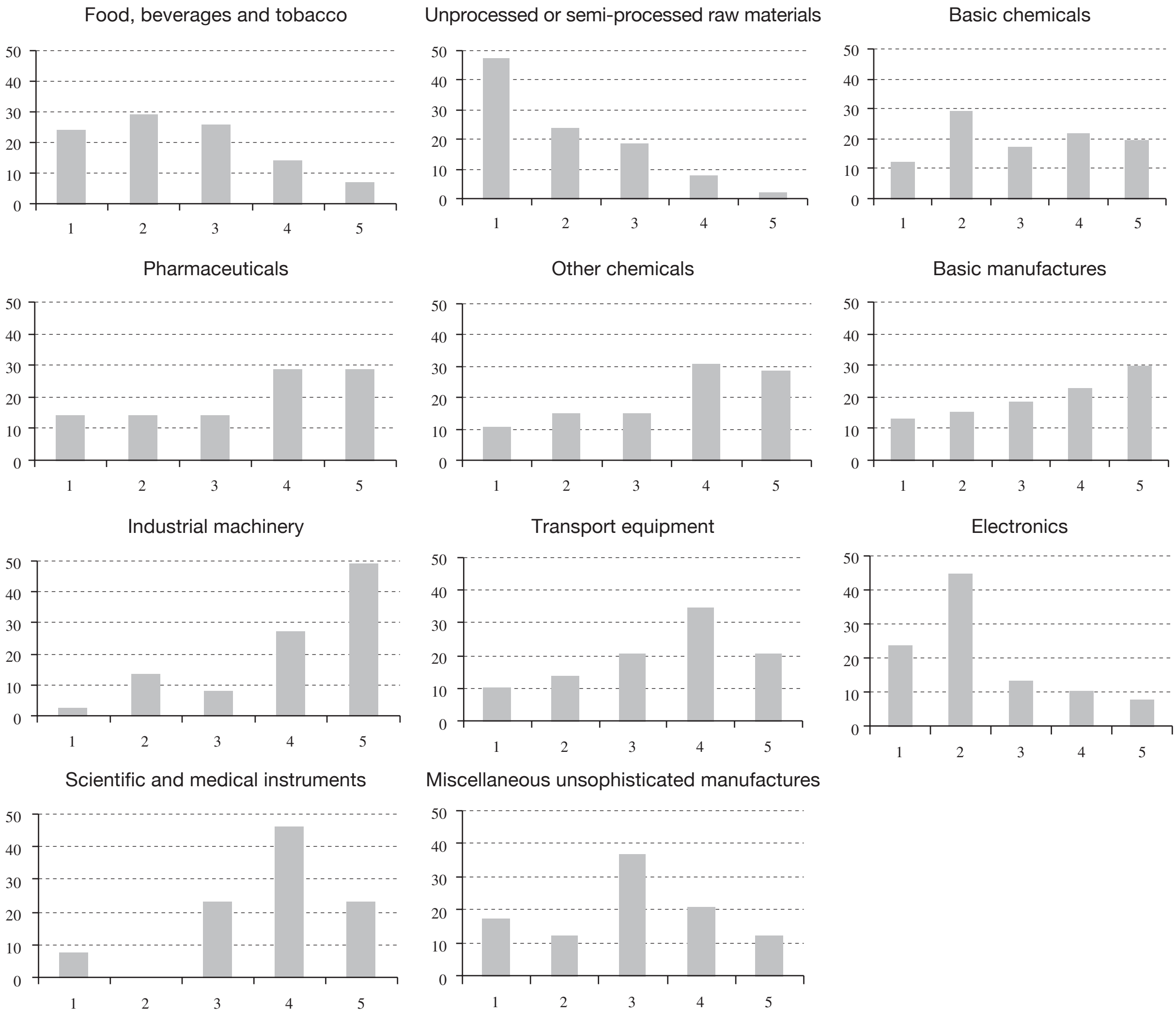
While the pharmaceuticals sector is the most sophisticated, its pervasiveness indicator is relatively low (i.e. it is profitable but requires technological capabilities that are not widespread). The situation is much the same for the sector of scientific and medical instruments. On the other hand, the industrial machinery sector is highly sophisticated (third-highest ranking) and is pervasive (top ranking). This sector therefore ranks the highest on the "successive steps" indicator and is thus clearly a key sector. Other sectors, such as basic manufactures and transport equipment, are pervasive but are fairly unsophisticated. These sectors therefore have mid-range rankings on the overall indicator.

