SCHUMPETERIAN LOOPS IN INTERNATIONAL TRADE: THE EVIDENCE OF THE OECD COUNTRIES

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SCHUMPETERIAN LOOPS IN INTERNATIONAL TRADE: THE EVIDENCE OF THE OECD COUNTRIES [1]

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ABSTRACT

The paper shows how and why international trade and endogenous technological change are part of a Schumpeterian loop in advanced countries. Imports stir the creative response of firms exposed to global competition and engender the introduction of productivity-enhancing innovations that are contingent upon the knowledge and competence available in each industry. The introduction of new industry-specific technologies augments both productivity and exports. The long-term empirical evidence of the manufacturing industries of 13 OECD countries from 1995 to 2015 fully confirms the Schumpeterian loop.

KEY WORDS: Heckscher-Ohlin; localized learning; creative response; industry-specific technological change.

JEL CODES: O33; F12.

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1. INTRODUCTION

The Schumpeterian loop is a spiraling dynamic process that takes place when technological change is determined by changes in product and factor markets and engenders, in turn, new changes in product and factor markets. Therefore, both technological and market changes are reciprocally endogenous. The Schumpeterian notion of creative response provides the basic stone upon which the Schumpeterian loop can be understood and takes place when firms try and cope by means of the introduction of innovations to out-of-equilibrium changes in product and factor markets.

The fast rates of globalization of international product markets and the sharp increase of horizontal intra-industry trade in international product markets question the traditional assumptions of the Heckscher and Ohlin (HO) approach and the advances of the global value chain analyses that focus the inter-industrial and vertical characters of international trade. The increasing evidence about intra-industrial trade calls for the grafting of the Schumpeterian loop to analyze the dynamics of international trade through the integration of the tools elaborated by international economics and the economics of innovation and knowledge.

Increasing literature has explored the relationship between globalization and the rate of technological change. Much attention has been paid to the relationship between exports and rates of innovation (Bernard et al., 2007; Aghion et al., 2018; Fassio, 2018). An important contribution has been made by the literature that has identified the positive effects of the imports on the value chain of incumbents with eventual positive effects on their international competitiveness (Bas and Strauss-Kahn, 2014). Lesser attention has been paid to the relationship between imports, the rates of technological change, the increased competitiveness of incumbents within the same industry, and the increase of exports.

With a pathbreaking contribution, Scherer and Huh (1992) explored the reaction of US firms to high-technology imports competition. Their results suggest that the reaction of firms aggressed in their domestic markets lead to an increase of the research and development (R&D) spending that was larger the stronger the concentration of the industry, the higher the levels of diversification of the firms, the larger their size and their multinational scope of action. Bloom et al. (2016) investigate the effect of Chinese imports on patenting, productivity, and investment in information technology across a broad set of firms based in twelve European countries from 1996 to 2007. Their evidence suggests that the increase in imports from China induced faster technological change both in terms of the introduction and the adoption of new technologies. The pressure of increasing imports triggered the selection of incumbents favoring the exit of less productive firms, fastened the diffusion of new existing technologies, and, finally, pushed the introduction of more innovations. Autor et al. (2018) analyze the response of US firms to Chinese imports and find strong negative effects on R&D expenditures, innovation, and patents. Similarly, Ghazalian (2012) shows that in the food sector over the period 1987-2006, an increase in imports in the OECD countries reduces private R&D expenditures. Yet Chen, Zhang, and Zheng (2017) provide reliable empirical evidence on the positive effects of imports on Chinese incumbents that increase R&D expenditures to cope with the increasing challenge of foreign competitors. Rivera Batiz and

Romer (1991) integrate international trade in the endogenous growth theory and stress the positive role of the imports of cheaper intermediary inputs - with particular attention to the role of knowledge- for the competitive advantage of downstream users.

The literature that looks at vertical trade has identified the positive effects exerted by imports on exports, mainly through imported intermediate and capital goods with some embodied technology, which eventually allow companies to upgrade their products, and possibly also export. For example, the import of advanced spinning machinery or sophisticated yarns used to produce textile products in Italy will be an inter-industrial vertical type of trade for Italian textiles companies that buy that machine or intermediate good and are -consequently- better able to compete on international markets (Lo Turco and Maggioni, 2013; Damijan and Kostevc, 2015).

The analysis of the positive loops between import and export within the same industry can be implemented by an approach that investigates the import competition effect, i.e. the results of the part of imports that represents a substitution for domestic products that stirs the creative response of incumbents, the introduction of innovations, and the eventual increase of their international competitiveness.

The integration of the classic trade literature with the Schumpeterian literature provides the tools to explore the positive loop grafting on the international trade theory and the framework of the creative response (Schumpeter, 1947; Antonelli, 2017 and 2019).

In this set-up, the introduction of technological change is endogenous as it is the outcome of the creative response that takes place when firms try to cope with changes in product and factor markets and can rely upon the knowledge externalities made possible by localized learning and competence. The successful outcome of the creative response triggers the introduction of localized innovations that favor productivity and competitivity. The introduction of new technologies is highly industry-specific as it takes place primarily in the industries where each country has a competitive advantage and stronger learning opportunities (Leamer, 1996; Lööf et al., 2015).

The application of this framework to international trade suggests that the following Schumpeterian loop may take place: 1) the increase of imports engenders out-of-equilibrium conditions that 2) lead to the creative response of incumbents 3) contingent upon the stock of knowledge and competence available in the industry and 4) the introduction of new technologies that 5) trigger larger productivity that, in turn, 6) favors exports in the same industry.

Using the STAN database from 1995 to 2015 at the manufacturing level of 13 OECD countries, we confirm that imports, localized and industry-specific technological change, and exports are part of a Schumpeterian loop where each exerts causal effects on the others in a historic long-term spiraling relationship.

The rest of the paper investigates this relationship. Section 2 elaborates on a unifying framework to articulate the Schumpeterian loop. Section 3 provides the empirical analysis to test the loop. Section 4 summarizes the results. Finally, Appendix shows the robustness checks.

2. THE SCHUMPETERIAN LOOP

2.1 THE BUILDING BLOCKS

The Schumpeterian creative response framework can be used to enrich the traditional theory of international trade based upon the HO model and its recent advances based upon the analyses of global value chains and elaborate a dynamic analysis of intra-industrial (horizontal) trade. Let us start with a brief review of the HO frame.

