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REGULAR ARTICLE

# Variety patterns in defense and health technological systems: evidence from international trade data

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## Abstract

In recent years, a debate on the technological sources of the next long wave of growth has emerged. In this context, some authors consider that health-related industries will be more likely to generate new technological systems than defense-related industries, which have entered a stage of technological maturity (Ruttan 2006; Steinbock 2014; among others). Based on evolutionary works, in this paper we state that technological systems are characterized by a high degree of technological relatedness, which is positively associated with the possibility of a system to generate variety through the recombination of knowledge from a common base. Following this statement, this work aims to analyze technological relatedness between defense (and health) technological system(s) and other groups of products to compare their variety patterns. Based on international trade data (a panel for 60 countries and 17 years), and different measures of proximity and relatedness (e.g. sectoral competitiveness of countries), we compare defense and health technological systems regarding their potential of generating related variety through two main methods: network analysis and econometrical analysis. The main results support Ruttan's hypothesis. The network analysis shows the potential for both systems to generate related variety, but higher centrality indicators for health products. In line with that, competitiveness in health products presents a stronger correlation with competitiveness in other groups of products, both related and high and medium technology. This suggests that an improvement in countries' competitiveness in health sectors can generate spillovers on other related sectors, which can strengthen structural competitiveness and sustain long-term growth.

**Keywords** Technological paradigms · Related variety · Product space · Technological systems · Health economics · Defense economics · Economic development

**JEL classification** O10 · O15 · O33 · I15

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## 1 Introduction

In recent years, the debates on long waves of growth and techno-economical paradigms have regained certain relevance, motivated by the attempt of different authors to anticipate the technological sources of the next great wave. In this sense, the potentialities of biotechnology, nanotechnology, cyber physical systems or environmental technologies (among others) have been investigated in order to establish if they constitute technological systems capable of driving great changes at innovation trajectories, learning sources and productive structures (Linstone 2004; Bainbridge and Roco 2006; Coccia 2010; Daim et al. 2006; Jazdi 2014; Colombo et al. 2017; etc.). These debates usually put the public sector in a central place, since it has historically played a very important role in the emergence of new technologies, from the promotion of variety (e.g. financing basic R&D), through the generation of technology selection mechanisms (e.g., regulations, public procurement), and consolidating and accelerating technological trajectories (Cimoli et al. 2006). For example, mission-oriented policies towards defense goals carried out by US Department of Defense during the second post-war period are often highlighted, especially since they led later to various spin-offs and spillovers in non-military sectors with special relevance in those of medium and high technology (Chiang 1991; Ruttan 2006; Mowery and Rosenberg 1999; Mazzucato and Penna 2016). In this regard, mission-oriented policies, although motivated in coping with social challenges, were grounded in their capacity to expand industrial capacity and competitiveness in a wide range of activities. Defense, health, energy, among other sectors have been exposed (in different times) to challenges that justified strong interventions oriented to the configuring of new technological systems, which were drivers of competitiveness, growth and development (Ergas 1987; Sampat 2012; Mowery 2009, 2012; Foray et al. 2012; Mazzucato 2015; UNCTAD 2017; among others).

However, possibilities of cross-fertilization and knowledge spreading between sectors are not static, but depend on the technological context. Ruttan (2006) argued that, while defense and defense-related research, development and procurement in the current context are unlikely to generate new technological systems able to expand national competitiveness,[1] molecular biology and biotechnology are emerging as a new source of technological opportunities in the early decades of the twenty-first century. Some authors have also perceived a decline in the capacity of the defense technology system in its innovative potential (Yudken 2010; Steinbock 2014; Sempere 2017), while other authors have postulated that the health technology system is the key to the shaping of a new paradigm centered on biotechnologies and health equipment, among others (Lipsey et al. 2005; Linstone 2004; Linstone and Devezas 2012; Lavarello and Jelinsky 2017; among others).

These debates take place simultaneously with the recent emergence of works that vindicate the role of the state in technological policies and point to the need to “return” to mission-oriented policies, now around the new social challenges of the twenty-first century, many of them linked to health, such as the treatment of diseases without a cure (Swedish EU Presidency 2009; European Commission 2011; Foray et al. 2012; Mazzucato 2015, 2018; Mazzucato and Penna 2016; UNCTAD 2017; UCL 2018).

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[1] The main arguments to explain this declination of defense system are summarized in Section 3.

Based on evolutionary works, in this paper we state that technological systems are characterized by a high degree of technological relatedness, which is positively associated with the possibility of a system to generate variety through the recombination of knowledge from a common base. Therefore, a common base of knowledge may act as a channel through which competitiveness spread out the productive structure, extending the competitiveness from one sector closely related to the technological system to another with a different degree of proximity (Hidalgo et al. 2007; Hidalgo and Hausmann 2009). Following this statement, this work aims to analyze correlation in sectoral competitiveness of countries between defense (and health) technological system(s) and related products. Based on international trade data, and different measures of proximity and relatedness, we compare defense and health technological systems regarding their potential of generating related variety, as well as variety on high and medium technology products.

We estimate variety from health and defense groups of products on two different targets: first, on related products, following Hidalgo et al.'s (2007) and Saviotti and Frenken's (2006) definitions; second, on high (and medium) technology products (Lall 2001), trying to grasp the effect of those technological systems on technologically dynamic products. This will be assessed in a trade panel data with information for 60 countries and 17 years.[2]

The structure of the work is as follows. In the next section, a theoretical discussion about different dimensions of variety generation processes is developed, emphasizing the usefulness of technological system concept to explain sectoral trajectories as variety in an evolutionary framework. In the third section, we present the two empirical analyses made to answer the research questions and hypotheses. In the fourth section, we express the conclusions.

## 2 Variety, relatedness and technological systems

Over the last four decades, the evolutionary approach has analyzed the processes of technological change based on the interaction between mechanisms of variety, retention and selection (Dosi and Nelson 1994). Variety generation has both temporal and spatial consequences.

From a strictly temporary point of view, innovation processes are path-dependent and are characterized by their irreversibility. Path dependency implies that it is not the pricing system that exclusively defines the direction of technical change: variety is generated along trajectories defined by the procedures and problem-solving routines established by a technological paradigm. Technological trajectories are then defined around a sectoral knowledge base that allows the generation of variety, but over certain more or less defined limits (Dosi 1982). At the same time, the definition of trajectories within the framework of a paradigm is characterized by passing through different phases: a flexible, slow, uncertain and exploratory first phase is followed by a phase of accelerated incremental changes once a dominant design is imposed, and then enters

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[2] We ran the estimations also for a broad database (103 countries, 20 years), but these results are in the Annex for different reasons (see Section 3).

a phase of maturation where standardization is high and there are few profitable trajectories to explore (Utterback and Abernathy 1975; Arthur 1989; Perez 2010).

Based on the definition of technological and techno-economic paradigms, different cycles or long waves of growth have been established, and some central technologies in these cycles have been highlighted (Dosi 1982; Freeman and Perez 1988; Perez 2010). Because of their power to generate large productivity gains and substantial changes in the economic landscape, some authors have focused on so-called GPTs, characterized by their pervasiveness, their inherent potential for technical improvements, and their innovational complementarities (Bresnahan and Trajtenberg 1995). GPTs are a fundamental element in the development of a paradigm, as highlighted by Ruttan (2006). However, although they model search heuristics across a broad set of technologies, they are not the only source of variety or the only engine of economic growth. As was highlighted by Cantner and Vannuccini (2012), the pervasiveness, prevalence and persistence of a specific GPT could be better explained through an evolutionary framework, because GPTs are the result of collective innovation processes, characterized by both competitive selection between different technologies (ending in a dominant design) and by non-linearities, feedbacks and interrelations between multiple actors. In this sense, incremental innovations (or related variety) within a system are the usual context in which a GPT could randomly emerge and make powerful changes throughout the structure. While it is difficult to separate the effects of incremental and radical innovations, it is important to distinguish them as processes of different natures and characterized by different transmission mechanisms.

From a strictly spatial point of view, the generation of variety depends on and percolates through geographical and territorial specificities. Learning processes are interactive: firms resort to external sources of knowledge, many of which are tacit, and their absorption capacities are heterogeneous, which also influences their capacities to recombine and exploit knowledge (Cohen and Levinthal 1990; Carlsson and Stankiewicz 1991). Therefore, proximity on various dimensions to enable effective knowledge transfer between firms and interactive learning is required, and, in particular, the technological proximity between firms, sectors and branches of activity is a key element for the generation of variety (Boschma and Frenken 2009; Belderbos and Mohnen 2013; Hidalgo et al. 2018). Two firms with similar or compatible (complementary) knowledge bases will benefit more from the interactions between them than two firms working in different or incompatible fields of knowledge. In turn, the ability of different sectors to generate related variety depends on the usefulness and applicability of their knowledge and innovations in other (more or less) related sectors. In this regard, Boschma and Frenken (2009) highlight four mechanisms of technological relatedness or proximity: producer-user relationships (Lundvall 1992), production-system interdependency (Landes 1969; Dahmen 1991), technological complementarity (Rosenberg 1982), and interdependencies derived from common base technologies. These mechanisms, while present in a large number of technologies and sectors, are found with greater intensity in sectors and “key technologies” that provide more (and ‘better’) linkages than others (Hirschman 1959; Bresnahan and Trajtenberg 1995; Abeles et al. 2017).

Thus, through the concepts of relatedness or proximity, the literature has tried to analyze the synchronic interactions between different fields of knowledge available in the same geographical space, while concepts such as technological trajectory or technological paradigm have been used predominantly to refer to diachronic interactions between fields of knowledge. However, as Boschma & Frenken (2009: p. 2) highlight, sectoral technological development paths can be (and have been since the 1980s) interpreted from the analysis of the technological relationships or proximities that characterize them:

> In the 1980s, this idea of technological relatedness was applied to the sectoral level. Notions like technology systems (…) were developed to account for technological interdependencies between industries. Key sectors were identified that heralded new technological paradigms, and which provided the main sources of knowledge for new technological trajectories (Dosi 1982; Freeman and Perez 1988). Since such key sectors are characterized by high pervasiveness and inter-industry cross-fertilization among emerging technologies, they bring about major economic changes, and boost long-term economic development…

In this sense, one of the greatest merits of systemic visions of innovation is that they have combined both the temporal and spatial elements of variety generation. In this sense, we highlight the notion of technological systems (Nelson and Winter 1977; Gille 1978; Rosenberg and Frischtak 1984; Freeman 1992; Perez 2010; Carlsson and Stankiewicz 1991; De Liso and Metcalfe 1996) because it serves to characterize the processes of variety generation from a perspective that puts in first place the proximity between technologies and fields of knowledge, emphasizing the importance of the processes of construction of capabilities in the firms from the use of sources of knowledge both internal and external. In this aspect, a technological paradigm models the process of knowledge production in a sector, and this process is nourished by interactions with the social environment where the previous trajectories of the actors (their capacities) play a crucial role.

In this sense, one of the key ideas behind the concept of technological systems is that, by identifying the relationships and proximities between sectors and products (technological interdependencies or relatedness), it is possible to interpret patterns of related variety over time. This is particularly interesting for the purpose of this paper, which seeks to compare two variety patterns (defense-related and health-related) following Ruttan's hypothesis (Ruttan 2006), based on the analysis of relationships between products characteristic of specific technological systems.

## 3 Defense and health technological systems

The empirical analysis in this paper will focus on two sectors and their potential to consolidate diverse and sophisticated technological systems. Based on Saviotti's distinction between technical and service characteristics of a technology (Saviotti 1997), it is important to note that defense and health technology systems are particular in both aspects. On the technical side, they are "knowledge-intensive" systems, since basic research has historically been of fundamental relevance to both. In terms of service characteristics, these are systems in which the search for variety is usually driven by the demand for specific social needs.

The importance of the first aspect lies in the fact that, although the literature has highlighted that variety, and especially unrelated variety, has a positive relationship with long-term economic growth (Saviotti and Frenken 2008; Hidalgo et al. 2007), some authors argue that related variety has significant effects on growth when it occurs in “knowledge-intensive” sectors (Bishop and Gripaios 2010; Cortinovis and Van Oort 2015; Hartog et al. 2012; Mameli et al. 2012; Pinheiro et al. 2018).

The second aspect is also important because socio-economic defense and health goals have motivated the development of new technologies, mainly (but not exclusively) in the shape of state-driven missions (Ergas 1987; Foray et al. 2012; Coccia 2016; Sampat 2012; Mazzucato 2015). While mission-oriented policies stand out for establishing new directions in the technical change of a system, making possible ‘great leaps’ towards unrelated varieties and major structural changes (Mazzucato 2015; Mazzucato and Penna 2016; Hidalgo et al. 2007), these new directions multiply opportunities around specific technological paradigms, which allow the emergence of related variety in those sectors and can consolidate technological trajectories through cross-fertilization (Dosi 1982; Saviotti and Frenken 2008).

Despite these two similarities, defense and health systems have historically differed with respect to the degree of knowledge diffusion throughout the system. This is the main argument of some authors to sustain the declination of defense system: military secrecy has fostered a scarcity of links between the large firms of the military-industrial complex and the rest of the productive structure that could not be compensated with a higher orientation towards the development of dual-use technologies, and has hindered system’s capacity to generate related and unrelated variety (Chiang 1991; Ruttan 2006; Sempere 2017). These difficulties deepened after the end of the Cold War because of the lack of a strong external threat, which reduced the budget allocated to defense and promoted a greater disconnection among the components of the system, and because of the maturity of the technological paradigm based on metal-mechanics, automation and control technologies (Leske 2018; Ruttan 2006; Serfati 2008). According to some authors (Molas-Gallart 2008; Leske 2018), armed forces’ loss of influence over the system led companies to increase their openness and the technological trajectory became commanded by civilian technologies. However, other authors point out that this opening, far from encouraging knowledge diffusion in the system, promoted its disintegration in the face of an increase in the offshoring of large firms (Yudken 2010; Steinbock 2014; Pisano and Shih 2009). For its part, a third group believes that military priorities and expenses continue setting the pace of innovation in the sector (Schmid 2018).