Since these are averages for sectors that include a number of different products, the results of our computations do not provide a clear enough picture of the results for the goods making up each sector. Figure 1 plots out the distribution of the indicator for these products by quintile within each sector (except for the armaments sector, which represents a single product):

FIGURE 1

Distribution of goods within each sector, by quantile, based on the "successive steps" indicator

(Percentages)



Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

The table shows that 50% of the goods in the industrial machinery sector are in the fifth quintile and almost no products are in the first. These results shape a very clear-cut trend towards a concentration of the component products in the higher quintiles. The situation in the sector of unprocessed or semi-processed raw materials is almost the opposite. The results for the scientific and medical instruments category are similar to those for the industrial machinery sector, but there is a greater concentration of products in the fourth quintile. A similar result, although the trend is less clear, is obtained for the transport equipment sector. Other sectors, however, such as those of basic chemicals, basic manufactures and miscellaneous unsophisticated manufactures, display a great deal of internal heterogeneity, with significant percentages of their component goods in all the quintiles. Accordingly, caution has to be used when interpreting these results. That being said, in the case of basic manufactures, a trend towards the higher quintiles is clearly discernible.

The results for the electronics sector are interesting. While this sector has an intermediate level of sophistication, its pervasiveness indicator is very low. This is a very large sector that has been heavily impacted by the trend towards a segmentation of production processes and greater use of offshoring in recent years. This trend, which has been widely commented upon in the literature (see, for example, Srholec, 2005; Lall, Weiss and Zhang, 2005), suggests (although further research would be needed) that it provides an opportunity for multinationals to set up assembly plants in countries where they have very few linkages with the surrounding economy. This kind of situation is associated with very few technological spillovers and less pervasiveness. In addition, cost-reduction strategies driven by the fierce competition that exists in this sector prompt producers to site certain links in the production chain in low-income countries, which tends to diminish the sophistication of products when measured by the PRODY.

It should be remembered that the goods in this sector are primarily final consumer products. The highly advanced electronic inputs in the industrial machinery and scientific and medical instruments categories, for example, are not included, as was discussed in the section on the shortcomings of the methodology being used for this study.

One noteworthy facet of the results is that the correlation between sophistication and pervasiveness, while positive, is quite weak. In fact, the correlation between the coefficients for the PRODY and the proximity to the product space is 0.11. This calls into question the hypothesis advanced in the product-space literature according to which there is a close relationship between the two attributes and appears to indicate that the most pervasive technologies are very mature ones.

As for the overarching interpretation of the results, at first glance it is not clear that they corroborate the presence of the ICT-based techno-productive paradigm that the neo-Schumpeterian school of thought describes as being characteristic of today's economy. An examination of the key sectors points up the fact that a number of them, such as industrial machinery (first place) or transport equipment (fourth place) and even basic manufactures (sixth place, when the results are averaged with those shown in table 2) appear to fit in with what the neo-Schumpeterians describe as the earlier techno-productive paradigm (which Freeman and Pérez (1988) call the "mass-production era"). If we narrow the focus to include only the attribute of pervasiveness, which is the main characteristic of a "key input", this is even more evident, as the classification is headed up by industrial machinery, followed by transport equipment and basic manufactures, many of which are produced by metallurgical and metal-working industries.