According to the HO basic model, some countries specialize in the production and export of goods that are imported by other countries that, in turn, specialize in the production and exports of other goods. The possibility frontiers of the two trading countries are assumed to be asymmetric: capital abundant countries produce capital abundant goods, and labor abundant countries produce labor abundant goods. The asymmetric shape of the possibility frontiers is assumed as exogenous, static, and no explanation is provided about its actual determinants. In the well-known equilibrium solution, labor abundant countries export labor abundant goods, and capital abundant countries export capital abundant ones. The entry of new -labor abundant- countries in the global market yields the reorganization of international product markets through new flows of exports of labor-intensive goods from labor abundant countries and new flows of capital-intensive exports from capital abundant countries.

International trade in the HO framework is exclusively vertical and inter-industrial: countries export some goods and import others. In the HO model, moreover, there is no account of the endogenous dynamics of technological change: how trade itself may trigger the introduction of new technologies and how it affects the specialization of trading countries (Dosi et al., 1990).

Recent developments in the analysis of international value chains have renewed the interest in vertical trade stressing the role of technological change and the effects of imports of upstream intermediary products to support the exports of downstream industries. As in the HO model, the global value chain approach concludes that international trade is intrinsically inter-industrial (Baldwin and Lopez-Gonzalez, 2015; Amador and Cabral, 2016).

An alternative approach based upon endogenous dynamics can be grafted onto the static frame of the international trade theory based upon the HO model by the integration of the economics of innovation and knowledge that builds upon the Schumpeterian legacy of the creative response (Antonelli, 2017 and 2019).

The economics of innovation and technological change has explored the endogenous determinants of the rate (and direction) of technological change. According to the Schumpeterian creative response, technological change is the endogenous consequence of the out-of-equilibrium conditions of product -and factor- markets. When a mismatch between expected and actual conditions of product and/or factor markets takes place, firms try and cope with the changes in their product and factor markets by means of a creative response that impinges upon the knowledge externalities that are provided by the access to and the use of the stock of both tacit and codified knowledge as an indispensable input for the generation of new technological knowledge and the eventual introduction of new productivity-enhancing technologies.

The size of the stock of technological knowledge available in each economic system plays a crucial role in supporting the creative response. Because of its limited exhaustibility and appropriability, the new flows of knowledge add on to the previous ones and increase long-lasting knowledge spillovers (Lucas, 1988). The larger is the stock of knowledge available in each industry and economic system, and the lower are the costs of the recombinant generation of new knowledge (Antonelli, 2018). The lower are the costs of the generation of new knowledge, and the larger is the likelihood that firms try and cope with the changes brought about by the increasing levels of exports in their product markets through research activities aimed at making the creative response possible. R&D expenditures contingent upon the size of the knowledge stocks enable the creative response that makes the increase of productivity and exports possible (Boler at al., 2015; Bustos, 2011).

The creative response is supported by localized technological knowledge that has been built out of learning activities. It is the result of the bottom-up processes of induction based on tacit knowledge that is eventually implemented and codified. Firms can improve only the technologies they have been able to practice and upon which they have acquired a distinctive competence that is characterized by an idiosyncratic and narrow scope of application.

Localized learning is highly industry- and product-specific. Indeed, the accumulation of competence is easier and more effective not only in the techniques where firms have been based (Atkinson and Stiglitz, 1969) but also in the specific range of products and industries where firms and countries are specialized and command a distinctive competitive advantage (Leamer, 1996).

The chances that firms can try and elaborate a creative response to the out-of-equilibrium conditions of their product -and factor- markets is constrained not only within the limited range of techniques and products upon which they have been learning but also by the size of the industry-specific stock of codified knowledge that has been accumulated by means of R&D expenditures. Both tacit knowledge and codified knowledge generated by R&D activities are localized and make the creative response strongly highly industry-specific.

The globalization of product markets exerts strong and direct effects on the introduction of industry-specific technological change primarily based in the products where learning and knowledge accumulation have been taking place. The industry-specific technological change that impinges upon the stock of tacit knowledge accumulated through localized learning processes augments the productivity and competitivity of importing countries in the same industries where the penetration of foreign products is taking place and opens new room for new flows of exports that in turn triggers augmented levels of openness and exposure to international trade.

In the new HO frame enriched by the grafting of the Schumpeterian creative response, international trade is not only inter-industrial and vertical but also intra-industrial and horizontal. Indeed, it is true that countries export some goods and import others, as suggested by the standard HO model and the new analyses of global value chains, but also that countries export and import the same goods in a spiraling loop triggered by the localized and industry-specific dynamics of the creative response (Atkeson and Burstein, 2010).

The working of the creative response framework in international trade theory, outlined so far, can take place with different force across industries and countries. The creative response dynamics should apply with special intensity in the industries of advanced countries that specialize in final products. The imports of labor-intensive products from industrializing countries should trigger the upgrade of the production of incumbents and trigger the introduction not only of process innovations but also of product innovations geared to the internal demand of their high-income consumers. This dynamic is especially evident in the fashion industry, including apparel, furniture, and leather, where imports of cheap products have, at the same time, substituted the local production and pushed it towards luxury and high-end products. The same process takes place in intermediary goods where imports of commodities push incumbents to specialize in high-quality products exported in international markets: the evidence of this process in the chemical and metal industries is especially strong. The dynamics of the creative response, however, may also apply to a smaller extent- to capital goods where the imports of advanced countries from labor-intensive ones favor the division of labor with the substitution of the local production of standardized capital goods and the shift of incumbents towards more R&D intensive customized products with higher levels of international competitiveness.

2.2 THE HYPOTHESES

The analysis of the integration of the Schumpeterian creative response into the HO frame enable to articulate the following hypotheses:

i) The out-of-equilibrium conditions of product markets brought about by globalization with the increase of imports can stir the creative response of firms that enable the introduction of new technologies that increase productivity.

ii) The likelihood that the creative response actually takes place and triggers productivity-enhancing technological change is larger, the larger the stock of quasi-public technological knowledge and the consequent availability of "cheap" knowledge inputs that feed the recombinant generation of the new technological knowledge that is necessary to make the creative response possible.

iii) The introduction of technological change is highly industry- and product-specific. Because of the central role of the competence acquired in learning processes, firms specializing in a given industry and product market try and elaborate a creative response impinging upon their specific and localized competence that is based in the industries and the goods they have been producing.

iv) The dynamics of the creative response stirred by the increased competition of imported products and supported by the stock of technological knowledge and the industry-specific competence enables firms to introduce productivity-enhancing innovations in their industries and increase exports in turn.

v) In the Schumpeterian loop, imports trigger localized innovative efforts, conditional to the stock of knowledge available, that enable firms to compete in the same industries and increase exports: horizontal and intra-industrial trade is augmented.

vi) The overall Schumpeterian loop is expected to be heterogeneous among industries, i.e. it is industry- and product-specific.