In comparison, the health system usually stands out by its multiple mechanisms of technological complementarity and user-producer interactions (Gelijns and Rosenberg 1994; Consoli and Mina 2008). As it is not restricted by military secrecy, it has allowed a greater knowledge diffusion in the context of mission-oriented programs. Although knowledge protection through patents and IPRs can establish restrictions on the diffusion in the system, these restrictions are much smaller in comparison with the industrial (and military) secrets that still today characterize the defense system.[3] Likewise, in the context of the current technological paradigm linked to ICTs and with the development of molecular biology, it is assumed that the technological health system has a much greater potential for expanding technological opportunities than in the past (Mazzucato and Dosi 2006; Lipsey et al. 2005).

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[3] For a summary of the ways in which patents can promote or restrict knowledge diffusion, see Mokyr (2009) or Mazzucato and Dosi (2006).

Hence, as our purpose is not to make technological foresight in terms of unrelated varieties or 'great leaps', but to interpret the last decades from what Ruttan posed about the decline of the defense industry vis-à-vis biotechnology industries, it is important to evaluate their degree of technological relatedness. In this sense, the focus of this paper is to assess the degree of related variety generated by such technological systems, especially in terms of their connections with high and medium technological content sectors, which are interpreted as having high absorption capacities, that is to say, although we were stimulated by a large number of works that have tried to anticipate new sources of unrelated variety (Linstone 2004; Bainbridge and Roco 2006; Coccia 2010, 2016; Daim et al. 2006; Jazdi 2014; Colombo et al. 2017; etc.), here we compare two past trajectories of technological systems to answer if we can observe the maturity of one system with respect to the other (its potential for generating not only unrelated but also related variety). This could raise some interesting insights for doing foresight, but this is not our main goal.

Although the literature on patterns of variety and technological relatedness is very abundant, few empirical attempts have been made to compare sectoral technological paths from relationships between products. Some of them, although focused in explaining countries' development strategies (diversification, specialization) and using patent data analysis, are those of Verspagen (2007), Petralia et al. (2017), Rigby (2012), Boschma et al. (2014) and Breschi et al. (2003). Hidalgo and Hausmann (2009) and Alshamsi et al. (2018) add international trade data to also analyze diversification paths.

In the present work, we analyze relations between products to assess if health technological system presents a greater potential for variety than defense technological system. While the literature identifies multiple criteria to define relationships between products, in this paper we consider knowledge shared by products as the key factor determining whether two products are related, because cognitive proximity is a requirement for firms receiving new knowledge to exploit. In this line, we are also interested in such variety that could pervade technologically dynamic sectors, where absorption capacities are usually greater (Cohen and Levinthal 1990; Nooteboom 2000; Saviotti and Frenken 2006; Frenken et al. 2007; Boschma and Frenken 2009).

This theoretical criterion based on cognitive proximity or common knowledge base is what Saviotti and Frenken (2006) and Hidalgo et al. (2007) considered in order to establish whether two products are related to each other. However, as we will see in the Methodology Section, two different empirical ways of defining this relationship or proximity are inferred from the same theoretical criterion.

## 4 Empirical analysis

### 4.1 General hypothesis

This paper proposes two general hypotheses: i) both defense and health technological systems present a high degree of technological relatedness; ii) the health system has presented in the last years a greater potential of variety generation than the defense system.

Due to the fact that the analysis uses data on international trade in goods, in this work we will follow a strategy based on the analysis of Hidalgo et al. (2007), who interpret the proximity relationship between different products as the probability of finding many countries that present joint competitiveness in such products. In dynamic terms, a joint increase in competitiveness in two products can be interpreted as the presence of a relationship between the two, based on latent capacities that are common to their production.

The first exercise that is proposed to answer the raised hypotheses is to find the direct connections generated by defense and health products in Hidalgo et al.'s (2007) "proximity matrix". Given that this matrix has been prepared from a small number of years (1998–2000) and that the *ex post* criterion established to define proximities might not accurately account for compatibilities between knowledge fields but for other reasons (Content and Frenken 2016), there is a second empirical exercise in this work. It is an econometric analysis that attempts, for a longer period (1995–2014), to make up for this shortcoming by looking for correlations between competitiveness for defense and health products, respectively, and competitiveness for other related products, based on the *ex ante* definition of related products designed by Saviotti and Frenken (2006).

## 4.2 Assessing relatedness through Hidalgo et al.'s proximity matrix

### 4.2.1 "Defense" products and "health" products

As regards the classification of military products, a set of codes of the Harmonized System linked to products associated with the defense industry was obtained from the Report on Defense Markets for the year 2016, prepared by the International Trade Administration of the United States Department of Commerce (ITA-USDC).[4] Similarly, health products were identified by means of Harmonized System codes from the ITA-USDC Report on Pharmaceuticals[5] and the ITA-USDC Report on Medical Devices.[6]

Tables 6 and 7 in the Appendix present the codes and product descriptions of each of the groups, as well as their equivalence with the third revision of the SITC, which is the classification used by Hidalgo et al. (2007) to assemble its product network. In the case of health products, the following were excluded on the grounds that their inclusion was inappropriate because of the low weight of world exports of health products within these groups: 611512 (synthetic fibre socks), 611,519 (panty hose), 611,592 (cotton hosiery), 611,593 (knitted articles), 630,720 (belts and life jackets), 630,790 (textile articles, made up).

### 4.2.2 Related products

Hidalgo et al. (2007) define a pair of products as related according to their level of proximity (or "similarity"). Proximity is defined as the conditional probability that such products will be exported jointly by several countries in the same period, or, strictly speaking, that many countries have joint competitiveness in such products, where

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[4] http://www.trade.gov/topmarkets/pdf/Defense_Top_Markets_Report.pdf, accessed September 3rd, 2018.

[5] http://www.trade.gov/topmarkets/pdf/Pharmaceuticals_Top_Markets_Reports.pdf, accessed September 3rd, 2018.

[6] https://www.trade.gov/topmarkets/pdf/Medical_Devices_Top_Markets_Report.pdf, accessed September 3rd, 2018.

**Fig. 1** **Examples of proximity relationships not based on common capabilities.** Source: Atlas of Economic Complexity (http://atlas.cid.harvard.edu, accessed September 3rd, 2018)

competitiveness is measured by Balassa's (1965) Revealed Comparative Advantages (RCA) index.

Although the authors of this method propose that proximity is defined on the basis of technical compatibilities (Hausmann et al. 2013), the Hidalgo et al. indicator has some limitations to explain the obtained relationship in several cases. In some cases, relationships could be justified much more by complementarity in uses or by the satisfaction of a similar spectrum of needs than by technical correspondence. Even in other cases, there does not seem to be an underlying explanation, as happens, for example, with the connection presented in the network of Hidalgo et al. vegetable or animal fats or oils (HS1518) and motorcycle parts (HS8714), or that presented by gloves (HS6116) and photo cameras (HS9006) (see Fig. 1).

On the other hand, the period used as a reference to calculate the proximity matrix has a very significant influence on the results of that matrix, which reveals a kind of static bias in the methodology and restricts the possibility of carrying out representative analyses for very long periods. These limitations of the Hidalgo et al. methodology confront us with the need to complement this notion of proximity with other criteria of relation between products (such as Saviotti and Frenken 2006), as we will do in the econometric analysis of Sub-section 3.3.

Finally, it is important to mention that the analysis tried to achieve an approximation to the quality of the connections for which the technological content indicator of Lall (2001) was chosen, around which defense and health products and related products were classified. This taxonomy classifies commodities into six categories: (i) primary goods; (ii) manufactures based on natural resources (primary origin); (iii) low technological content; (iv) medium technology content; (v) high technological content; and vi) other products.[7] As a referee of this article suggested, this indicator is useful to reflect the absorption capabilities or even the firm commercializing competencies because it is based on R&D intensity (Cohen and Levinthal 1990; Eliasson 2010). This, in turn, is also in the core of the notion of technological system, which combines technological interdependencies and common knowledge bases with pre-existing capabilities of firms to exploit external knowledge.

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[7] For a critical analysis of taxonomies based on technological content or intensity, see Aboal et al. (2017) and Marin and Petralia (2018).

### 4.2.3 Analysing the network

First, we explore Hidalgo et al.'s product network, which is based on the proximity matrix calculated by these authors taking the triennium 1998–2000 as reference (see Appendix). They conclude that it can be useful to explain countries' development levels in terms of their economic structure: products located in the center of the network have a greater number of connections and, therefore, a country that specializes in a product located in a dense and highly interconnected sub-section of the network will have greater possibilities of diversifying its production into different fields of knowledge (Hidalgo et al. 2007). From Fig. 2, it can be seen that health products are located in areas closer to the center of Hidalgo et al.'s network than defense products. This first overview is important because, although the network analysis of this work will be done on the same proximity matrix established by Hidalgo et al., the construction of the network by these authors follows methodologies that differ from those used in this work to deploy the sub-networks described in Figs. 3 and 4 (see Appendix). As we will see, beyond the network layout, the proximities matrix will allow us to graph networks where the conclusions will be similar (health products with greater centrality and connections than those of defense).

Second, after knowing in which parts of the network the health and defense products are located, we are able to focus only on their "influential areas ". Thus, we define a minimum proximity threshold (0.40), above which we consider that there is a significant relationship between products. Taking this reference into account, a new binary matrix was built and different centrality measures for defense and health products were analyzed. These measures indicate the relative importance of these products (nodes) within the network. In particular, we focus on four main indicators of centrality (see Appendix), the values of which are presented in Table 1 for defense and health products, respectively. It is important to say that the interpretation of some centrality indicators has greater relevance in valued matrices (that is, not binary). Thus,

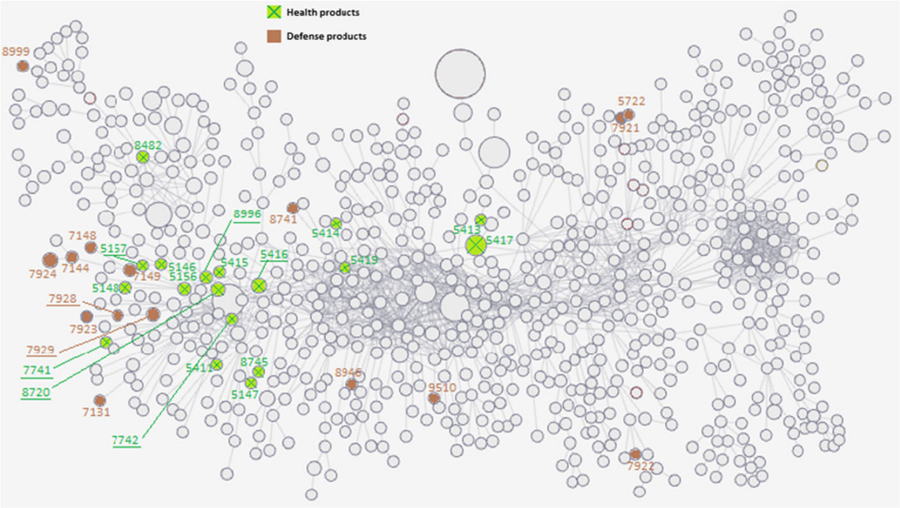

**Fig. 2 Locating defense and health products in Hidalgo et al.'s network (SITC 3rd rev.).** Source: Own elaboration based on the Atlas of Economic Complexity (http://atlas.cid.harvard.edu/)

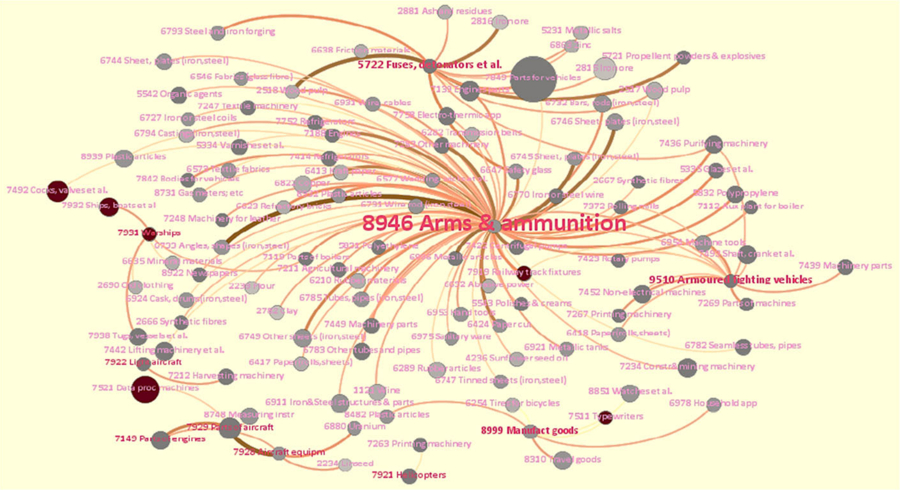

**Fig. 3** Defense products network (which include its related products), following proximity matrix from Hidalgo et al. (2007). Note: Node sizes were drawn in proportion to world trade in these products in 2014, while the scale of colors indicate products' technological content according to Lall (2001): light grey for primary and Low-Tech products, dark grey for Medium-Tech products, black for High-Tech products. Source: Own elaboration.

depending on the case, we will use the binary matrix or the valued matrix as a reference for analysis.

Let's first analyze the defense products. As for the 16 defense products, we can observe that six of them in the binary matrix do not have any type of connection (so technically the binary network of defense products has 10 nodes), while two others have only one link. In this sense, the analysis through centrality measures allows us to highlight three products by their degree indicator (Detonators −5722-, Arms and ammunition −8946- and Armored fighting vehicles −9510), and two others by their indirect connections (Warships −7931- and Light Aircraft −7922-), which is observed in their indicators of 2 Step, Closeness and Eigenvector (in binary as well as in valued matrix).