It should be borne in mind that the industrial machinery sector includes highly automated goods in which crucial electronic components, robotics, software and ICTs are embedded. Verspagen (2004) develops this argument and concludes that the new ICTs are more properly supplementary or complementary components rather than substitutes for their predecessors. The industrial machinery sector's position in the classification thus does not necessarily refute the hypothesis of an ICT-based paradigm; it may be a question of looking more closely at the technological applications of products rather than simply cataloguing final goods. This approach is outside the scope of the methodology being used here, however. The rankings of the scientific and medical instruments and the pharmaceutical sectors can be interpreted in the same way. This latter sector is closely linked to biotechnologies, which are commonly cited as being a fundamental component of today's production paradigm (Freeman and Pérez, 1988).

In order to take a more in-depth look at the results and gauge the degree to which they correspond to earlier theoretical constructs, an examination of the products in all the sectors that are in the tenth decile of the "successive steps" indicator is informative. The complete list is provided in annex 1, but in order to provide an idea of the situation without being overwhelmed by the sheer volume of data, table 4 list the divisions (at the two-digit level) or groups (at the three-digit level) that have at least three products in that decile.

TABLE 4

Product divisions and groups with at least three products in the tenth decile

Sector	Divisions or groups
Industrial machinery	Power-generating machinery and equipment; machinery specialized for particular industries; agricultural machinery, general industrial machinery and equipment, heating and cooling equipment and parts thereof, pumps and compressors, centrifuges
Scientific and medical instruments	None
Pharmaceuticals	None
Transport equipment	Road vehicles
Other chemicals	Polymers and copolymers
Basic manufactures	Rubber manufactures, non-metallic mineral manufactures, iron and steel, metal manufactures n.e.s.
Basic chemicals	Pigments, paints, varnishes and related products
Other unsophisticated manufactures	None
Armaments	None
Food, beverages and tobacco	None
Electronics	None
Unprocessed or semi-processed raw materials	None

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).
n.e.s.: not elsewhere specified.

This review leads to the conclusion that, rather than witnessing a new ICT- and biotechnology-based production paradigm, what we are seeing is a mix of sectors originating in different stages of the technological revolution. There are signs of the new paradigm in the rankings of the pharmaceutical and the scientific and medical instruments sectors. A number of the products in the industrial machinery sector certainly represent examples of the electronics or robotics that make up part of the new paradigm as well. But others hark back to the previous paradigm (transport equipment, many types of industrial machinery, some chemicals), and there are also sectors that have their origins in still older paradigms (metallurgical products, for example).

This could provide some useful clues for the interpretation of the surprisingly low correlation between sophistication and pervasiveness. If the key sectors in previous paradigms continue to be centrally positioned, then they should presumably register a high degree of pervasiveness. In the case of mature technologies, however, the level of sophistication is not going to be very high. And this is precisely the situation with respect to sectors such as transport equipment, basic manufactures, and other chemicals, as shown in table 3.

As noted earlier, however, this study may also suffer from methodological constraints that prevent it from providing a clear picture of the sectoral patterns that are shaping the current paradigm. The most influential of these limitations is surely the fact that trade in services is not included in the calculations, since services are an increasingly important factor in international trade and in production.