3. THE EMPIRICAL ANALYSIS

3.1 THE ECONOMETRIC MODEL

The hypotheses are tested on an industrial database to analyze the matching between imports as the primary causal factor of the dynamics of the creative response, supported by the stock of knowledge at the industrial level that accounts for the levels of productivity and performances in terms of exports. The test of the hypotheses relies on the classical structured econometric CDM approach implemented by the inclusion of a performance equation that adds to the "innovation" equation and the "productivity" equation (Crépon et al., 1998).

The innovation equation tests the hypothesis that innovation efforts are stirred by the competitive challenge of imports and supported by the stock of technological knowledge localized within each industry. The inclusion of the industrial stock of knowledge is expected to account for the effects of the limited exhaustibility of knowledge on the cost of knowledge. We expect that the larger is the stock of knowledge at the industrial level, and the lower are the costs of innovative efforts. Consequently, the larger should be the flows of R&D activities that support the creative response. Firms that have access to a large stock of knowledge specific to their industry can try and cope with the competitive pressure of foreign producers through the introduction of innovations.

In the productivity equation, labor productivity is explained by the ratio of capital to labor and by the endogenous stock of knowledge. The latter is obtained as the intertemporal sum of the endogenous flows of R&D activities explained by the innovation equation with the standard inventory procedure (Hall, 2005). Finally, following Guarascio at al. (2016), we add to the classic CDM frame a “performance equation”, where the endogenous levels of productivity explain exports.

3.2 THE DATABASE

Imports may affect innovation and exports not only in the vertical - interindustrial- international trade (Colantone and Crinò, 2014) but also in the horizontal (intra-industrial) one. The theoretical framework previously described focuses the second mechanism, anyway, without excluding the existence and relevance of the other, especially when the definition of industry is broad. The French imports of cheap yarns may favor exports of apparel classified within the same broad industry.

The structural analysis (STAN) database provides a unique opportunity to test the proposed spiraling relationship at the industrial level on 13 OECD countries: Belgium, Canada, the Czech Republic, Finland, France, Germany, Italy, Mexico, Norway, Portugal, Slovenia, the United Kingdom, and the United States.[2] The STAN database provides data from 1995 to 2015 for the manufacturing industries aggregated in 8 sectors following revision 4 of the international standard classification of the productive activities (ISIC Rev. 4). We, therefore, have the following manufacturing activities for each country: food products, beverages, and tobacco; textiles, wearing apparel, leather, and related products; wood and paper products, and printing; chemical, rubber, plastics, fuel products, and other non-metallic mineral products; basic metals and fabricated metal products, except machinery and equipment; machinery and equipment; transport equipment; furniture, other manufacturing, repair and installation of machinery, and equipment.

From the unbalanced STAN database, the following variables are used:[3] gross output at current prices, i.e. the production, Y; the number of persons engaged in millions, L; the gross fixed capital formation at current prices, i.e. the investments, I; the exports of goods at current prices, X; the imports of goods at current prices, M; and the R&D expenditures at current prices.

[2] http://www.oecd.org/industry/ind/stanstructuralanalysisdatabase.htm
[3] The database is unbalanced because there are no data on Canada for 2015 and on R&D for 1995 and 1996 in Slovenia.

All data are converted into purchasing power parities in millions of dollars in 2010.

Contrary to the World Input-Output Tables (WIOD) database, which distinguishes intermediate imports from final output imports (household and government), in the STAN database the imports are constructed using the UN Comtrade statistics (customs data). Then, in the STAN database there is no prior information about who is importing a given product. Therefore, it assigns imports to industries through product-industry correspondences, defined at the producer level. The data is on the producer, and there is homogeneity between the products contained in imports and exports statistics.

For R&D expenditures could be available two data: by industry and by main activity. The difference between them could emerge only when firms have multiple lines of business. If data are allocated by industry, the R&D expenditures of these firms are correctly split up in each line of their own business. Vice versa, if data are allocated by main activity, the R&D expenditures are all allocated in the central business' line of the differentiated firms. The R&D expenditures allocated by industry are most informative, but only Belgium and the UK have the data for the overall analyzed period.[4] However, using the two-digit sector aggregations of 8 industries previously described, the difference between the two R&D expenditures are not very relevant.[5] We have then used the data on R&D

[4] The data on the R&D expenditures by industry are rare. However, we have also this information from: 2004 for the Czech Republic; 2008 for Italy and Portugal; and 2010 for Finland. Moreover, France has these data until 2013.

[5] The granularity of the industrial analysis could limit two mutually exclusive criticisms. On the one hand, a thinner industry classification considers the offshore. On the other hand, a broader industry classification allows firms to be

expenditures by industry when they are available and the data on R&D expenditures by the main activity otherwise. We call this variable $R\&D$.

3.3 THE METHODOLOGY

To obtain the stock variables of capital, K, and of R&D, $\Sigma R\&D$, we apply the usual inventory procedure suggested by Hall (2005) assuming a constant discount rate of 20% each year:

$$K_t = I_t + 0.8I_{t-1} + 0.6I_{t-2} + 0.4I_{t-3} + 0.2I_{t-4}\,; \tag{1}$$

$$\Sigma R\&D_t = R\&D_t + 0.8R\&D_{t-1} + 0.6R\&D_{t-2} + 0.4R\&D_{t-3} + 0.2R\&D_{t-4}\,. \tag{2}$$

We then implicitly assume that intangible and tangible investments have an average duration of 5 years.