As far as health products are concerned, the eighteen products have at least one connection. Six of them have a higher than average degree, of which four are pharmaceuticals and biopharmaceuticals (pharmaceutic. ls −5419-, medicaments −5417-, glycosides and vaccines −5416-, hormones −5415-), while two are medical equipment (X-ray equipment −7742- and electro-medical equipment −7741-). These six products also have an above-average "2 Step" centrality. Other products with high "2 Step" centrality are antibiotics −5413- and vegetable alkaloids −5414-.

Concerning closeness, the products with the highest degree in binary matrix also have a high closeness (except in the case of X-ray equipment). In this sense, there would be a clear predominance of pharmaceuticals and biopharmaceuticals among the closest products. When we also consider the valued matrix, other products are added, where antibiotics −5413-, aminated compounds with oxygen function −5146-, measuring instruments −8745-, and vegetable alkaloids −5414- are the most salient examples. As for the eigenvector centrality, we observe a summary of the measurements of degree and closeness (taking both binary and valued matrix).

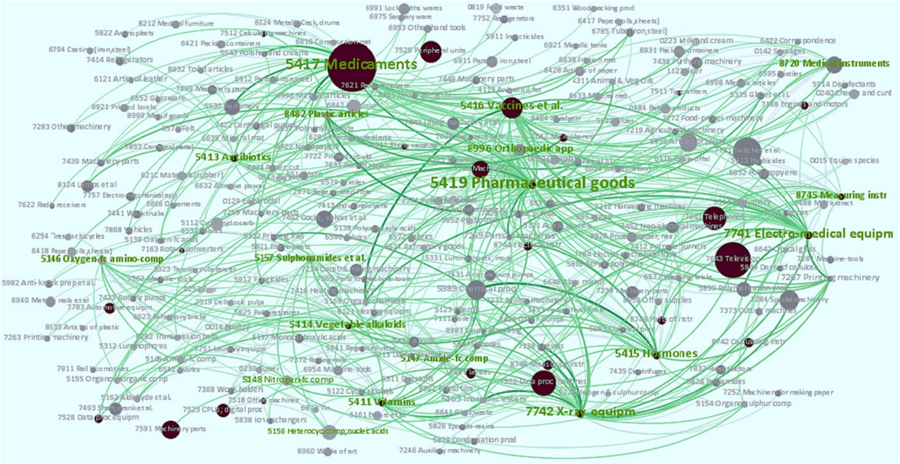

**Fig. 4** Health products network (which include its related products), following proximity matrix from Hidalgo et al. (2007). Note: Node sizes were established in proportion to world trade in these products in 2014, while the scale of colors indicate products' technological content according to Lall (2001): light grey for primary and Low-Tech products, dark grey for Medium-Tech products, black for High-Tech products. Source: Own elaboration.

In general, the analysis of centrality measures yields higher average values for health products vis-à-vis defense products, which might show that health products have greater possibilities for related diversification.

Third, we will concentrate on the analysis of the direct links that defense and health products develop in the network, disregarding secondary (mediated) links and other unrelated products. Technically, this is known as isolating and examining the "ego" networks for these products. The sub-networks of health products and defense products (Figs. 3 and 4 respectively) analyzed here include the direct links (greater than 0.40) between these products and other related products, while also graphing the links between the related products. Indirect links were excluded for this analysis.

At first glance, the health products network has more connections than that of defense products for the same proximity threshold. Table 1 summarizes the number of connections (degree) of the binary matrices of defense and health products (respectively), distinguishing how many of those connections are with High and Medium-Tech products. For military products, we see that the products with the largest connections are not necessarily those with the best connections in terms of technological content. The connections with High TC products are few (1 in 8, on average) and those of Medium TC are greater (5 in 8), highlighting Aircraft Parts (7929), Warships (7931), Weapons and armored combat (9510) and Parachutes (8999).

For health products, the picture is similar. Products with larger connections are not particularly notable for having connections with High-Tech products. The main exceptions are Electro-medical equipment (7741) and Hormones (5415). When we include Medium-tech products in the analysis, Pharmaceuticals (5419) and X-Ray equipment (7742) are also important. In addition to these, there are other products that, without having many connections, have many of them with High-Tech products: Lactamas (5156), Measuring Instruments (8745), Medical Instruments (8720), and Other

**Table 1** Main measures of centrality for the defense and health nodes

| SITC (3rd rev.) | Description | Direct conexions | | | Indirect conexions | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Degree | High Tech links (as part of Degree) | Medium Tech links (as part of Degree) | 2 step | Closeness* | | Eigenvector | |
| | | BM | BM | BM | BM | BM | VM | BM | VM |
| Defense products | | | | | | | | | |
| 5722 | Fuses, caps, igniters, detonators | 14 | 0 | 4 | 249 | 0,047 | 0,128 | 0,059 | 0,713 |
| 7131 | Engines, for aircraft, and parts | 0 | ... | ... | ... | ... | 0,123 | ... | 0,381 |
| 7144 | Reaction engines | 0 | ... | ... | ... | ... | 0,122 | ... | 0,351 |
| 7148 | Gas turbines | 0 | ... | ... | ... | ... | 0,125 | ... | 0,417 |
| 7149 | Part of engines | 2 | 0 | 1 | 6 | 0,028 | 0,113 | 0,000 | 0,323 |
| 7921 | Helicopters | 1 | 0 | 1 | 33 | 0,035 | 0,125 | 0,002 | 0,434 |
| 7922 | Aircraft (weight < 2000 kg) | 1 | 0 | 1 | 116 | 0,041 | 0,127 | 0,010 | 0,535 |
| 7923 | Aircraft (2000 kg to 15,000 kg) | 0 | ... | ... | ... | ... | 0,125 | ... | 0,477 |
| 7924 | Aircraft (weight > 15,000 kg) | 0 | ... | ... | ... | ... | 0,117 | ... | 0,241 |
| 7928 | Aircraft, nes and associated equipment | 4 | 0 | 2 | 7 | 0,028 | 0,110 | 0,000 | 0,300 |
| 7929 | Parts, nes of the aircraft of heading 792 | 4 | 1 | 1 | 51 | 0,034 | 0,110 | 0,002 | 0,283 |
| 7931 | Warships | 5 | 1 | 2 | 136 | 0,043 | 0,127 | 0,017 | 0,622 |
| 8741 | Navigational instruments, nonelectrical | 0 | ... | ... | ... | ... | 0,104 | ... | 0,458 |
| 8946 | Arms and ammunition | 74 | 2 | 33 | 410 | 0,056 | 0,127 | 0,477 | 0,865 |
| 8999 | Manufactured goods, nes | 6 | 1 | 0 | 55 | 0,037 | 0,104 | 0,001 | 0,287 |
| 9510 | Armoured fighting vehicles et al. | 13 | 1 | 9 | 285 | 0,048 | 0,126 | 0,114 | 0,672 |
| Health products | | | | | | | | | |
| 5146 | Oxygen-function amino-compounds | 15 | 0 | 6 | 259 | 0,047 | 0,127 | 0,039 | 0,720 |
| 5147 | Amide-function compounds | 17 | 1 | 9 | 214 | 0,044 | 0,123 | 0,043 | 0,588 |
| 5148 | Other nitrogen-function compounds | 10 | 3 | 2 | 116 | 0,039 | 0,119 | 0,009 | 0,389 |

**Table 1** (continued)

| SITC (3rd rev.) | Description | Direct conexions | | | Indirect conexions | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Degree | High Tech links (as part of Degree) | Medium Tech links (as part of Degree) | 2 step | Closeness* | | Eigenvector | |
| | | BM | BM | BM | BM | BM | VM | BM | VM |
| 5156 | Heterocyclic compound; nucleic acids | 6 | 2 | 2 | 86 | 0,037 | 0,124 | 0,005 | 0,420 |
| 5157 | Sulphonamides, sultones and sultams | 16 | 2 | 7 | 187 | 0,042 | 0,124 | 0,026 | 0,526 |
| 5411 | Provitamins and vitamins | 25 | 6 | 11 | 256 | 0,046 | 0,124 | 0,046 | 0,594 |
| 5413 | Antibiotics | 24 | 1 | 10 | 327 | 0,050 | 0,129 | 0,192 | 0,773 |
| 5414 | Vegetable alkaloids and derivatives | 23 | 1 | 13 | 308 | 0,049 | 0,125 | 0,164 | 0,703 |
| 5415 | Hormones, in bulk | 37 | 7 | 17 | 274 | 0,047 | 0,124 | 0,116 | 0,615 |
| 5416 | Glycosides, glands, antisera, vaccines | 40 | 5 | 16 | 315 | 0,050 | 0,123 | 0,134 | 0,682 |
| 5417 | Medicaments | 63 | 4 | 23 | 400 | 0,055 | 0,128 | 0,411 | 0,848 |
| 5419 | Pharmaceutical goods (exc. medicaments) | 76 | 7 | 38 | 396 | 0,054 | 0,124 | 0,488 | 0,806 |
| 7741 | Electro-medical equipment | 45 | 10 | 27 | 326 | 0,049 | 0,123 | 0,223 | 0,675 |
| 7742 | X-ray equipment | 47 | 7 | 30 | 299 | 0,047 | 0,120 | 0,138 | 0,579 |
| 8482 | Clothing accessories of plastic or rubber | 17 | 4 | 9 | 135 | 0,043 | 0,114 | 0,007 | 0,406 |
| 8720 | Medical instruments and appliances, nes | 16 | 5 | 7 | 243 | 0,045 | 0,124 | 0,049 | 0,587 |
| 8745 | Measuring instruments, nes | 19 | 6 | 11 | 270 | 0,046 | 0,125 | 0,065 | 0,595 |
| 8996 | Orthopaedic appliances | 23 | 6 | 12 | 279 | 0,047 | 0,123 | 0,100 | 0,607 |
| Avg. Defense products | | 8 | 1 | 5 | 135 | 0,038 | 0,120 | 0,068 | 0,460 |
| Avg. Health products | | 29 | 4 | 14 | 261 | 0,046 | 0,123 | 0,125 | 0,617 |
| Total average | | 30 | n.a | n.a | 199 | 0,046 | 0,122 | 0,149 | 0,595 |

*Values for the closeness indicator correspond to the inverse of Freeman's original indicator (1979)

Source: Own elaboration

compounds with nitrogen functions (5148), among others. Beyond the similarities, on average, health products present more High-Tech connections and less Medium-Tech connections than defense products.

In summary, taking into account both the quantity and quality dimensions of the connections analyzed, although both groups of products have related diversification possibilities, they seem to be greater for health products than for defense products. The greater potential of related variety of health products is revealed not only in the centrality indicators, but also by having on average greater connections with High-Tech products, especially in some specific products. However, the analysis from Hidalgo et al.'s networks presents several limitations that were already mentioned, so we will try to complement it with an econometric exercise in the next section.

### 4.3 Assessing variety following Saviotti and Frenken (2006)

In the previous section, we evaluated relationships between defense and human health product groups and other products, defined according to the methodology of Hidalgo et al. (2007). In this section, we assume (as do Saviotti and Frenken 2006) that the codes of the harmonized system of classification of goods pose a satisfactory approximation towards the relations between products. In this way, we try to find evidence of related variety for a longer period (1995–2011). Also, a question is raised about the relations on high and medium-tech products. It would be expected that the effect on related sectors would be greater, and would diminish as more "distant" relationships are established.

The working hypotheses shall be as follows:

- Hypothesis 1: A country's competitiveness in defense products correlates with its competitiveness in:
- "Related" products: Scenario 1A.
- High-tech products (exc. Military products): Scenario 1B.
- High-tech and Medium-Tech products (exc. Military products): Scenario 1C.
- Hypothesis 2: A country's competitiveness in health products correlates with its competitiveness in:
- "Related" products: Scenario 2A.
- High-tech products (exc. Health products): Scenario 2B.
- High-tech and Medium-Tech products (exc. Health products): Scenario 2C.
- Hypothesis 3: Health products have more relations with other products than defense products (health products competitiveness correlates better with other products than defense products competitiveness).

#### 4.3.1 Data source and preparation

Panel data are made up of export values published by BACI International Trade Database (BACI 2010). This database is compounded by trade data from COMTRADE Database (United Nations), harmonized considering the resulting discrepancies in freight and insurance costs. The panel uses data for a period of 20 years (1995–2014) and for 103 selected countries (representative of 99% of world exports, mean for 1995–

2014).[8] The original BACI Database present disaggregated product information at six-digit Harmonized System 1992 (HS-92). We keep with defense and health products as well as those related to them: high and medium technology products, and products of the same chapter (two-digit) and division (four-digit) of HS-92. As regards the classification of defense and health products, they were defined following the same definition (based on HS codes) that was used for the network analysis. To classify the products according to technological content, Lall's (2001) taxonomy was used.

With data of these products, we estimated a measure of competitiveness (Balassa's RCA index) for different product groups, defined as: defense products, health products, high technology products (defense excl.), high and medium technology products (defense excl.), high technology products (health excl.), or high and medium technology products (health excl.) and related products (as defined by Saviotti and Frenken 2006).[9] Finally we ran different sets of models (pooled, fixed effects and random effects) for each hypothesis, considering also temporal effects in every model.

Additionally, some controlling variables were included in the models. On the one hand, GDP per capita was included as a controlling variable (after its logarithmic transformation) in all models, because the relative wealth of the country could influence its performance in exports. The GDP per capita data for each country during the period were obtained from the World Development Indicators database of the World Bank.

On the other hand, we incorporated a control to the models considering the kind of participation of the countries in global value chains. This is oriented to separate the effect of 'assembling countries': there are countries that have good RCA indexes for high technology exports without having an indigenous learning process (only importing intermediate products and assembling these parts to be subsequently exported).[10] We try to isolate this effect considering a measure of import content of exports (ICOE) for every different group of products and every country. We built this index based on data available from 1995 to 2011 of Trade in Value Added Database (published by OECD and WTO). Using TIVA database constrains the BACI database, because it has data for 60 countries, but these are also representative of world trade (approx. 92% of world exports, mean for 1995–2014).[11]

### 4.3.2 Models and main results

First, we redefined the group of related products following the definition of Saviotti and Frenken (2006), in which related products are those belonging to a same chapter and

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[8] We ran estimations for this period and this number of countries, but the results are presented in the Annex because we consider more relevant to present the results after the introduction of ICOE control (see below). The results of these models do not change significantly the conclusions.