VI

Conclusions

The results back up the concerns expressed about Latin America's recent export trends, since most of the key sectors that have been identified are far removed from commodity production sectors. Specifically, the main key sectors in the world economy are, in descending order, industrial machinery, scientific and medical instruments, and pharmaceuticals. The first of these sectors combines a high level of sophistication with a high level of pervasiveness and thus fully qualifies as what we have defined here as a key sector. The other two, however, exhibit a high degree of sophistication but no more than an intermediate degree of pervasiveness. In addition, the poor overall results for the electronics sector and the high degree of pervasiveness registered for mature-technology categories such as the basic manufactures and transport equipment sectors indicate that what we are witnessing is not the consolidation of a new ICT-based paradigm but rather a mixture of overlapping key sectors originating in different stages of technological development that can be likened to a cross-cutting view of different geological strata. This does not necessarily mean that the posited paradigm does not exist; it may be simply that the methodology used in this study does not provide a full picture of the situation. It would appear to be the case that the level of sophistication of sectors that come to play a key role in a given technological paradigm tends to be eroded as opportunities for incremental innovations diminish and as new, radical innovations alter the trend and characteristics of economic growth. Nonetheless, these sectors remain pervasive for extended periods of time. In other words, they have lost the ability to generate windfall profits because of the effects of technological diffusion and greater competition, but they continue to play a key role in terms of the production system. These findings are in line with earlier studies (Freeman and Louça, 2001; Verspagen, 2004). This could also help to explain another striking result, which is that, while positive, the correlation between sophistication and pervasiveness is very low. While, a priori, a strong correlation was expected, this finding seems to be consistent with the other results. This suggests the possibility that a trade-off exists between sophistication and pervasiveness at certain stages in the innovation process. When radical, highly sophisticated innovations are first introduced, they are capable of generating huge profits, since they have not yet become diffused and they are therefore the domain of very few companies. There may then be a phase during which the technology become diffused but is still highly sophisticated because many incremental innovations follow in its wake. This makes it possible for firms that have mastered that technology to continue to reap large profits even while other companies, countries and production sectors are beginning to do so, which heightens the product's pervasiveness. Ultimately, as the technology becomes standardized and more diffused, and as the imitation of that technology increases, its profitability declines as does its sophistication while, at the same time, it is becoming more pervasive. It is only when new radical innovations completely overhaul existing production processes and products that older technologies will gradually become less pervasive as they are replaced by newer technologies throughout the economic system.

If production sectors that use mature technologies remain pervasive over an extended period of time, even if their degree of sophistication declines, they may offer a potential pathway for structural change in developing countries. The high degree of pervasiveness associated with these sectors may open up a pathway that leads to a gradual restructuring of these countries' production systems. This may open the way for a learning process that starts from simple, standardized technologies and progress to more and more sophisticated ones. This line of reasoning is backed up by the track record of technologically mature sectors (textiles, steel, motor vehicles) in countries that have been making major strides in their development in recent years.

These findings are a powerful argument for the development of new approaches capable of analysing the individual technologies that are embedded in different products, as distinct from studies such as this, which are based on classifications of final products. The approach used here assumes that all the products subsumed under a given SITC code are based on the same technologies, and it is therefore impossible to discern the influence that new technologies that are introduced into existing products exert on the production process or on the possibility of new and better applications or reformulations.

ANNEX

TABLE A.1

Products (SITC Rev. 2 at the 4-digit level) in the tenth decile of the successive steps indicator