From Y and L, we obtain a standards measure of the productivity of labor, $y = \ln(Y/L)$, and then, by symmetry, the capital over labor, $k = \ln(K/L)$; the flow and the stock of R&D over labor, $rd = \ln(R\&D/L)$ and $\Sigma rd = \ln(\Sigma R\&D/L)$, respectively; and the exports and the imports over labor, $x = \ln(X/L)$ and $m = \ln(M/L)$, respectively. Moreover, we measure catch-up at time t for each industry in a country as the closeness of its productivity of labor with the US one, i.e. $cu = y - y_{US}$. We expect that the closer is the labor productivity of each industry in each country to the international frontier, the stronger will be the positive effects of the creative response. The more advanced the industry and the stronger the reliance on knowledge

active in multiple sectors. Given the key role of R&D in the framework, we minimize the second criticism. However, imports could be overestimated because they also consider some effect of outsourcing in the value chain.

to cope with out-of-equilibrium conditions of product and factor markets. Finally, all variables are measured in logarithms to prevent the risk of outliers, and then all the estimated coefficients are interpreted as elasticities.[6]

Using the long-term panel database of 8 manufacturing sectors of 13 OECD countries, the recursive sequential loop between imports, creative response, innovation, productivity, and exports can be tested through a three-stages least squares (3SLS) empirical estimation.

In the first step, we rely upon an innovation equation to test the hypothesis that the creative response takes place when product markets exhibit out-of-equilibrium conditions stirred by the entry of competitors in international markets and is contingent upon the size of the stock of technological knowledge available in each industry. We indeed suppose that the larger is the stock of industry-specific knowledge and the lower R&D costs -because of the knowledge spillovers- and the larger the chances that firms can engage in innovative efforts to cope with the emerging out-of-equilibrium conditions of their product markets. To avoid the effects of reverse causality, we estimate the lagged effect of both imports, m, and the stock of R&D per employee, Σrd, on the innovative efforts that are necessary to support the creative response, approximated with the flow of R&D, rd:

$$rd_t = a_0 + a_1 m_{t-1} + a_2 \Sigma rd_{t-1} + a_3 cu_{t-1} + \sum a_Y YD + \varepsilon_t \,, \qquad (3)$$

[6] The value of capital over labor could be affected by the unity of measure used in the database. In the Appendix, we use Zuleta (2012)'s procedure to solve this potential bias issue.

where YD is the year dummies variable and ε is the error term. To account the idiosyncratic characteristics of the countries and manufacturing industries, we use fixed effects estimations with the year dummies to correct the trend. From (3), we can estimate the flow of R&D per employee:

$$\widehat{rd}_t = \hat{a}_0 + \hat{a}_1 m_{t-1} + \hat{a}_2 \Sigma rd_{t-1} + \hat{a}_3 cu_{t-1} + \sum \hat{a}_Y YD \; , \tag{4}$$

where $\hat{a}_0$, $\hat{a}_1$, $\hat{a}_2$, $\hat{a}_3$, and $\hat{a}_Y$ are the estimated coefficients of a_0, a_1, a_2, a_3, and a_Y, respectively.

Using (4) as the instrumental variable in the second step of the 3SLS econometric estimation, we have:

$$y_t = b_0 + b_1 \widehat{rd}_t + b_2 k_t + \sum b_Y YD + \varepsilon_t' \; . \tag{5}$$

From Griliches (1979 and 1992), the stock of knowledge and not its flow affects productivity. Therefore, we also replicate the second step of the empirical procedure as follows:

$$y_t = b_0 + b_1 \widehat{\Sigma rd}_t + b_2 k_t + \sum b_Y YD + \varepsilon_t'' \; , \tag{6}$$

where $\widehat{\Sigma rd}_t = \widehat{rd}_t + 0.8\widehat{rd}_{t-1} + 0.6\widehat{rd}_{t-2} + 0.4\widehat{rd}_{t-3} + 0.2\widehat{rd}_{t-4}$.

In (5) and (6), as well, we use fixed effects estimations to account the idiosyncratic characteristics of the countries and industries, and we use the year dummies to take into account the effect of time. We can then test the hypothesis that the creative response supported by the size of the stock of knowledge available in each industry and by new innovative efforts is able to increase the productivity of labor under the control of the capital intensity. From (5), we estimate the productivity of labor as follows:

$$\hat{y}_t = \hat{b}_0 + \hat{b}_1 \widehat{rd}_t + \hat{b}_2 k_t + \sum \hat{b}_Y YD, \tag{7}$$

and from (6) as:

$$\hat{y}_t = \hat{b}_0 + \hat{b}_1 \widehat{\Sigma rd}_t + \hat{b}_2 k_t + \sum \hat{b}_Y YD, \tag{8}$$

In (7) and (8) innovative efforts are endogenous as they have been estimated by the innovation equation. Equation (7) uses the flow of R&D expenditures to account for the effects of current innovative efforts. Equation (8) follows, instead, the standard procedure elaborated by Griliches (1979 and 1992) according to which the stock of R&D expenditures matters in the technology production function.

Finally, we test the hypothesis that: the endogenous increase of productivity i) stemming from the creative response and ii) stirred by imports iii) is made possible by the innovative efforts that iv) can take place when the size of the localized technological knowledge yields a large flow of industrial knowledge spillover that v) pushes the cost of new knowledge below equilibrium levels and vi) enables firms to increase their productivity and competitivity in international product markets and to increase their exports within the same product markets. To test this third step, we use the instrumental variable of y described either in (7) or (8) in the last fix effects regressions of the empirical methodology:

$$x = c_0 + c_1\hat{y}_t + \sum c_Y YD + \varepsilon_t''' , \tag{9}$$

where $\hat{y}$ could be estimated by (7) and (8).

To test the potential asymmetry of the Schumpeterian loop across the 8 industries analyzed, we extend (9) as follow:

$$x = c_0 + c_1\hat{y}_t + \sum c_M\hat{y}_t MD_t + \sum c_Y YD + \varepsilon_t^{\prime v} , \tag{10}$$

where MD_t is the manufacturing dummy variable, i.e. it is equal to 1 in the industry M and 0 otherwise. To avoid multicollinearity, we exclude as categorical variable the transport equipment industry. Transport equipment includes both final (cars) and capital goods (trucks, ships, airplanes): as such, it can be regarded as a reliable proxy of a mixed industry composition. If we estimate the regression (10) only for the transport equipment industry, we observe that $\sum c_M\hat{y}_t MD_t$ is equal to zero and consequently a unit increase of $\hat{y}$ brings a variation of x equal to c_1. If we estimate the regression for only the industry M, say for food products, beverages, and tobacco (FBT), then a unit increase of $\hat{y}$ brings a variation of x equal to $c_1 + c_{FBT}$. Note that c_{FBT} also measures how much to increase or decrease the effect of the transport equipment industry (c_1) to estimate the overall effect of food on export. Generalizing this framework, c_1 is the estimated elasticity of the omitted categorical variable, and $c_1 + c_M$ is the estimated elasticity of the industry M. The advantage of (10) is that it directly identifies the degree of statistical significance of the industry asymmetry, c_M.