[9] As it has been highlighted by an anonymous reviewer, the utilization of Balassa's index could not reflect all possible spillover effects in this exercise. For example, new firm formation based on defense or health technological systems could not be completely captured by this indicator. However, it was chosen to maintain the same criteria to define competitiveness that was raised in Hidalgo et al.'s analysis, and also because we consider that variety patterns that we analyze in this work converge into complex interactive processes that are expressed in structural competitiveness of countries (even when there are new firms that do not export).

[10] Two figures are able in the Annex in which can be seen the coexistence of high ICOE values and high RCA on High-Tech products in some countries (Figures 5 and 6 in the Annex).

[11] The countries and their export level of military and health products can be observed in Table 5 in the Annex.

sections of Harmonized System (2 and 4 digits of HS 1992). Based on this definition, we analysed if being competitive in defense (and health) products is correlated with being competitive in other related products.

Second, we analyzed the relation between the competitiveness of defense (and health) products and the competitiveness of high technology products (excluding defense or health in each case), considering that being competitive in those products could be correlated with being competitive in other high technology products. The same was also done for a broader group, composed of high as well as medium technology products.

Based on that, two sets of three different models were formulated to answer the hypothesis[12]:

***For military products:***

***Set 1: Controlling by Import Content of Exports.***

**Model 1A:** $RCAREL_{i,t} = \beta_0 + \beta_1 RCAMIL_{i,t} + \beta_2 GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

**Model 1B:** $RCAHT_{i,t}^{-MIL} = \beta_0 + \beta_1\ RCAMIL_{i,t} + \beta_2\ GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

**Model 1C:** $RCAHMT_{i,t}^{-MIL} = \beta_0 + \beta_1\ RCAMIL_{i,t} + \beta_2\ GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

***For health products:***

***Set 2: Controlling by Import Content of Exports.***

**Model 2A:** $RCAREL_{i,t} = \beta_0 + \beta_1 RCAHEA_{i,t} + \beta_2 GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

**Model 2B:** $RCAHT_{i,t}^{-HEA} = \beta_0 + \beta_1\ RCAHEA_{i,t} + \beta_2\ GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

**Model 2C:** $RCAHMT_{i,t}^{-HEA} = \beta_0 + \beta_1\ RCAHEA_{i,t} + \beta_2\ GDPPC_{i,t} + ICOE_{i,t} + \eta_t + v_i + \mu_{i,t}$

Where:

- $RCAMIL_{i,t}$: Revealed comparative advantages for military products.
- $RCAHEA_{i,t}$: Revealed comparative advantages for health products.
- $RCAHT_{i,t}^{-MIL}$: Revealed comparative advantages for high technology products, excluding military products.
- $RCAHMT_{i,t}^{-MIL}$: Revealed comparative advantages for high and medium technology products, excluding military products.
- $RCAREL_{i,t}$: Revealed comparative advantages for related products (as defined by Saviotti and Frenken 2006).
- $RCAHT_{i,t}^{-HEA}$: Revealed comparative advantages for high technology products, excluding health products.
- $RCAHMT_{i,t}^{-HEA}$: Revealed comparative advantages for high and medium technology products, excluding health products.
- $GDPPC_{i,t}$: GDP per capita.
- $ICOE_{i,t}$: Import content of exports.
- $\eta_t$: Unobservable temporal effects.
- $v_i$: Unobservable individual effects.
- $\mu_{i,t}$: Random error.

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[12] The estimation results for these models without controlling by ICOE are shown in the Annex. They cover 103 countries and a period of 20 years (1995–2014).

*Note 1: the RCA indicator is in all cases Balassa's indicator and was normalized by the application of natural logarithm.*

*Note 2: natural logarithm was applied to GDP* per capita.

The results for the estimated models, both *pooled OLS* regression as well as fixed effects regression, are presented in Tables 2 and 3.[13] They both include also temporal effects (*dummy* variables for each year of the panel). We present only the results of the models with the introduction of the "import content of exports" (ICOE) control (60 countries, 17 years), although we ran the estimations also for the broad BACI database (103 countries, 20 years). The results for this broad database are in the Appendix.

In general, the estimated results of our models offer empirical evidence in favor of the hypothesis. Except for a few cases, it can be seen that the introduction of the ICOE control is very relevant, given the significance and positivity in all the models of the coefficient that accompanies it. The inclusion of GDP per capita as control is also relevant for fixed-effect models.

First, the results for defense products are presented in Table 2. Model 1A, which estimates correlation with other related products (as defined by Saviotti & Frenken), has a significant and positive value in the fixed-effects model for the estimated parameter $\beta_1$. This estimated parameter has to be interpreted as an elasticity (*log-log* model), but it is not an efficient estimator (because we have a fixed-effects specification). The same can be said for high and medium-tech products (Models 1B and 1C), where the coefficients are also significant and positive (0.099 and 0.083 in fixed-effects models). The values for the coefficients grow as we move from related products to high and medium-tech products, and to high-tech products. This is not very intuitive: we emphasized previously that we expected related products to have a greater value because of cognitive proximity. Two possible explanations can be given for this unexpected result: the first is that Saviotti & Frenken's definition of related product does not really capture a proximity between products in terms of technical base; the second is that defense products could have a much more transversal effect throughout the productive structure, affecting groups of products a priori less related. In this sense, the relation would be more related to the service than to the technical characteristics of technology. We do not rule out this hypothesis given the capacity of the defense sector to generate general-purpose technologies, but the interpretations are merely hypothetical.

Second, Table 3 shows the results for health products, which are very similar. They support Hypothesis 2 because there are significant and positive values for the estimated parameters of RCA for health products. Model 2A, which estimates the impact on other related products according to the criteria of Saviotti and Frenken (2006), again shows a significant and positive $\beta_1$ coefficient for both the pooled and fixed-effect models. In contrast with defense products, the value for the coefficients decrease as we move from related products to high and medium-tech and to high-tech products. The introduction of the ICOE control is very relevant in almost all models, given the significance and positivity in many models of the coefficient that accompanies it. However, for related products, it is not significant in the fixed-effects model, which leads us to think of the possibility of a

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[13] Estimates of the parameters estimated with fixed-effect models are the most robust since this specification allows us to control the -observable and unobservable- idiosyncratic characteristics invariant over time, which could lead to biases. Then, it was chosen to show results for fixed effects specification for all models, based not only on the consistency of fixed effects estimators but also on results of Hausman tests (see Annex).

**Table 2** Results for ‘Pooled OLS’ and fixed effects estimates on formulated models to test defense products

| Model (Group of products defined in dependent variable) | 1A Related products as defined by Saviotti and Frenken (excluding military products) | | 1B High technology products (excluding military products) | | 1C High and Medium technology products (excluding military products) | |
|---|---|---|---|---|---|---|
| | Pooled | FE | Pooled | FE | Pooled | FE |
| RCA_military prod | 0.748*** | 0.064** | 0.346*** | 0.099*** | 0.346*** | 0.083*** |
| ln (pbi pc) | −0.011 | 0.706*** | 0.011 | 0.451*** | −0.047* | 0.368*** |
| Import content | 0.032* | 0.053*** | 0.113*** | 0.031*** | 0.067*** | 0.021*** |
| 1995 (base) | . | . | . | . | . | . |
| 1996 | 0.012 | 0.007 | 0.088 | 0.099* | 0.032 | 0.032 |
| 1997 | 0.040 | −0.042 | 0.090 | 0.110** | 0.051 | 0.042 |
| 1998 | 0.151 | −0.034 | 0.100 | 0.129** | 0.059 | 0.035 |
| 1999 | −0.023 | −0.131 | −0.022 | 0.056 | −0.014 | 0.005 |
| 2000 | −0.099 | −0.233** | −0.193 | −0.044 | −0.108 | −0.049 |
| 2001 | 0.038 | −0.159 | −0.062 | 0.034 | −0.004 | 0.014 |
| 2002 | 0.061 | −0.140 | −0.037 | 0.020 | −0.002 | −0.006 |
| 2003 | 0.076 | −0.112 | −0.075 | 0.015 | −0.035 | −0.018 |
| 2004 | 0.153 | −0.083 | −0.108 | −0.024 | −0.029 | −0.022 |
| 2005 | 0.147 | −0.110 | −0.110 | −0.054 | −0.043 | −0.055 |
| 2006 | 0.263 | −0.022 | −0.128 | −0.072 | −0.039 | −0.057 |
| 2007 | 0.320 | −0.052 | −0.096 | −0.106 | −0.021 | −0.095* |
| 2008 | 0.297 | −0.028 | −0.052 | −0.085 | 0.019 | −0.062 |
| 2009 | 0.449* | 0.199 | −0.094 | −0.021 | 0.116 | −0.023 |
| 2010 | 0.382 | 0.030 | −0.027 | −0.068 | 0.099 | −0.029 |
| 2011 | 0.289 | −0.048 | 0.035 | −0.061 | 0.088 | −0.035 |
| _cons | −0.569 | −8.244*** | −1.513*** | −5.287*** | −0.382 | −4.161*** |
| $R^2$ “between” | . | 0,149 | . | 0,355 | . | 0,382 |
| $R^2$ “within” | . | 0,220 | . | 0,220 | . | 0,302 |
| $R^2$ “overall” | . | 0,149 | . | 0,340 | . | 0,370 |
| sigma_u | . | 0,149 | . | 0.108 | . | 0,726 |
| sigma_e | . | 0,504 | . | 0,291 | . | 0,204 |
| rho | . | 0,898 | . | 0,932 | . | 0,927 |
| N | 1018 | 1018 | 1019 | 1019 | 1019 | 1019 |

Source: Own elaboration based on panel data

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

lower incidence of “assembly” in sectors related to health (which would show a greater incidence of local capacity building in the competitiveness of these products).

In Table 4, we present a summary of the econometric results: the values of the coefficients $\beta_1$ for the different fixed-effect models are presented together in the same table, including the levels of significance. The results can provide some evidence to support Hypothesis 3, in the sense that the potential for variety is greater in health systems than in military systems.

To sum up, the results obtained in the econometric exercise confirm those that were obtained in the previous network analysis: both greater competitiveness in defense

**Table 3** Results for ‘Pooled OLS’ and Fixed Effects estimates on formulated models to test health products

| Model (Group of products defined in dependent variable) | 2A Related products as defined by Saviotti and Frenken (excluding health products) | | 2B High technology products (excluding health products) | | 1C High and Medium technology products (excluding health products) | |
|---|---|---|---|---|---|---|
| | Pooled | FE | Pooled | FE | Pooled | FE |
| RCA_health prod | 0.672*** | 0.423*** | 0.395*** | 0.149*** | 0.324*** | 0.225*** |
| ln (pbi pc) | −0.129** | 0.435*** | 0.110*** | 0.519*** | 0.093* | 0.426*** |
| Import content | 0.069*** | −0.025 | 0.094*** | 0.042*** | 0.048*** | 0.027*** |
| 1995 (base) | . | . | . | . | . | . |
| 1996 | 0.016 | 0.001 | 0.043 | 0.057 | 0.005 | 0.001 |
| 1997 | −0.019 | 0.012 | 0.009 | 0.039 | −0.010 | −0.015 |
| 1998 | −0.054 | −0.064 | −0.005 | 0.039 | −0.031 | −0.035 |
| 1999 | −0.198 | −0.226** | −0.057 | −0.014 | −0.039 | −0.048 |
| 2000 | −0.272 | −0.247** | −0.129 | −0.066 | −0.075 | −0.086** |
| 2001 | −0.272 | −0.247** | 0.129 | 0.066 | −0.075 | −0.086** |
| 2002 | −0.210 | −0.264** | −0.009 | −0.025 | 0.007 | −0.046 |
| 2003 | −0.108 | −0.171 | −0.007 | −0.021 | 0.010 | −0.050 |
| 2004 | −0.199 | −0.276** | −0.072 | −0.082 | −0.011 | −0.078* |
| 2005 | −0.215 | −0.322** | −0.065 | −0.103 | −0.022 | −0.111** |
| 2006 | 0.206 | −0.355** | −0.067 | −0.125 | −0.007 | −0.119** |
| 2007 | −0.241 | −0.452*** | −0.034 | −0.137 | −0.010 | −0.152*** |
| 2008 | −0.275 | −0.496*** | 0.040 | −0.089 | 0.033 | −0.128** |
| 2009 | −0.058 | 0.313** | 0.105 | −0.071 | 0.093 | −0.089* |
| 2010 | −0.186 | −0.434*** | −0.011 | −0.163* | 0.052 | −0.127** |
| 2011 | −0.126 | −0.393** | 0.026 | −0.143 | 0.061 | −0.131** |
| _cons | 0.546 | −4.628*** | 2.505*** | −5.088*** | −1.705*** | −4.670*** |
| $R^2$ “between” | . | 0,268 | . | 0,488 | . | 0,537 |
| $R^2$ “within” | . | 0,083 | . | 0,228 | . | 0,372 |
| $R^2$ “overall” | . | 0,232 | . | 0,468 | . | 0,525 |
| sigma_u | . | 0,133 | . | 0.962 | . | 0,604 |
| sigma_e | . | 0,549 | . | 0,327 | . | 0,198 |
| rho | . | 0,855 | . | 0,897 | . | 0,903 |
| N | 1014 | 1014 | 1020 | 1020 | 1020 | 1020 |

Source: Own elaboration based on panel data

* Significant at 10%; ** Significant at 5%; *** Significant at 1%

products and greater competitiveness in health products would be correlated with competitiveness in other product groups. Likewise, a big portion of these relations (which we suppose mainly “technological”) are with sophisticated products (“intensive on knowledge”). Also, there is a possibility, because of the incidence on High-Tech and Medium-Tech products, of unrelated variety.