Code	Description	Sector	Code	Description	Sector
8939	Miscellaneous articles of materials in Division 58	12	6997	Articles of iron or steel n.e.s.	6
8922	Newspaper, journals, periodicals, whether or not illustrated	12	6996	Misceallneous articles of base metal	6
8743	Instruments for measuring and checking flow, pressure andother variables for liquids and gases	10	6994	Springs and leaves for springs of iron, steel or copper	6
8219	Other furniture and parts, n.e.s.	12	6992	Chain and parts thereof, of iron or steel	6
8124	Lighting fixtures and fittings, lamps, lanterns and parts, n.e.s.	12	6975	Base metal indoors sanitary ware and parts thereof, n.e.s.	6
8121	Central heating equipment, not electrically heated, parts, n.e.s.	12	6954	Interchangeable tools for hand or machine tools	6
7919	Railway and tramway track fixtures and fittings and parts, signalling equipment	8	6953	Other hand tools	6
7868	Other vehicles, not mechanically propelled, parts	8	6940	Nails, screws, nuts, bolts, rivets, etc., of copper, iron or steel	6
7849	Other parts and accessories for vehicles under headings 772, 781, 782, 783	8	6924	Casks, drums, etc. of iron, steel, aluminium, for packing goods	6
7810	Passenger motor cars for transport of passengers and goods	8	6912	Structures and parts of aluminium; plates, rods and the like	6
7783	Electrical equipment for internal combustion engines and vehicles and their parts	9	6911	Structures and parts of iron and steel (hangars, bridges, buildings and their parts)	6
7493	Transmission shafts, cranks, bearing housings, etc.	7	6842	Aluminium and aluminium alloys, worked	6
7492	Taps, cocks, valves, etc. for pipes, tanks, vats, etc.	7	6794	Castings of iron or steel, in rough state	6
7449	Parts for machinery classified under section 7442	7	6785	Tube and pipe fittings, of iron and steel	6
7441	Work trucks of the type used in factories, dock areas, etc.	7	6782	Seamless tubes, pipes or iron or steel	6
7439	Parts of machinery classified under headings 7435 and 7436	7	6644	Glass, cast, rolled, etc.	6
7436	Filetering and purifying machinery, apparatus for liquids and gases	7	6635	Wool (expanding or insulating mineral materials, n.e.s.)	6
7432	Parts, n.e.s., of the pumps and compressors falling under section 7431	7	6633	Manufactures of mineral materials, n.e.s. (other than ceramic)	6
7431	Air pumps, vacuum pumps and air or gas compressors	7	6632	Abrasive powder or grain, natural or artificial	6
7429	Parts, n.e.s., of pumps and liquids elevators falling under section 742	7	6572	Bonded fibre fabrics	6
7416	Machinery, plant, laboratory equipment for heating and cooling, n.e.s.	7	6546	Fabrics of glass fibre	6
7414	Non-domestic refrigerators and refrigrerating equipment, n.e.s.	7	6424	Paper and paperboard, cut to size or shape, n.e.s.	6
7413	Industrial and laboratory furnaces and ovens, etc., parts, n.e.s.	7	6422	Correspondence stationary	6
7412	Furnace burners, mechanical stokers, etc. and parts thereof, n.e.s.	7	6289	Other articles of rubber, n.e.s.	6
7372	Rolling mills, rolls therefor and parts, n.e.s. of rolling mills	7	6282	Transmission, conveyor or elevator belts of vulcanized rubber	6
7369	Parts n.e.s. and accessories for machine-tools falling under heading 736	7	6210	Materials of rubber	6
7269	Parts n.e.s. of machines falling under headings 7263 and 7264	7	5836	Acrylic and metha-acrylic polymers; acrylo-methacrylic copolymers	5

Table A.1 (conclusion)

Code	Description	Sector	Code	Description	Sector
7247	Textile machinery n.e.s. for cleaning, cutting, etc. and parts n.e.s.	7	5834	Polyvinyl chloride	5
7224	Wheeled tractors	7	5831	Polyethylene	5
7219	Agricultural machinery and appliances, n.e.s. and parts thereof, n.e.s.	7	5824	Polyamides	5
7212	Harvesting and threshing machines	7	5542	Organic surface-active agents n.e.s.	5
7211	Agricultural and horticultural machinery for soil preparation, etc.	7	5335	Glazes, driers, putty, etc.	3
7188	Engines and motors n.e.s. (wind, hot-air engines, water wheels, etc.)	7	5334	Varnishes and lacquers; distempers, etc.	3
7169	Parts n.e.s. of roating electric plants	7	5332	Printing inks	3
7162	Electric motors, generators, generating sets	7	5162	Aldehyde, ketone and quinone-function compounds	3
7139	Piston engine parts, n.e.s., falling under the headings of 7132, 7133 and 7138	7	3345	Lubricating petroleum oils and preparations n.e.s.	2
7132	Motor vehicle piston engines under Division 78	7	913	Lard, pig and poultry fat, rendered or solvent-extracted	1
7129	Parts, n.e.s. of steam power units that come under heading 7126	7	142	Sausages and the like, of meat, meat offal or animal blood	1
6998	Articles of copper, nickel, aluminium, lead, zinc and tin n.e.s.	6			

Source: prepared by the author on the basis of Commodity Trade Statistics Database (COMTRADE).

SITC: Standard International Trade Classification.
n.e.s.: not elsewhere specified.

Bibliography

Antonelli, C. (2007), "The foundations of the economics of innovation", *Working Paper*, No. 02/007, Turin, University of Turin.

Balassa, B. (1964), "The purchasing-power parity doctrine-A reappraisal", *Journal of Political Economy*, vol. 72, No. 6, Chicago, University of Chicago Press.