Before to present the results, Table 1 summarizes the main descriptive statistics.

Table 1: Descriptive statistics

Variables	Obs.	Mean	Std. Dev.	Min	Max
y	2174	5.34	0.54	3.80	6.86
x	2174	10.87	1.65	6.16	14.52
m	2174	11.01	1.60	6.33	14.26
cu	2174	-0.06	0.07	-0.30	0.09
rd	2174	13.97	1.75	7.21	17.63
Σrd	1758	15.16	1.67	9.70	18.70
k	1758	3.56	0.72	1.37	5.39

Source: STAN (ISIC Rev. 4) database and our elaborations.

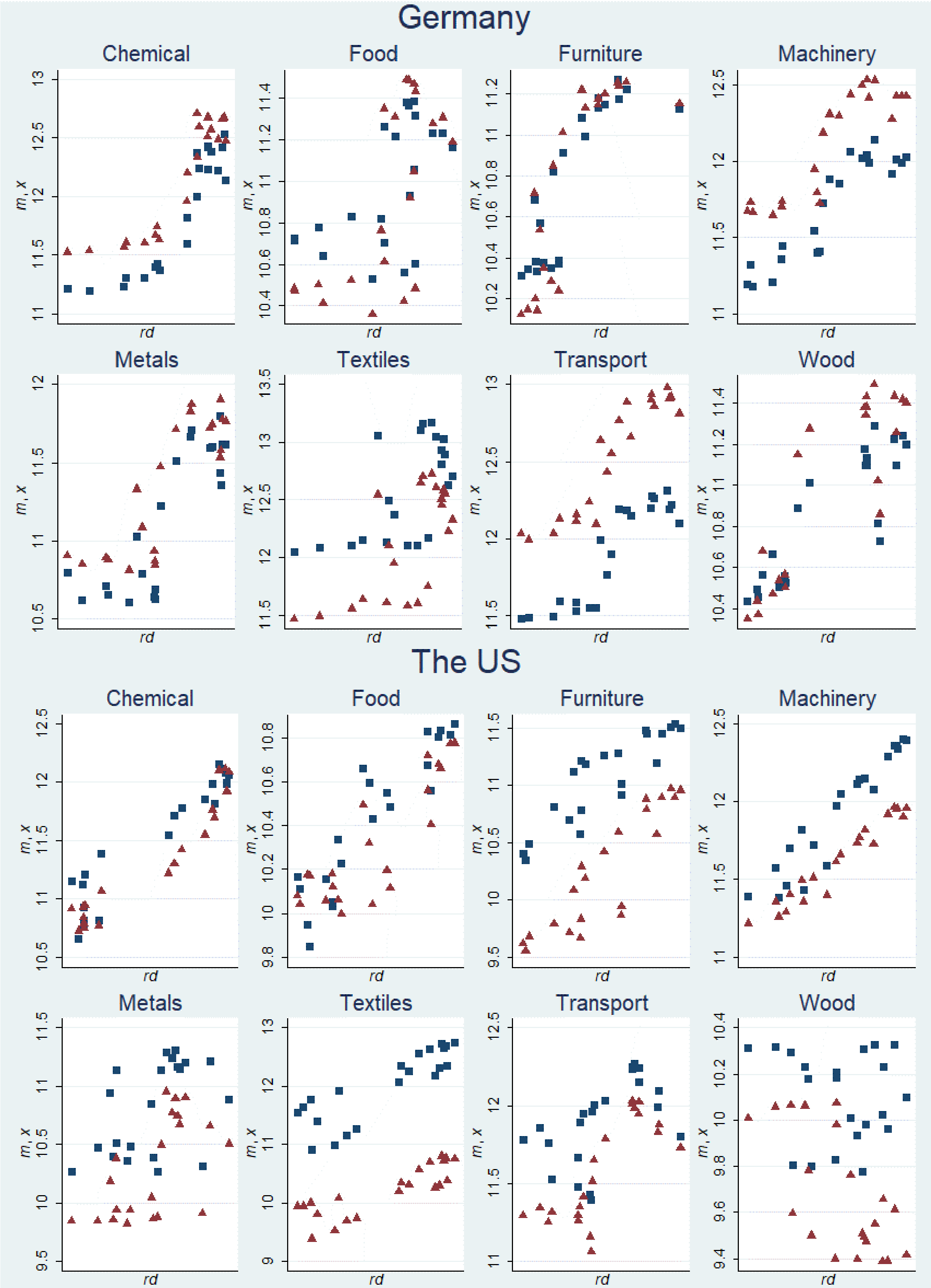
3.4 PRELIMINARY EVIDENCE

Figures 1 and 2 show the relationship between rd and x, triangles, and between rd and m, squares, in some countries and industries. In the US, export over labor is almost always lower than import over labor, independently of the manufacturing industry analyzed. Vice versa, in Germany, this is limited only to the textiles, wearing apparel, leather, and related products industries. In industries as the chemical, rubber, plastics, fuel products, and other non-metallic mineral products, the machinery and equipment, and the transport equipment, import over labor is, on average, higher than export over labor. In other German industries, the sign of net exports is less explicit. Analyzing the correlations of rd on x and m in other OECD countries, the same heterogeneous picture emerges in two selected industries: chemical, rubber, plastics, fuel products, and other non-metallic mineral products, and, again, the fashion industries, textiles, wearing apparel, leather, and related products.

All graphs in both figures show the positive link of the R&D on the two measures of international trade. Using the previous framework, we interpret this result as preliminary evidence of the Schumpeterian loop. We show the Schumpeterian loop's first step: the import increases the flow of R&D, i.e. the larger competitiveness of the foreign firms stirs the creative response of national firms that enable them to improve their productivity. Moreover, also the last step of the Schumpeterian loop emerges from the two figures: the flow of R&D increases the export, i.e. the larger productivity induced by the creative response improves the competitiveness of the national firms. In other words, Figure 1 graphicly exemplifies the Schumpeterian loop in all the industries of Germany and the US. Figure 2 shows this spiraling correlation for the remaining 11 OECD countries in the chemical, rubber, plastics, fuel products, and other non-metallic mineral products industries and in the fashion industries such as the textiles, wearing apparel, leather, and related products.