When comparing both product groups, we can see that the coefficient for health products is much higher compared to the coefficient for defense products. Therefore,

**Table 4** Summary of results of the econometric exercise

| Data | Products | Defense | Health |
|---|---|---|---|
| 60 countries, 17 years (with ICOE control) | Related (Saviotti-Frenken) | 0.064** | 0.423*** |
| | High-Tech | 0.099*** | 0.149*** |
| | High and Medium Tech | 0.083*** | 0.225*** |

Source: Own elaboration based on panel data

judging from the magnitude of the coefficients, the potential for variety from health products appears to have been greater than that of defense products for the period analyzed. These results follow the same line and complement that of network analysis.

With respect to the first hypothesis, which states that greater competitiveness of a country in military products correlates positively with competitiveness in other product groups, results were obtained that supported it. If we complement these results with those obtained in the networks analysis, we find mainly three products that have many direct connections –Detonators (5722), Arms and ammunition (8946) and Armored fighting vehicles (9510). To these products others can be added that, in a second order, without presenting many direct connections, have good indirect connectivity. These are the cases of Warships (7931) and Light Aircraft (7922). However, military products would not have in general many connections with High-Tech products (one out of eight connections, on average), while the opposite is true for Medium-Tech products (five out of eight).

With respect to the second hypothesis, which states that greater competitiveness of a country in health products would be positively correlated with the competitiveness in other product groups, results were also obtained that supported it. From the econometric exercise, it is inferred that the incidence would be significant and positive on related products –according to the criteria of Saviotti and Frenken 2006–, as well as on sophisticated products, both High-Tech and High and Medium-Tech products. As for the analysis of networks, the eighteen health products present connections, of which six are above average: pharmaceuticals (5419), medicaments (5417), glycosides and vaccines (5416), hormones (5415), X-ray equipment (7742) and electro-medical equipment (7741). Most of them also show many indirect connections –the exception is hormones (5415)–, while other products are central in terms of the network despite not having a large number of direct connections, the cases of antibiotics (5413) and vegetable alkaloids (5414).

However, the products with the greatest connections are not particularly notable for having connections with High-Tech products. The only exceptions are Electro-medical devices (7741) and Hormones (5415). As for defense products, the analysis of networks reveals that health products in general do not stand out for their connections with High-Tech products (four out of 29 connections, on average) and present many connections with Medium-Tech products (14 out of 29).

With respect to the third hypothesis, which states, in line with Ruttan (2006), that health technology systems would have a greater potential for generating variety than defense technology systems, the results seem to support it much more strongly. The results obtained in the econometric exercise correspond to those obtained in the analysis of networks: competitiveness in health products presents a stronger correlation with competitiveness in other groups of products, both related and sophisticated. The coefficients for health models are much higher than the coefficients for defense models in all the cases raised. On the other hand, the analysis of networks reveals a greater centrality of health products and a higher average of connections with sophisticated products (above all, of High-Tech, since for those of Medium-Tech it is similar).

## 5 Concluding remarks

This work has aimed to compare variety patterns of two technological systems: defense and health. The cases were chosen taking as inspiration the debate on the potential of certain technological systems to become central to the next long wave, and both cases have particularities. As has been said before, both are "knowledge-intensive" systems, where basic research has historically been of fundamental relevance, and both are systems where the search for variety is usually driven by the demand for specific social needs.

In this sense, we tested two general hypotheses (from which three specific hypotheses were inferred): i) that both technological systems have had potential to generate related variety and improve competitiveness, and ii) that health technological systems would have had more potential of variety generation than defense systems, as was suggested by Ruttan and other authors.

Based on the idea that technological relatedness is positively associated with the possibility of a system to generate variety through the recombination of knowledge from a common base, we analyzed two methods trying to infer variety generation from these technological systems. The results supported the first and the second specific hypotheses, which reveal the potential of related variety generation that both systems have had, even in terms of sophisticated sectors, whose firms (and systems in general) are supposed to have important absorptive capabilities to use and economically to exploit common knowledge bases. The results for third specific hypothesis supports that health technological systems could have more potential to generate related variety than defense systems, and this could be attributed to maturity of defense systems (based in an old metal-mechanical paradigm) and to a knowledge diffusion pattern mainly based on IPRs, much more open than a pattern based on industrial secret. In this sense, the four elements of technological relatedness identified by Boschma and Frenken (2009) are possibly highly present in health systems and they result in higher competitiveness for countries with past trajectories in health research and development. The results (specifically the higher related variety in health vis a vis defense) also could support the idea that health technological systems could be more effective in this term because they can exploit better local competencies and capabilities, while defense industries could have suffered an "offshoring pressure" in the last two decades (Yudken 2010).

These results can suggest two ideas as a corollary (which can stimulate future research). First, that there is empirical evidence from a technological system perspective to support Ruttan's hypothesis about the maturity of defense-related innovation and consolidation of biotechnologies. These results could be associated with the recent growth of works that announce or promote the strengthening of the military-industrial complex based mainly on bio-defense strategies (Armstrong et al. 2010; Dieuliis 2018; Thompson 2018).[14] Second, that re-emergence of mission-oriented policies in public

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[14] See Almeida (2015) for an overview of the historical relations between biotechnologies and defense objectives.

debate, associated mainly (but not only) with socio-economic health objectives (see UCL 2018; Mazzucato 2018), is a manifestation of the necessity of certain actors to promote a new agenda that can generate a new system with more technological opportunities (and more socially legitimate, especially after COVID-19 crisis) than defense systems. In this regard, if mission-oriented policies could strengthen countries' competitiveness in health sectors, that would probably generate spillovers on other related or proximate sectors, which can improve structural competitiveness and long term growth.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

## Appendix

### Countries and products

**Table 5** List of countries and their exports of military and health products

| Country | Is it in TIVA Database? | Exports of Military Prod. (2014) | Partic. | Exports of Health Prod. (2014) | Partic. |
|---|---|---|---|---|---|
| Algeria | | 20.00 | 0.01% | 3.77 | 0.00% |
| Angola | | 14.00 | 0.01% | 0.11 | 0.00% |
| Argentina | X | 380.00 | 0.16% | 552.00 | 0.16% |
| Australia | X | 864.00 | 0.37% | 1970.00 | 0.56% |
| Austria | X | 1200.00 | 0.52% | 5220.00 | 1.48% |
| Azerbaijan | | 20.80 | 0.01% | 5.63 | 0.00% |
| Bahrain | | 44.90 | 0.02% | 1.10 | 0.00% |
| Bangladesh | | 17.40 | 0.01% | 24.40 | 0.01% |
| Belarus | | 20.90 | 0.01% | 75.70 | 0.02% |
| Belgium-Luxembourg | X | 1840.00 | 0.80% | 19,300.00 | 5.49% |
| Bolivia | | 42.40 | 0.02% | 2.09 | 0.00% |
| Brazil | X | 3800.00 | 1.65% | 1060.00 | 0.30% |
| Brunei | X | 8.01 | 0.00% | 12.50 | 0.00% |
| Bulgaria | X | 50.00 | 0.02% | 369.00 | 0.10% |
| Burma | | 2.25 | 0.00% | 0.31 | 0.00% |
| Cambodia | X | 0.79 | 0.00% | 1.35 | 0.00% |
| Canada | X | 11,800.00 | 5.10% | 4000.00 | 1.14% |

**Table 5** (continued)

| Country | Is it in TIVA Database? | Exports of Military Prod. (2014) | Partic. | Exports of Health Prod. (2014) | Partic. |
|---|---|---|---|---|---|
| Chile | X | 88.50 | 0.04% | 101.00 | 0.03% |
| China | X | 2280.00 | 0.99% | 8740.00 | 2.49% |
| Colombia | X | 104.00 | 0.05% | 309.00 | 0.09% |
| Costa Rica | X | 17.10 | 0.01% | 167.00 | 0.05% |
| Cote d'Ivoire |  | 140.00 | 0.06% | 3.49 | 0.00% |
| Croatia | X | 95.50 | 0.04% | 342.00 | 0.10% |
| Czech Republic | X | 671.00 | 0.29% | 808.00 | 0.23% |
| Denmark | X | 438.00 | 0.19% | 7740.00 | 2.20% |
| Dominican Republic |  | 1.25 | 0.00% | 23.90 | 0.01% |
| Ecuador |  | 14.30 | 0.01% | 45.20 | 0.01% |
| Egypt |  | 48.00 | 0.02% | 159.00 | 0.05% |
| Equatorial Guinea |  | 25.60 | 0.01% | 0.01 | 0.00% |
| Estonia | X | 19.40 | 0.01% | 44.30 | 0.01% |
| Finland | X | 357.00 | 0.15% | 1070.00 | 0.30% |
| France | X | 40,700.00 | 17.65% | 25,900.00 | 7.36% |
| Gabon |  | 16.90 | 0.01% | 0.37 | 0.00% |
| Germany | X | 26,300.00 | 11.41% | 44,800.00 | 12.73% |
| Ghana |  | 31.70 | 0.01% | 5.53 | 0.00% |
| Greece | X | 227.00 | 0.10% | 789.00 | 0.22% |
| Guatemala |  | 2.49 | 0.00% | 145.00 | 0.04% |
| Honduras |  | 3.06 | 0.00% | 14.80 | 0.00% |
| Hong Kong | X | 1100.00 | 0.48% | 507.00 | 0.14% |
| Hungary | X | 377.00 | 0.16% | 1960.00 | 0.56% |
| Iceland | X | 109.00 | 0.05% | 88.60 | 0.03% |
| India | X | 1070.00 | 0.47% | 7100.00 | 2.02% |
| Indonesia | X | 175.00 | 0.08% | 508.00 | 0.14% |
| Iran |  | 59.30 | 0.03% | 58.80 | 0.02% |
| Iraq |  | 0.63 | 0.00% | 0.48 | 0.00% |
| Ireland | X | 938.00 | 0.41% | 44,400.00 | 12.64% |
| Israel | X | 1860.00 | 0.80% | 3610.00 | 1.03% |
| Italy | X | 5950.00 | 2.58% | 16,100.00 | 4.58% |
| Japan | X | 5060.00 | 2.20% | 7390.00 | 2.10% |
| Jordan |  | 67.60 | 0.03% | 430.00 | 0.12% |
| Kazakhstan |  | 150.00 | 0.07% | 10.40 | 0.00% |
| Kuwait |  | 59.00 | 0.03% | 14.30 | 0.00% |
| Latvia | X | 31.00 | 0.01% | 164.00 | 0.05% |
| Libya |  | 8.12 | 0.00% | 0.41 | 0.00% |
| Lithuania | X | 76.70 | 0.03% | 167.00 | 0.05% |
| Malaysia | X | 759.00 | 0.33% | 190.00 | 0.05% |
| Malta | X | 50.60 | 0.02% | 171.00 | 0.05% |
| Mexico | X | 1460.00 | 0.63% | 1510.00 | 0.43% |
| Morocco | X | 124.00 | 0.05% | 36.00 | 0.01% |
| Netherlands | X | 2380.00 | 1.03% | 13,200.00 | 3.75% |
| New Zealand | X | 135.00 | 0.06% | 182.00 | 0.05% |
| Nigeria |  | 43.90 | 0.02% | 4.41 | 0.00% |
| Norway | X | 1040.00 | 0.45% | 1140.00 | 0.33% |
| Oman |  | 88.80 | 0.04% | 36.20 | 0.01% |

**Table 5** (continued)

| Country | Is it in TIVA Database? | Exports of Military Prod. (2014) | Partic. | Exports of Health Prod. (2014) | Partic. |
|---|---|---|---|---|---|
| Pakistan | | 57.40 | 0.02% | 84.30 | 0.02% |
| Panama | | 15.50 | 0.01% | 756.00 | 0.22% |
| Papua New Guinea | | 14.90 | 0.01% | 0.14 | 0.00% |
| Peru | X | 26.30 | 0.01% | 26.50 | 0.01% |
| Philippines | X | 203.00 | 0.09% | 36.80 | 0.01% |
| Poland | X | 1040.00 | 0.45% | 1070.00 | 0.30% |
| Portugal | X | 268.00 | 0.12% | 576.00 | 0.16% |
| Qatar | | 52.60 | 0.02% | 2.62 | 0.00% |
| Republic of the Congo | | 11.00 | 0.00% | 1.39 | 0.00% |
| Romania | X | 345.00 | 0.15% | 322.00 | 0.09% |
| Russia | X | 2420.00 | 1.05% | 333.00 | 0.09% |
| Saudi Arabia | X | 702.00 | 0.30% | 162.00 | 0.05% |
| Serbia | | 56.10 | 0.02% | 134.00 | 0.04% |
| Singapore | X | 2400.00 | 1.04% | 8260.00 | 2.35% |
| Slovakia | X | 78.60 | 0.03% | 313.00 | 0.09% |
| Slovenia | X | 63.30 | 0.03% | 1410.00 | 0.40% |
| South Africa | X | 519.00 | 0.23% | 221.00 | 0.06% |
| South Korea | X | 1340.00 | 0.58% | 1310.00 | 0.37% |
| Spain | X | 3110.00 | 1.35% | 8310.00 | 2.37% |
| Sri Lanka | | 45.70 | 0.02% | 4.71 | 0.00% |
| Sudan | | 5.30 | 0.00% | 0.69 | 0.00% |
| Sweden | X | 1730.00 | 0.75% | 7100.00 | 2.02% |
| Switzerland | X | 3300.00 | 1.43% | 32,100.00 | 9.14% |
| Syria | | 8.16 | 0.00% | 45.70 | 0.01% |
| Thailand | X | 614.00 | 0.27% | 279.00 | 0.08% |
| Trinidad and Tobago | | 15.70 | 0.01% | 2.64 | 0.00% |
| Tunisia | X | 74.20 | 0.03% | 19.90 | 0.01% |
| Turkey | X | 740.00 | 0.32% | 480.00 | 0.14% |
| Turkmenistan | | 7.83 | 0.00% | 0.03 | 0.00% |
| Ukraine | | 687.00 | 0.30% | 135.00 | 0.04% |
| United Arab Emirates | | 748.00 | 0.32% | 218.00 | 0.06% |
| United Kingdom | X | 18,400.00 | 7.98% | 25,400.00 | 7.24% |
| United States | X | 76,500.00 | 33.17% | 39,400.00 | 11.20% |
| Uruguay | | 6.72 | 0.00% | 109.00 | 0.03% |
| Uzbekistan | | 11.80 | 0.01% | 3.78 | 0.00% |
| Venezuela | | 37.70 | 0.02% | 56.40 | 0.02% |
| Vietnam | X | 61.00 | 0.03% | 42.10 | 0.01% |
| Yemen | | 11.90 | 0.01% | 1.79 | 0.00% |
| Zambia | | 10.00 | 0.00% | 0.96 | 0.00% |
| **TOTAL** | **60** | **230,616.62** | **100.00%** | **351,512.62** | **100.00%** |
| **Herfindahl-Hirschman Index** | – | – | **0.166** | – | **0.074** |