Cimoli, M. (comp.) (2005), *Heterogeneidad estructural, asimetrías tecnológicas y crecimiento de América Latina* (LC/W.35), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC)/Inter-American Development Bank (IDB).

Dalum, B., K. Laursen and B. Verspagen (1999), "Does specialization matter for growth?", *Industrial and Corporate Change*, vol. 8, No. 2, Oxford, Oxford University Press.

ECLAC (Economic Commission for Latin America and the Caribbean) (2012), *Structural Change for Equality: An Integrated Approach to Development* (LC/G.2524(SES.34/3)), Santiago, Chile.

_______ (2007), *Progreso técnico y cambio estructural en América Latina* (LC/W.136), Santiago, Chile.

Freeman, C. and F. Louça (2001), *As Time Goes By: From the Industrial Revolution to the Information Revolution*, New York, Oxford University Press.

Freeman, C. and C. Pérez (1988), "Structural crises of adjustment, business cycles and investment behavior", *Technical Change and Economic Theory*, G. Dosi and others (eds.), London, Pinter Publishers.

Hatzichronoglu, T. (1997), "Revision of the high technology sector and product classification", *OECD Science and Technology Working Papers*, No. 1997/02, Paris, OECD Publishing.

Hausmann, R. and B. Klinger (2007), "The structure of the product space and the evolution of comparative advantage", *CID Working Paper*, No. 146, Center for International Development, Harvard University.

_______ (2006a), "Structural transformation and patterns of comparative advantage in the product space", *CID Working Paper*, No. 128, Center for International Development, Harvard University.

_______ (2006b), "South Africa's export predicament", *CID Working Paper*, No. 129, Center for International Development, Harvard University.

Hausmann, R., J. Hwang and D. Rodrik (2005), "What you export matters", *CID Development Working Paper*, No. 123, Center for International Development, Harvard University.

Hidalgo, C. and others (2007), "The product space conditions the development of nations", *Science*, vol. 317, No. 5837, American Association for the Advancement of Science.

Katz, J. and G. Stumpo (2001), "Sectoral regimes, productivity and international competitiveness", *CEPAL Review*, No. 75 (LC/G.2150-P), Santiago, Chile.

Lall, S. (2000), "The technological structure and performance of developing country manufactured exports, 1985-1998", *QEH Working Papers*, No. 44, Oxford, University of Oxford.

Lall, S., J. Weiss and J. Zhang (2005), "The 'sophistication' of exports: a new measure of product characteristics", *QEH Working Papers*, No. 123, Oxford, University of Oxford.

Nelson, R. and S. Winter (1982), *An Evolutionary Theory of Economic Change*, London, The Belknap Press.

Pavitt, K. (1984), "Sectoral patterns of the technical change: towards a taxonomy and a theory", *Research Policy*, vol. 13, No. 6, Amsterdam, Elsevier.

Peres, W. and A. Primi (2009), "Theory and practice of industrial policy. Evidence from the Latin American experience", *Desarrollo Productivo series* (LC/L.3013-P), Santiago, Chile, Economic Commission for Latin America and the Caribbean (ECLAC). United Nations publication, Sales No. E.09.II.G.34.

Schumpeter, J. (1939), *Business Cycles: a Theoretical, Historical and Statistical Analysis of the Capitalist Process*, New York, McGraw-Hill Book Company.

Srholec, M. (2005), "High-tech export from developing countries: A symptom of technology spurts or statistical illusion?", *Working Papers on Innovation Studies*, No. 20051215, Oslo, University of Oslo.

Thirlwall, A.P. (1979), "The balance of payments constraint as an explanation of international growth rate differences", *BNL Quarterly Review*, vol. 32, No. 128, Rome, Banca Nazionale del Lavoro.

United Nations (1975), *Standard International Trade Classification (SITC) Revision 2*, Series M, No. 34/Rev. 2, New York. United Nations publication, Sales No. 75.XVII.6.

Verspagen, B. (2004), "Structural change and technology. A long view", *Revue économique*, vol. 55, No. 6, Presses de Science Po.