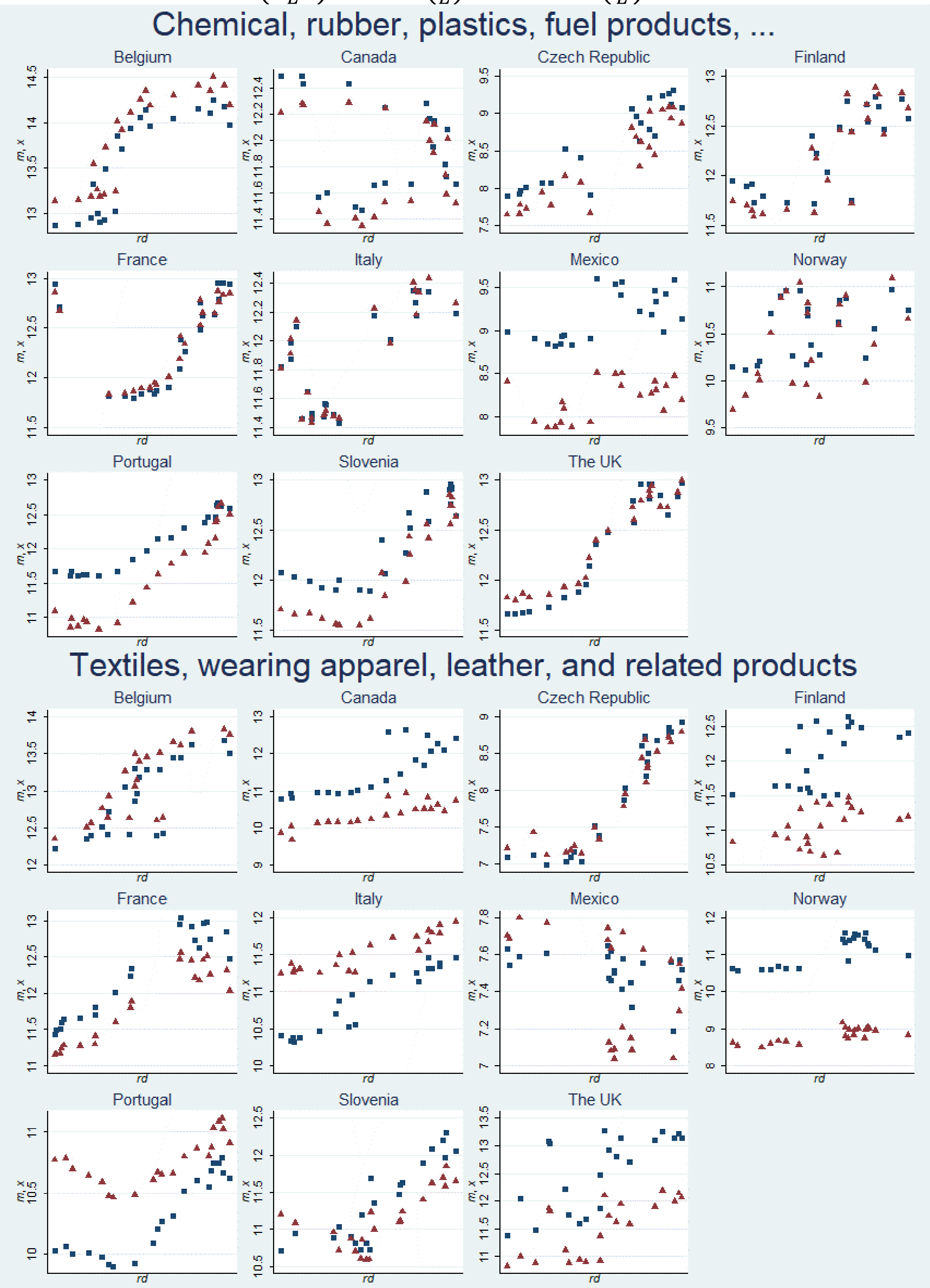
Although the positive sign of the two relationships seems homogeneous in the database, the magnitude of the effect and its standard deviation appear to be very heterogeneous. For example, the Schumpeterian loop's impact on the furniture, other manufacturing, repair and installation of machinery, and equipment industry seems to be higher than the transport equipment industry, both in Germany and in the US. Moreover, the UK Schumpeterian loop appears to be higher than Norway in both the selected industries in Figure 2. In the next section, we will find more robust empirical evidence of the Schumpeterian loop in the overall database with the econometric investigations previously outlined.

Figure 1: Link on $\ln\left(\frac{R\&D}{L}\right)$ and $\ln\left(\frac{X}{L}\right)$, ▲, and $\ln\left(\frac{M}{L}\right)$, ■, in two countries.



Source: STAN (ISIC Rev. 4) database and our elaborations.

Figure 2: Link on $\ln\left(\frac{R\&D}{L}\right)$ and $\ln\left(\frac{X}{L}\right)$, ▲, and $\ln\left(\frac{M}{L}\right)$, ■, in two industries.



Source: STAN (ISIC Rev. 4) database and our elaborations.

3.5 THE RESULTS OF THE ECONOMETRIC ANALYSES

Table 2 provides the econometric estimations of (3). Contrary to Ghazalian (2012) and Autor et al. (2018), we observe that the increase of imports stirs the creative response of firms that enable the introduction of new technologies (Scherer and Huh, 1992). Indeed, larger imports at time t induce larger innovations efforts in the future, approximated with the investment in R&D. Moreover, the larger the stock of R&D at time t, and the stronger the new flow of R&D. Finally, we observe that when the industry is closer to the technological frontier, i.e. the catch-up is high, the investment in R&D increases.