Source: Own elaboration with data from BACI and TiVA-OECD

**Table 6** List of military products

| ITA-USDC (HS 1992) | Equiv. (SITC rev.4) | Description | ITA-USDC (HS 1992) | Equiv. (SITC rev.4) | Description |
|---|---|---|---|---|---|
| 360300 | 5722 | Safety or detonating fuses, detonators, igniters | 880250 | 7924 | Spacecraft, satellites and spacecraft launch vehicles |
| 840710 | 7131 | Aircraft engines, spark-ignition | 880310 | 7929 | Aircraft propellers, rotors and parts therof |
| 840910 | 7131 | Parts for spark-ignition aircraft engines | 880320 | 7929 | Aircraft under-carriages and parts thereof |
| 841111 | 7144 | Turbo-jet engines of a thrust <25 KN | 880330 | 7929 | Aircraft part nes |
| 841112 | 7144 | Turbo-jet engines of a thrust <25 KN | 880390 | 7929 | Parts of balloons, dirigibles, spacecraft |
| 841121 | 7148 | Turbo-propeller engines of a power < 1100 kW | 880400 | 8999 | Parachutes, parts and accessories thereof |
| 841122 | 7148 | Turbo-propeller engines of a power > 1100 kW | 880510 | 7928 | Aircraft launching and deck-arrestor gear, parts |
| 841181 | 7148 | Gas turbine engines nes of a power < 5000 kW | 880520 | 7928 | Flight simulators, parts thereof |
| 841182 | 7148 | Gas turbine engines nes of a power < 5000 kW | 890600 | 7931 | Warships, lifeboats, hospital ships, vessels nes |
| 841191 | 7149 | Parts of turbo-jet or turbo-propeller engines | 901420 | 8741 | Instruments nes for aeronautical/space navigation |
| 841199 | 7149 | Parts of gas turbine engines except turbo-propeller engines | 930100 | 9510 | Military weapons, other than hand guns, swords, etc |
| 871000 | 9510 | Tanks and other armoured fighting vehicles | 930590 | 9510 | Parts and accessories nes of weapons, nes |
| 880211 | 7921 | Helicopters of an unladen weight < 2000 kg | 930621 | 8946 | Cartridges, shotgun |
| 880212 | 7921 | Helicopters of an unladen weight < 2000 kg | 930629 | 8946 | Air gun pellets, parts of shotgun cartridges |
| 880220 | 7922 | Fixed wing aircraft, unladen weight < 2000 kg | 930630 | 9510 | Cartridges nes parts thereof |
| 880230 | 7923 | Fixed wing aircraft, unladen weight < 2000–15,000 kg | 930690 | 9510 | Munitions of war, ammunition/projectiles and parts |
| 880240 | 7924 | Fixed wing aircraft, unladen weight > 15,000 kg | 930700 | 9510 | Swords, cutlasses, bayonets, lances, scabbards, etc |

Source: Own elaboration with data from ITA-USDC

**Table 7** List of health products

| Health products | | | | | |
|---|---|---|---|---|---|
| ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description | ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description |
| 290550 | – | Derivatives of acyclic alcohols | 300331 | 5417 | Insulin, formulated, in bulk |
| 291822 | – | O-acetylsalicyclic acid, its salts & esters | 300339 | 5417 | Hormones nes, no antibiotics, bulk, not contraceptive |
| 292149 | – | Aromatic monoamines nes, derivatives, salts thereof | 300340 | 5417 | Alkaloids, derivs, without antibiotics, hormones, bul |
| 292219 | 5146 | Amino alcohols nes, their ethers and esters, salts | 300390 | 5417 | Medicaments nes formulated in bulk |
| 292230 | 5146 | Amino-aldehydes, ketones and quinones, salts thereof | 300410 | 5417 | Penicillins and streptomycins, derivs in dosage |
| 292241 | 5146 | Lysine, esters, salts thereof | 300420 | 5417 | Antibiotics nes, in dosage |
| 292249 | 5146 | Amino acids nes, esters, salts thereof | 300431 | 5417 | Insulin, in dosage |
| 292250 | 5146 | Amino-alcohol-phenols etc. with oxygen function | 300432 | 5417 | Adrenal cortical hormones, in dosage |
| 292410 | 5147 | Acyclic amides, derivatives, salts thereof | 300439 | 5417 | Hoemones nes, except caontraceptives, in dosage |
| 292429 | 5147 | Cyclic amides, derivatives, nes, salts thereof | 30440 | 5417 | Alkaloids, derivs, no antibiotics, hormones, in dosage |
| 292519 | 5148 | Imides, except saccharin, derivatives, salts thereof | 300540 | 5417 | Vitamins, derivatives, in dosage |
| 292520 | 5148 | Imines, derivatives, salts thereof300510 | 300490 | 5417 | Medicaments nes, in dosage |
| 293221 | 5156 | Coumarin, methylcoumarins and ethylcoumarins | 300510 | 5419 | Medical dressings etc., having an adhesive layer |
| 293311 | 5156 | Phenazone (antipyrin), derivatives | 300590 | 5419 | Medical dressings etc. except those with adhesive laye |
| 293339 | 5156 | Heterocyclic compounds with unfused pyridine ring, nes | 300610 | 5419 | Suture materails, sterile surgical and dental goods |
| 293340 | 5156 | Heterocyc compounds quinoline ring not further fused | 300620 | 5419 | Blood-grouping reagents |
| 293351 | 5148 | Barbituric acid, derivavtives, salts thereof | 300630 | 5419 | Opacifying preparations, x-ray, diagnostic reagents |
| 293359 | 5156 | Hetercyclic compounds with pyrimidine ring nes | 300640 | 5419 | Dental cements and other dental fillings, bone cement |
| 293379 | 5156 | Lactams other than 6-hexanelactam | 300650 | 5419 | First-aid boxes and kits |
| 293390 | 5148 | Heterocyclic compounds with N-hetero-atom(s) only, ne | 300600 | 5417 | Contraceptive preps based on hormones or spemicides |
| 293430 | 5156 | Heterocyclic compounds containing a phenothiazine rin | 340700 | – | Model, paste, dental paste and wax, etc |

**Table 7** (continued)

Health products

| ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description | ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description |
|---|---|---|---|---|---|
| 293490 | 5156 | Heterocyclic compounds, nes | 382100 | – | Prepared culture media for developing micro-organisms |
| 293500 | 5157 | Sulphonamides in bulk | 382200 | – | Composite diagnostic or laboratory reagents, nes |
| 293610 | 5411 | Provitamins, unmixed | 392690 | – | Plastic articles nes |
| 293621 | 5411 | Vitamins, A, derivavtives, unmixed | 401511 | 8482 | Rubber surgical gloves |
| 293622 | 5411 | Vitamin B1, derivavtives, unmixed | 401519 | 8482 | Gloves other than surgical, of rubber |
| 293623 | 5411 | Vitamin B2, derivavtives, unmixed | 420610 | – | Articles of catgut |
| 293624 | 5411 | Vitamins B3 & B5, D-or DL-panthothenic acid, derivative | 650610 | – | Safety headgear |
| 293625 | 5411 | Vitamin B6, derivatives, unmixed | 681250 | – | Asbestos fabricated products nes |
| 293626 | 5411 | Vitamin B12, derivatives, unmixed | 681290 | – | Medical, surgical or laboratory sterilizers |
| 293627 | 5411 | Vitamin C, derivatives, unmixed | 841920 | – | Medical, surgical or laboratory sterilizers |
| 293628 | 5411 | Vitamin E, derivatives, unmixed | 841990 | – | Parts, laboratory/industrial heating/cooling machiner |
| 293629 | 5411 | Vitamins nes, derivatives, unmixed | 854380 | – | Electrical machines and apparatus, nes |
| 293690 | 5411 | Vitamin concentrates, intermixtures of vitamins | 871310 | – | Wheelchairs not mechanically propelled |
| 293710 | 5415 | Pituitary anterior hormones and derivatives, in bulk | 871390 | – | Wheelchairs, mechanically propelled |
| 293721 | 5415 | Cortisone, hydrocortisone, prednisone, prednisolone, bul | 871420 | – | Wheelchair parts |
| 293722 | 5415 | Halogenated derivs adrenalal cortical hormones, bulk | 901811 | 7741 | Electro-cardiographs |
| 293729 | 5415 | Adrenal cortical hormones nes, in bulk, derivatives | 901819 | 7741 | Electro-diagnostic apparatus, nes |
| 293791 | 5415 | Insulin, salts, in bulk | 901820 | 7741 | Ultra-violet or infra-red ray apparatus |
| 293792 | 5415 | Oestrogens and progestogens, in bulk | 901831 | 8720 | Syringes, with or without needles |
| 293799 | 5415 | Hormones nes, derivavtives, in bulk, steroids nes | 901832 | 8720 | Tubular metal needles and needles for sutures |
| 293810 | 5416 | Rutoside (rutin), derivavtives, in bulk | 901839 | 8720 | Needles, catheters, cannulae etc., (medical) |

**Table 7** (continued)

| Health products | | | | | |
|---|---|---|---|---|---|
| ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description | ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description |
| 293890 | 5416 | Glycosides and salts, ethers, esters, derivs, in bulk, salts thereof | 901841 | 8720 | Dental drill engines |
| 293910 | 5414 | Opium alkaloids, their derivs, in bulk, salts thereof | 901849 | 8720 | Instruments and appliances, used in dentistry |
| 293921 | 5414 | Quinine, salts, in bulk | 901850 | 8720 | Ophthalmic instruments and appliances |
| 293929 | 5414 | Cinchona, alkaloids, derivatives nes, in bulk salts | 901890 | 8720 | Instruments and appliances, used in dentistry |
| 293930 | 5414 | Caffeine, salts, in bulk | 901910 | 8720 | Massage and psychological aptitude-test apparatus |
| 293940 | 5414 | Ephedrines, salts, in bulk | 901920 | 8720 | Therapeutic respiration apparatus |
| 293950 | 5414 | Theophylline and aminophylline, derivs, in bulk, salt | 902000 | 8720 | Massage and psychological aptitude-test apparatus |
| 293960 | 5414 | Rye ergot alkaloids, derivavtives, in bulk, salts | 902111 | 8996 | Therapeutic respiration apparatus |
| 293970 | 5414 | Nicotine, salts, in bulk | 902119 | 8996 | Breathing appliances and gas masks |
| 293990 | 5414 | Vegetable alkaloids nes, salts, ethers, esters in bul | 902121 | 8996 | Artificial joints |
| 294110 | 5413 | Penicillins, derivatives, in bulk, salts | 902129 | 8996 | Orthopaedic/fracture appliances, nes |
| 294120 | 5413 | Streptomycins, derivavtives, in bulk, salts | 902130 | 8996 | Artificial teeth |
| 294130 | 5413 | Tetracyclines, derivatives, in bulk, salts | 902140 | 8996 | Dental fittings, nes |
| 294140 | 5413 | Chloramphenicol, derivatives. in bulk, salts | 902150 | 8996 | Artificial body parts, aids and appliances, etc |
| 294150 | 5413 | Erythromycin, Derivatives, in bulk, salts | 902190 | 8996 | Hearing aids, except parts and accessories |
| 294190 | 5413 | Antibiotics nes, in bulk | 902211 | 8996 | Pacemakers for stimulating heart muscles |
| 300110 | 5413 | Glands and other organs, dried, for therapeutic uses | 902219 | 7742 | Orthopaedic appliances, nes |
| 300120 | 5416 | Extracts of glands etc. for therapeutic use | 902221 | 7742 | Medical X-rat apparatus |
| 300190 | 5416 | Heparin, salts, for therapeutic use | 902229 | 7742 | Non-medical apparatus using alpha/beata/gamma radiatio |
| 300210 | 5416 | Antisera and other blood fractions | 902230 | 7742 | X-ray tubes |
| 300220 | 5416 | Vaccines, human use | 902290 | 7742 | Parts and accessories for radiation apparatus |

**Table 7** (continued)

| Health products | | | | | |
|---|---|---|---|---|---|
| ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description | ITA-USDC (HS 1992) | Equiv. (SITC rev. 4) | Description |
| 300239 | 5416 | Vaccines, veterinary use, except foot and mouth | 902511 | 8745 | Thermometers, liquid-filled |
| 300290 | 5416 | Blood, toxins, cultures, medical use, nes | 902519 | 8745 | Thermometers, except, liquid filled |
| 300310 | 5417 | Penicillins or streptomycins and derivatives, in bulk | 940210 | – | Dentists, barbers or similar chairs and parts |
| 300320 | 5417 | Antibiotics nes, formulated, in bulk | 970600 | – | Antiques older than one hundred years |