Table 2: 1st step of the 3SLS

rd_t	[1]
m_{t-1}	0.15323***
	(0.05342)
cu_{t-1}	0.83857*
	(0.47797)
Σrd_{t-1}	0.71723***
	(0.02270)
Constant	1.55942**
	(0.65263)
Year Dummies	Yes
R^2	0.94321
Observations	1,654

Note: Fixed effects panel model. Dependent variable: the logarithmic flow of R&D per employee, rd. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

Columns [1] and [2] of Table 3 provide the econometric estimations at the industrial level of the productivity equation, the intermediate step of the empirical procedure described by (5) and (6), respectively. The econometric evidence provides strong support to the hypothesis that the productivity of labor, under the control of the levels of capital intensity, increases because of the endogenous innovative efforts accounted by the out-of-equilibrium conditions in each product market that have pushed firms -that could rely upon a localized stock of industrial knowledge- to improve their innovation efforts. The econometric results support the specification of both (8), where the stock of knowledge affects industrial productivity, and (7), where the flows of endogenous innovative efforts, instead of the stock, are considered. The tests of both specifications yield significant results and suggest that current innovative efforts as much as the stock of endogenous innovative efforts exert positive effects on labor productivity.

Table 3: 2nd step of the 3SLS

y_t	[1]	[2]
k_t	0.13025***	0.08760***
	(0.01492)	(0.01495)
$\widehat{rd_t}$	0.02560***	
	(0.00856)	
$\widehat{\Sigma rd_t}$		0.03983***
		(0.01003)
Constant	4.46897***	4.42474***
	(0.12347)	(0.15628)
Year dummies	Yes	Yes
R^2	0.62631	0.65256
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic productivity of labor, y. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

Building upon the previously supported hypothesis that more imports stir the creative response and the consequent introduction of technological change in each industry of the OECD countries, we test, in the last step of the 3SLS empirical estimation, the performance equation according to which the endogenous increase of productivity enables the industries exposed to the competitive challenge of foreign producers and exports to increase their exports in turn.

The results of the last step of the 3SLS empirical estimation are shown in Table 4. Each column of Table 4 directly follows from the estimation of the same column number of Table 3. Our results fully confirm, at the industrial level, the empirical evidence provided by Guarascio and Pianta (2016 and 2017) at the industrial level and by Greenaway and Kneller (2007), Cassiman et al. (2010), and Bernard et al. (2007) at the firm level: innovations lead export. The econometric evidence tests the hypothesis that the introduction of industry-specific technological change increases their performances in international product markets with positive effects on exports.

Table 4: 3rd step of the 3SLS

x_t	[1]	[2]
$\hat{y}_t$	1.77841***	2.61639***
	(0.20859)	(0.27040)
Constant	1.11837	-3.11373**

	(1.10106)	(1.44140)
Year Dummies	Yes	Yes
Measure of $\widehat{rd}_t$ 2nd step	Flow	Stock
R^2	0.21042	0.33311
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic exports per employee, x. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations

Table 5 extends the estimations of Table 4 by industries to statistically measure the industrial asymmetry of the overall effect of the Schumpeterian loop. We observe that the magnitude of the Schumpeterian loop is strongly heterogeneous among industries. In the industries of chemicals, rubber, plastics, fuel products, and other non-metallic minerals, basic metals, and fabricated metal products, the Schumpeterian loop has the largest impact. The Schumpeterian loop also has a huge effect on the fashion industries such as food, beverages, tobacco, textiles, wearing apparel, leather, and related products. Moreover, in both the wood and paper products, printing, furniture, other manufacturing, repair and installation of machinery, and equipment industries the effect of the theoretical productivity of labor over the export is positive but not larger than the transportation equipment industry, the omitted variable, and the machinery industry, where its effect is not statistically significantly different from the transportation one. The analysis of the variance across industries suggests that the Schumpeterian loop is stronger, the stronger the penetration of imports in domestic markets. This remark seems consistent with the basic intuition of the creative response that calls attention to the behavior of the industries that are more exposed to changes in their product markets. When the penetration is small, firms are less keen to implement the creative response. When the penetration is large, the creative response is necessary to cope with the fast changes: business as usual is no longer viable.

Table 5: 3SLS by industries

x_t	[1]	[2]
$\widehat{y_t}$	0.92577***	1.88202***
	(1.90888)	(0.30990)
$\widehat{y_t}$ · Food	1.17696***	1.25865***
	(0.20096)	(0.27587)
$\widehat{y_t}$ · Wood	0.34769	0.50343*
	(0.21450)	(0.28603)
$\widehat{y_t}$ · Machinery	0.14950	-0.17291
	(0.19414)	(0.26863)
$\widehat{y_t}$ · Metals	1.73071***	1.42795***
	(0.19653)	(0.26611)
$\widehat{y_t}$ · Chemical	1.94193***	1.71977***
	(0.18993)	(0.26701)
$\widehat{y_t}$ · Textiles	0.85410***	0.90437***
	(0.18966)	(0.25720)
$\widehat{y_t}$ · Furniture	0.45262**	0.35862
	(0.19613)	(0.26957)
Constant	1.22488	-3.19124**
	(1.06871)	(1.41809)
Year Dummies	Yes	Yes
Measure of $\widehat{rd_t}$ 2^{nd} step	Flow	Stock

R^2	0.00029	0.00019
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic exports per employee, x. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

The results of the econometric analysis confirm the working of the creative response mechanism that relates to the intra-industrial interdependence between imports and exports. Yet, it seems appropriate to take into consideration a possible source of ambiguity. The vertical trade and the creative response mechanisms are likely to be both at stake when one looks at the data and, most importantly, the industry analysis level. The use of STAN imports does not enable to exclude the positive effects of vertical trade within the same STAN industry: the imports of sophisticated yarn may affect the export of textiles. Elements of overlapping within the same broad industry can occur and should be considered in assessing the results of the econometric analysis.

In other words, the competition effect only emerges in horizontal trade, i.e., among either final goods or intermediary goods separately, and not in the vertical trade, i.e., between final and intermediary goods. This also could explain why the Schumpeterian loop clearly emerges in industries only more specialized in either final goods or intermediary goods, while it fails to appear strongly in industries with mixed composition.

4. CONCLUSIONS

The paper integrates the Schumpeterian framework of the creative response with the localized learning and the HO frameworks to elaborate on the hypothesis that the horizontal flows of international trade are the recursive outcome of the dynamics of endogenous innovation. The integration of international economics with the economics of knowledge and innovation is a fertile field of investigation. The dynamics of globalization are relevant to assess the rate of technological change as much as the rate (and the direction) of technological change is relevant to assess the specialization of countries and their trade.

Globalization exposes importing countries to increasing levels of competitive pressure. The introduction of technological change is actually necessary to cope with the out-of-equilibrium conditions of product (and factor) markets. The Schumpeterian creative response is indispensable to survive in international product markets where the domestic markets of each trading partner are exposed to international competition.

The pressure of imports threatens the performances of domestic producers and triggers the creative response of firms exposed to declining performances. When the stock of localized technological knowledge is large enough to support the creative response that enable the introduction of innovations that increase productivity, firms can cope with the new competition not only in their domestic markets but also in international ones and increase exports. The increase of intra-industrial trade is the outcome of the Schumpeterian loop.

Therefore, the endogenous dynamics of technological change yields several outcomes: i) it contributes understanding the dynamics of endogenous technological change localized by learning processes; ii) it sheds new light on the role of the industry-specific direction of technological change; iii) it enables to grasp the spiraling loop that relates imports, the rates of technological change, and exports; iv) it provides the foundations to expect ever-increasing globalization and gains from trade based upon persistent and increasing variety based upon localized learning processes among trading partners.

A result that deserves to be further explored is the clear heterogeneity of the Schumpeterian loop among industries and countries. This asymmetric effect is particularly relevant also because, in this paper, we analyze a quite homogenous database, i.e. only manufacturing sectors in OECD countries. It could be interesting to extend the results also in other sectors and countries. Moreover, future research could be made a larger effort to try to explain the industry-specificity of the link between creative response and trade, for example, by categorizing the industries into primary products, intermediate products, capital goods, and consumer goods to analyze their idiosyncrasies. Unfortunately, the granularity of this database does not allow for this analysis, such as the measurement of the ratio of the demand supplied by foreign firms to that supplied by national firms.

The results of the analysis have important policy implications. The plea in favor of increasing tariff barriers to protect domestic industries exposed to aggressive exports of emerging, labor abundant economies is not justified if and when domestic firms can implement an effective "creative response" that enables them to increase their exports. The support to the innovative efforts and R&D expenditures of labor-intensive industries of advanced countries that increase the stock of technological knowledge and the improvement of its governance seems, by far, the best policy instrument to enhance the international competitivity of labor-intensive productions in advanced countries, favoring the increase of their knowledge intensity.

Compliance with Ethical Standards: The authors declare that they have no conflict of interest.

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APPENDIX

Zuleta (2012) suggests an empirical procedure to correctly assign the unit of measurement for labor and capital. Indeed, each change in the capital over labor affects labor productivity. The magnitude of this effect depends on the abundance of capital and labor and then the inputs unit of measure could be relevant. In the following, we replicate the unit of measure suggested by the STAN database with the Zuleta (2012)'s procedure like robustness check. Tables A.1-A.5 replicate Tables 1-5 following the Zuleta (2012)'s procedure to obtain the unbiased units of measurement of the factors. All previous results are fully supported.

Table A.1: Descriptive statistics from the Zuleta (2012)'s unity of measures

Variables	Obs.	Mean	Std. Dev.	Min	Max
y	2174	3.39	0.72	1.60	5.24
x	2174	8.91	1.63	4.66	12.86
m	2174	9.05	1.53	4.67	12.60
Cu	2174	-0.50	0.22	-1.20	0.00
rd	2174	12.02	1.78	5.59	16.16
Σrd	1758	13.20	1.70	8.21	17.23
k	1758	1.61	0.99	-1.22	4.10

Source: STAN (ISIC Rev. 4) database and our elaborations.

Table A.2: 1st step of the 3SLS from the Zuleta (2012)

rd_t	[2]
m_{t-1}	0.14693***
	(0.05440)
cu_{t-1}	0.55486*
	(0.32515)
Σrd_{t-1}	0.71789***
	(0.02268)
Constant	1.58411***
	(0.60983)
Year Dummies	Yes
Measure of factors	Corrected
R^2	0.94842
Observations	1,654

Note: Fixed effects panel model. Dependent variable: the logarithmic flow of R&D per employee, rd. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

Table A.3: 2nd step of the 3SLS from the Zuleta (2012)'s unity of measures

y_t	[1]	[2]
k_t	0.12995***	0.08748***
	(0.01492)	(0.01494)
$\widehat{rd_t}$	0.02698***	
	(0.00856)	
$\widehat{\Sigma rd_t}$		0.04053***
		(0.01003)
Constant	2.80521***	2.71268***
	(0.10102)	(0.13136)
Year dummies	Yes	Yes
R^2	0.77038	0.75362
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic productivity of labor, y. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

Table A.4: 3rd step of the 3SLS from the Zuleta (2012)'s unity of measures

x_t	[1]	[2]
$\widehat{y_t}$	1.79476***	2.61346***
	(0.20734)	(0.26892)
Constant	2.58373***	0.05120
	(0.68973)	(0.90865)
Year Dummies	Yes	Yes
Measure of $\widehat{rd_t}$ 2nd step	Flow	Stock
R^2	0.23923	0.32499
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic exports per employee, x. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.

Table A.5: 3SLS by industries from the Zuleta (2012)'s unity of measures

x_t	[1]	[2]
$\widehat{y_t}$	0.93691***	1.87249**
	(0.22665)	(0.30875)
$\widehat{y_t}$ · Food	1.18172***	1.26044***
	(0.20082)	(0.27581)
$\widehat{y_t}$ · Wood	0.35495*	0.50409*
	(0.21428)	(0.28583)
$\widehat{y_t}$ · Machinery	0.15291	-0.16946
	(0.19411)	(0.26871)
$\widehat{y_t}$ · Metals	1.73140***	1.42435***
	(0.19629)	(0.26583)
$\widehat{y_t}$ · Chemical	1.94158***	1.71698***
	(0.18970)	(0.26670)
$\widehat{y_t}$ · Textiles	0.85236***	0.90775***
	(0.18935)	(0.25716)
$\widehat{y_t}$ · Furniture	0.45966**	0.36093
	(0.19611)	(0.26950)
Constant	2.65671***	0.02459
	(0.66947)	(0.89405)
Year Dummies	Yes	Yes
Measure of $\widehat{rd_t}$ 2nd step	Flow	Stock
R^2	0.00387	0.00086
Observations	1,654	1,238

Note: Fixed effects panel model. Dependent variable: the logarithmic exports per employee, x. Significant at *10%, **5%, and ***1%. Standards Errors are reported in parenthesis. Source: STAN (ISIC Rev. 4) database and our elaborations.