Source: Own elaboration with data from ITA-USDC

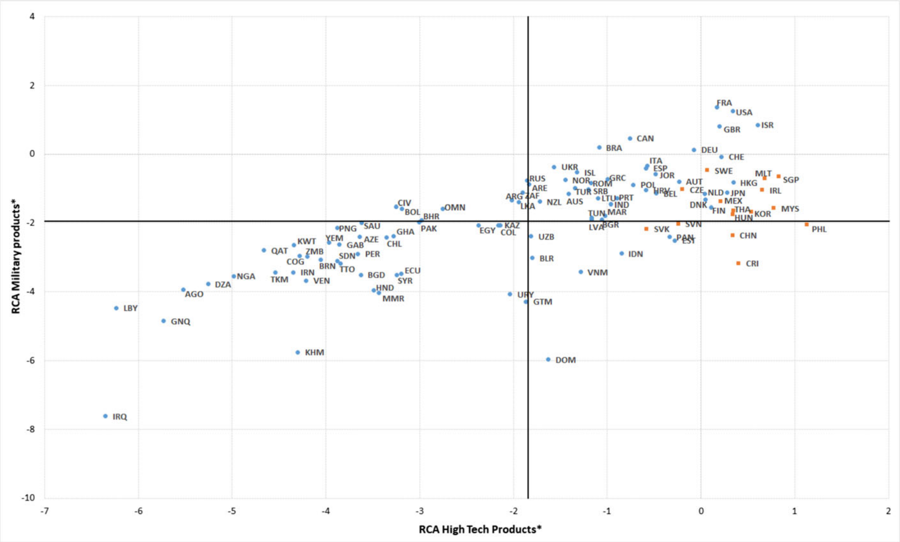


**Fig. 5** RCA (normalized) of high tech products vis a vis RCA (normalized) of military products. Mean 1995–2014

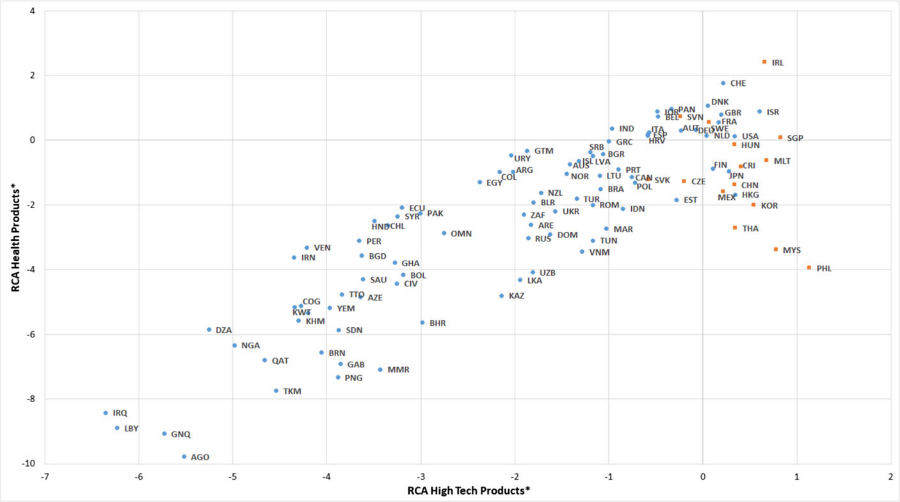


**Fig. 6** RCA (normalized) of high tech products vis a vis RCA (normalized) of health products. Mean 1995–2014

## Methodological notes

### Network analysis

The proximity matrix in which this analysis is based, as well as the procedure for its production, can be obtained from http://chidalgo.org/productspace/index.htm. Although the network analysis of this work is done on the same proximity matrix established by Hidalgo et al., the construction of the network by these authors follows methodologies that differ from those used in this work to deploy the sub-networks described in Figs. 3 and 4.

On the one hand, Hidalgo et al. (2007) use the following methods: Maximum Spanning Tree, Strongest Links (considering those links with proximity greater than or equal to 0.55), and a Force Spring Algorithm display.

On the other hand, in this work we represent the binary networks only with the Strongest Links method. For the construction of the binary matrix (composed by "zeros" and "ones"), the proximity threshold was defined at 0.40, which (although less than 0.55 established by Hidalgo et al.) is a fairly demanding measure, as it exceeds 96% of the observations in the matrix (the average proximity of the network is 0.168). This assures that the connections that persist will have a high level of proximity. Following this, only the proximity levels greater than or equal to 0.40 were replaced by "ones", and "zero" values were assigned to the rest of the levels.

Regarding the analysis, four centrality measures were assessed:

- **Degree:** It measures direct connections of a specific node (Freeman 1979; Borgatti 2005). A node is important in a network if it has many connections.
- **2 Step:** It measures, for every specific node, the number of paths of longitude equal to 1 or 2 (Sade 1989; Borgatti and Everett 2006).
- **Closeness:** It calculates the sum of the shortest distances from one node to all others (Freeman 1979). This indicator tries to represent purely the centrality of a product, in the literal sense of being located nearer to the center of the network (closer to most of the products).
- **Eigenvector:** This indicator adds to the other notions of centrality a dimension of quality. In other words, it measures whether a node has many connections with nodes that are well connected (Bonacich 1972, 1991).

### Econometric analysis

- Results without controlling by ICOE

***Set 1.B (Defense products): Without controlling by Import Content of Exports.***

| | |
|---|---|
| **Model A:** | $RCAREL_{i,t} = \beta_0 + \beta_1 RCAMIL_{i,t} + \beta_2 GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |
| **Model B:** | $RCAHT^{-MIL}_{i,t} = \beta_0 + \beta_1\ RCAMIL_{i,t} + \beta_2\ GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |
| **Model C:** | $RCAHMT^{-MIL}_{i,t} = \beta_0 + \beta_1\ RCAMIL_{i,t} + \beta_2\ GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |

***Set 2.B (Health products): Without controlling by Import Content of Exports.***

| | |
|---|---|
| **Model A:** | $RCAREL_{i,t} = \beta_0 + \beta_1 RCAHEA_{i,t} + \beta_2 GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |
| **Model B:** | $RCAHT_{i,t}^{-HEA} = \beta_0 + \beta_1\ RCAHEA_{i,t} + \beta_2\ GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |
| **Model C:** | $RCAHMT_{i,t}^{-HEA} = \beta_0 + \beta_1\ RCAHEA_{i,t} + \beta_2\ GDPPC_{i,t} + \eta_t + v_i + \mu_{i,t}$ |

As was said in the paper, we ran the models without controlling by the effect of global value chains (import content of exports) both in broad (103 countries, 20 years) and narrow (60 countries, 17 years) databases. The results are presented in Table 8, and are in line with the results obtained from the models with ICOE control.

- Results for Hausman Test

In panel data models, OLS estimators can fail if there are endogenous regressors, because variables can be correlated with the error term. Then, to know which is the correct specification for the model to choose the appropriate regression method that reduces endogeneity, we ran the Hausman test.

Results for Hausman test are presented in Tables 9 and 10.We present also here the results for Hausman test of the model without "import content of exports" control on the narrow database.

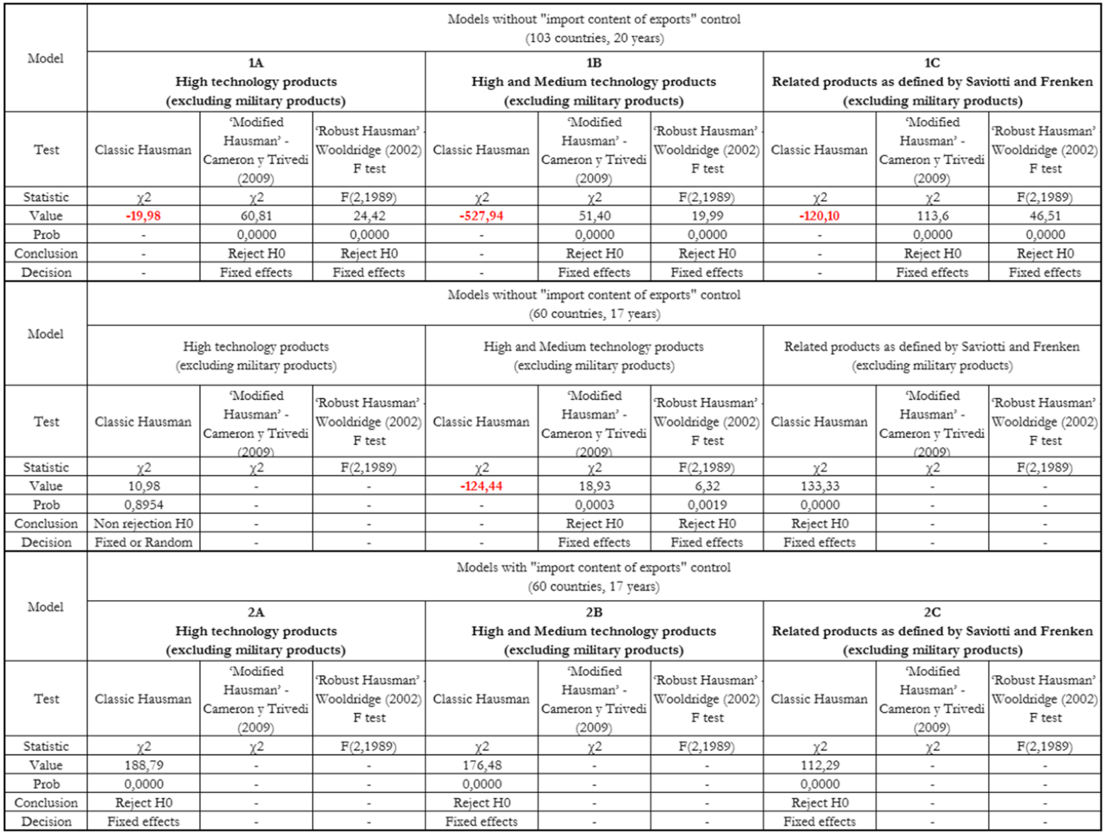
In some cases for military products, there is a negative value for $\chi^2$statistic. For this reason, we used methodologies that make modifications on the Hausman version, in particular, the methodologies of Cameron and Trivedi (2009) and Wooldridge (2002), which lead to reject H0 and to prefer the fixed effects estimates for these models.

**Table 8** Results for models without ICOE control

| Model | Models without "import content of exports" control (103 countries, 20 years) | | | | | | | | | | | | Models without "import content of exports" control (60 countries, 17 years) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Defense models | | | | | | Health models | | | | | | Defense models | | | | | | Health models | | | | | |
| | Related products | | High technology | | High and Medium | | Related products | | High technology | | High and Medium | | Related products | | High technology | | High and Medium | | Related products | | High technology | | High and Medium | |
| | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE | Pooled | FE |
| Beta1 | 0.391*** | 0.079*** | 0.759*** | 0.127*** | 0.572*** | 0.123*** | 0.454*** | 0.219*** | 0.913*** | 0.219*** | 0.611*** | 0.314*** | 0.748*** | 0.060* | 0.364*** | 0.094*** | 0.366*** | 0.080*** | 0.741*** | 0.423*** | 0.594*** | 0.105*** | 0.446*** | 0.196*** |
| ln (pbi pc) | 0.382*** | 0.214*** | 0.399*** | -0.027 | 0.375*** | 0.126* | 0.243*** | 0.313*** | -0.106** | -0.382** | 0.216*** | 0.339*** | -0.001 | 0.729*** | 0.099* | 0.570*** | -0.001 | 0.465*** | -0.143*** | 0.426*** | 0.087** | 0.674*** | 0.071*** | 0.545*** |
| 1995 (base) | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . | . |
| 1996 | -0.018 | 0.027 | 0.044 | 0.137 | -0.002 | 0.077 | 0.033 | 0.066 | -0.078 | 0.084 | 0.086 | 0.127 | 0.009 | 0.003 | 0.084 | 0.097* | 0.025 | 0.029 | 0.010 | 0.002 | 0.029 | 0.058 | -0.006 | -0.000 |
| 1997 | 0.065 | 0.092 | 0.133 | 0.194* | 0.089 | 0.126* | -0.020 | 0.023 | -0.154 | 0.092 | -0.003 | 0.048 | 0.042 | -0.037 | 0.144 | 0.118** | 0.081 | 0.046 | -0.013 | 0.009 | 0.040 | 0.057 | 0.003 | -0.006 |
| 1998 | 0.145 | 0.162*** | 0.217 | 0.313*** | 0.198 | 0.221*** | 0.080 | 0.117* | -0.050 | 0.208 | 0.157 | 0.199** | 0.158 | -0.024 | 0.232 | 0.155*** | 0.139 | 0.052 | -0.036 | -0.070 | 0.100 | 0.080 | 0.023 | -0.010 |
| 1999 | 0.038 | 0.081 | 0.025 | 0.181* | 0.047 | 0.126* | 0.074 | 0.082 | -0.136 | 0.101 | 0.124 | 0.145* | -0.016 | -0.120 | 0.133 | 0.087 | 0.080 | 0.025 | -0.180 | -0.231** | 0.076 | 0.032 | 0.030 | -0.020 |
| 2000 | -0.054 | -0.005 | -0.001 | 0.161 | -0.145 | -0.043 | -0.034 | -0.035 | -0.234 | -0.007 | -0.042 | -0.036 | -0.068 | -0.181* | 0.074 | 0.012 | 0.058 | -0.011 | -0.193 | -0.272** | 0.111 | 0.012 | 0.054 | -0.036 |
| 2001 | 0.045 | 0.081 | 0.124 | 0.233** | -0.009 | 0.058 | 0.044 | 0.030 | -0.015 | 0.170 | 0.002 | -0.010 | 0.066 | -0.113 | 0.173 | 0.077 | 0.147 | 0.043 | -0.073 | -0.195* | 0.207 | 0.053 | 0.134 | 0.008 |
| 2002 | 0.082 | 0.136** | 0.128 | 0.269** | -0.024 | 0.089 | 0.121 | 0.091 | -0.102 | 0.043 | 0.081 | 0.048 | 0.084 | -0.101 | 0.153 | 0.047 | 0.125 | 0.012 | -0.143 | -0.283** | 0.183 | 0.013 | 0.119 | -0.022 |
| 2003 | 0.020 | 0.111* | 0.036 | 0.295*** | -0.073 | 0.091 | 0.112 | 0.093 | -0.179 | 0.018 | 0.078 | 0.057 | 0.105 | -0.064 | 0.158 | 0.050 | 0.119 | 0.006 | -0.025 | -0.194* | 0.230 | 0.027 | 0.146 | -0.019 |
| 2004 | -0.020 | 0.138** | 0.003 | 0.368*** | -0.207 | 0.053 | 0.159 | 0.120* | -0.323 | -0.074 | 0.102 | 0.067 | 0.184 | -0.033 | 0.151 | 0.013 | 0.147 | 0.003 | -0.115 | -0.300** | 0.180 | -0.029 | 0.137 | -0.043 |
| 2005 | -0.030 | 0.124* | -0.048 | 0.317*** | -0.251 | 0.005 | 0.114 | 0.078 | -0.092 | 0.111 | 0.043 | 0.009 | 0.178 | -0.059 | 0.131 | -0.028 | 0.127 | -0.037 | -0.130 | -0.347*** | 0.174 | -0.064 | 0.122 | -0.085* |
| 2006 | -0.028 | 0.107 | 0.043 | 0.374*** | -0.207 | 0.020 | 0.126 | 0.061 | -0.218 | 0.010 | 0.063 | -0.011 | 0.296 | 0.031 | 0.139 | -0.048 | 0.150 | -0.040 | -0.113 | -0.381*** | 0.202 | -0.087 | 0.156 | -0.093* |
| 2007 | 0.002 | 0.168** | 0.059 | 0.461*** | -0.133 | 0.140* | 0.157 | 0.102 | -0.211 | 0.085 | 0.130 | 0.068 | 0.346 | -0.011 | 0.139 | -0.098 | 0.151 | -0.089 | -0.160 | -0.472*** | 0.217 | -0.121 | 0.146 | -0.141** |
| 2008 | 0.007 | 0.205*** | 0.078 | 0.550*** | -0.228 | 0.092 | 0.193* | 0.137* | -0.282 | 0.022 | 0.146 | 0.079 | 0.323 | 0.014 | 0.133 | -0.094 | 0.159 | -0.069 | -0.195 | -0.517*** | 0.244 | -0.094 | 0.163 | -0.132** |
| 2009 | 0.062 | 0.253*** | 0.176 | 0.633*** | -0.126 | 0.183** | 0.196* | 0.159** | -0.084 | 0.311* | 0.097 | 0.054 | 0.462* | 0.139 | 0.171 | -0.059 | 0.178 | -0.055 | -0.006 | -0.323** | 0.218 | -0.116 | 0.166 | -0.125** |
| 2010 | 0.091 | 0.265*** | 0.167 | 0.590*** | -0.173 | 0.111 | 0.197* | 0.153* | 0.116 | 0.455** | -0.027 | -0.079 | 0.400 | 0.057 | 0.149 | -0.098 | 0.195 | -0.053 | -0.128 | -0.447*** | 0.130 | -0.193** | 0.143 | -0.151** |
| 2011 | -0.001 | 0.178** | -0.039 | 0.399*** | -0.179 | 0.113 | 0.108 | 0.062 | -0.062 | 0.298 | -0.022 | -0.078 | 0.308 | -0.018 | 0.154 | -0.096 | 0.188 | -0.062 | -0.064 | -0.408** | 0.167 | -0.179* | 0.157 | -0.158*** |
| 2012 | 0.006 | 0.223*** | -0.214 | 0.305** | -0.302 | 0.045 | 0.166 | 0.118 | 0.002 | 0.394** | -0.028 | -0.090 | . | . | . | . | . | . | . | . | . | . | . | . |
| 2013 | 0.038 | 0.244*** | -0.005 | 0.496*** | -0.248 | 0.084 | 0.211* | 0.143* | 0.062 | 0.439** | -0.017 | -0.104 | . | . | . | . | . | . | . | . | . | . | . | . |
| 2014 | 0.019 | 0.175** | 0.017 | 0.419*** | -0.176 | 0.092 | 0.124 | 0.053 | 0.060 | 0.372* | -0.009 | -0.096 | . | . | . | . | . | . | . | . | . | . | . | . |
| _cons | -4.046*** | -3.182*** | -4.821*** | -2.312** | -4.140*** | -2.861*** | -2.716*** | -3.798*** | 0.538 | 0,172 | -2.798*** | -4.491*** | -0.563 | -8.294*** | -1.379** | -6.144*** | -0.118 | -4.852*** | 0.958* | -4.620*** | -1.340*** | -7.223*** | -0.917*** | -5.538*** |
| R$^2$ "between" | . | 0.366 | . | 0.54 | . | 0.393 | . | 0.698 | . | 0.407 | . | 0.633 | . | 0.145 | . | 0.100 | . | 0.138 | . | 0.291 | . | 0.148 | . | 0.289 |
| R$^2$ "within" | . | 0.119 | . | 0.064 | . | 0.076 | . | 0.138 | . | 0.033 | . | 0.103 | . | 0.212 | . | 0.156 | . | 0.240 | . | 0.081 | . | 0.137 | . | 0.276 |
| R$^2$ "overall" | . | 0.313 | . | 0.270 | . | 0.327 | . | 0.632 | . | 0.286 | . | 0.581 | . | 0.144 | . | 0.099 | . | 0.138 | . | 0.252 | . | 0.147 | . | 0.288 |
| sigma_u | . | 0.126 | . | 0.205 | . | 0.182 | . | 0.862 | . | 0.221 | . | 0.126 | . | 0.150 | . | 0.124 | . | 0.848 | . | 0.131 | . | 0.121 | . | 0.756 |
| sigma_e | . | 0.431 | . | 0.737 | . | 0.476 | . | 0.438 | . | 0.971 | . | 0.564 | . | 0.506 | . | 0.303 | . | 0.213 | . | 0.550 | . | 0.345 | . | 0.212 |
| rho | . | 0.895 | . | 0.886 | . | 0.936 | . | 0.795 | . | 0.838 | . | 0.833 | . | 0.897 | . | 0.944 | . | 0.941 | . | 0.851 | . | 0.924 | . | 0.927 |
| N | 1994 | 1994 | 1985 | 1985 | 1994 | 1994 | 2003 | 2003 | 1896 | 1896 | 2003 | 2003 | 1018 | 1018 | 1019 | 1019 | 1019 | 1019 | 1014 | 1014 | 1020 | 1020 | 1020 | 1020 |

Source: Own elaboration based on panel data

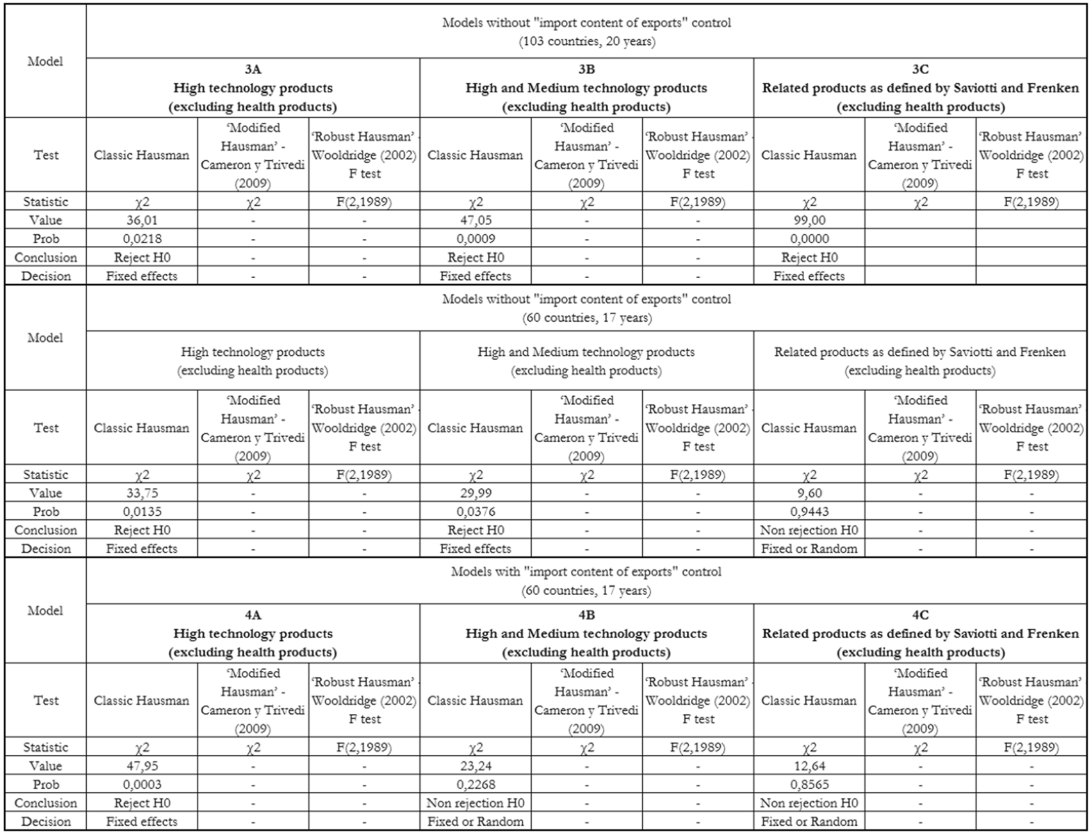
**Table 9** Results for Hausman test (Models for Military products)



| Model | Models without "import content of exports" control (103 countries, 20 years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1A<br>High technology products<br>(excluding military products)** | | | **1B<br>High and Medium technology products<br>(excluding military products)** | | | **1C<br>Related products as defined by Saviotti and Frenken<br>(excluding military products)** | | |
| Test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | -19,98 | 60,81 | 24,42 | -527,94 | 51,40 | 19,99 | -120,10 | 113,6 | 46,51 |
| Prob | - | 0,0000 | 0,0000 | - | 0,0000 | 0,0000 | - | 0,0000 | 0,0000 |
| Conclusion | - | Reject H0 | Reject H0 | - | Reject H0 | Reject H0 | - | Reject H0 | Reject H0 |
| Decision | - | Fixed effects | Fixed effects | - | Fixed effects | Fixed effects | - | Fixed effects | Fixed effects |
| Model | Models without "import content of exports" control (60 countries, 17 years) | | | | | | | | |
| | High technology products<br>(excluding military products) | | | High and Medium technology products<br>(excluding military products) | | | Related products as defined by Saviotti and Frenken<br>(excluding military products) | | |
| Test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | 10,98 | - | - | -124,44 | 18,93 | 6,32 | 133,33 | - | - |
| Prob | 0,8954 | - | - | - | 0,0003 | 0,0019 | 0,0000 | - | - |
| Conclusion | Non rejection H0 | - | - | - | Reject H0 | Reject H0 | Reject H0 | - | - |
| Decision | Fixed or Random | - | - | - | Fixed effects | Fixed effects | Fixed effects | - | - |
| Model | Models with "import content of exports" control (60 countries, 17 years) | | | | | | | | |
| | **2A<br>High technology products<br>(excluding military products)** | | | **2B<br>High and Medium technology products<br>(excluding military products)** | | | **2C<br>Related products as defined by Saviotti and Frenken<br>(excluding military products)** | | |
| Test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' - Wooldridge (2002) F test | Classic Hausman | 'Modified Hausman' - Cameron y Trivedi (2009) | 'Robust Hausman' Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | 188,79 | - | - | 176,48 | - | - | 112,29 | - | - |
| Prob | 0,0000 | - | - | 0,0000 | - | - | 0,0000 | - | - |
| Conclusion | Reject H0 | - | - | Reject H0 | - | - | Reject H0 | - | - |
| Decision | Fixed effects | - | - | Fixed effects | - | - | Fixed effects | - | - |

Source: Own elaboration based on panel data

**Table 10** Results for Hausman test (Models for Health products)



| Model | Models without "import content of exports" control (103 countries, 20 years) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **3A<br>High technology products (excluding health products)** | | | **3B<br>High and Medium technology products (excluding health products)** | | | **3C<br>Related products as defined by Saviotti and Frenken (excluding health products)** | | |
| Test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | 36,01 | - | - | 47,05 | - | - | 99,00 | | |
| Prob | 0,0218 | - | - | 0,0009 | - | - | 0,0000 | | |
| Conclusion | Reject H0 | - | - | Reject H0 | - | - | Reject H0 | | |
| Decision | Fixed effects | - | - | Fixed effects | - | - | Fixed effects | | |
| Model | Models without "import content of exports" control (60 countries, 17 years) | | | | | | | | |
| | High technology products (excluding health products) | | | High and Medium technology products (excluding health products) | | | Related products as defined by Saviotti and Frenken (excluding health products) | | |
| Test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | 33,75 | - | - | 29,99 | - | - | 9,60 | - | - |
| Prob | 0,0135 | - | - | 0,0376 | - | - | 0,9443 | - | - |
| Conclusion | Reject H0 | - | - | Reject H0 | - | - | Non rejection H0 | - | - |
| Decision | Fixed effects | - | - | Fixed effects | - | - | Fixed or Random | - | - |
| Model | Models with "import content of exports" control (60 countries, 17 years) | | | | | | | | |
| | **4A<br>High technology products (excluding health products)** | | | **4B<br>High and Medium technology products (excluding health products)** | | | **4C<br>Related products as defined by Saviotti and Frenken (excluding health products)** | | |
| Test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ - Wooldridge (2002) F test | Classic Hausman | ‘Modified Hausman’ - Cameron y Trivedi (2009) | ‘Robust Hausman’ Wooldridge (2002) F test |
| Statistic | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) | χ2 | χ2 | F(2,1989) |
| Value | 47,95 | - | - | 23,24 | - | - | 12,64 | - | - |
| Prob | 0,0003 | - | - | 0,2268 | - | - | 0,8565 | - | - |
| Conclusion | Reject H0 | - | - | Non rejection H0 | - | - | Non rejection H0 | - | - |
| Decision | Fixed effects | - | - | Fixed or Random | - | - | Fixed or Random | - | - |

Source: Own elaboration based on panel data

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