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Dipartimento Economia e Statistica Cognetti de Martiis

Working Paper Series

18/14

GLOBALIZATION AND THE KNOWLEDGE DRIVEN ECONOMY

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Bureau of Research on Innovation, Complexity and Knowledge

UNIVERSITÀ DEGLI STUDI DI TORINO

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GLOBALIZATION AND THE KNOWLEDGE DRIVEN ECONOMY[1]

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ABSTRACT.
The paper implements the Schumpeterian notion of creative reaction to articulate and test the hypothesis that the shift to the knowledge economy in advanced economies is the result of the creative reaction of firms, caught in out-of-equilibrium conditions by the fast globalization of product and factor markets since the last decades of the XX century. Advanced countries specialized in the generation and exploitation of knowledge because of its relative abundance stemming from their sophisticated knowledge governance mechanisms and the large stock of knowledge. On its turn this had strong positive effects on TFP. The empirical analysis confirms that in advanced economies the specialization in knowledge-based activities substituted the previous specialization in mass-manufacturing activities supporting the increase of TFP. The new specialization in knowledge intensive activities has been stronger the larger was the exposition to international trade, the intensity of patent activities and the revenue per capita.

KEY WORDS: GLOBALIZATION, CREATIVE RESPONSE, TECHNOLOGICAL CHANGE, STRUCTURAL CHANGE, KNOWLEDGE ECONOMY, PRODUCTIVITY GROWTH.

JEL CODES: O30

[1] This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no 266959. The authors acknowledge the institutional support of the Collegio Carlo Alberto and the University of Torino.

1. INTRODUCTION.

Since the last decade of the 20th century advanced economies have been experiencing radical structural change with a marked decline of mass production in manufacturing industries and an increasing specialization in knowledge intensive business services (KIBS) and knowledge intensive manufacturing (KIM) along with a rapid pace of introduction of new technologies, coupled with total factor productivity (TFP) growth. A large literature has analyzed the characteristics, the effects and some of the causes of these twin processes of structural and technological change (Schettkat and Yocarini, 2006; Nickell, Redding, Swaffield, 2008; Buera and Kaboski, 2012; Bonatti and Felice, 2008).

This paper applies the Schumpeterian notion of creative response enriched by the new economics of knowledge and the Kuznets's view that technological innovation and structural change are endogenous and strictly intertwined, to elaborate and test empirically an articulated explanatory framework according to which the shift to the knowledge economy was driven by the search for a new source of competitive advantage, stirred by globalization and based upon the strong and unique knowledge base of advanced economies with positive effects in terms of TFP growth (Schumpeter, 1947; Kuznets, 1965).

The rest of the paper is organized as it follows. Section 2 articulates the Schumpeterian approach and extracts the main hypotheses. Section 3 presents the empirical evidence. The conclusions summarize the main results and explore their policy implications.

2. THE CREATIVE RESPONSE

The 1947 contribution by Joseph Alois Schumpeter "The creative response in economic history" has received little attention by the economic literature and yet can and should be considered the synthesis of a long research process. In this path-breaking article, Schumpeter provides an articulated and coherent framework of analysis of technological change as an endogenous process that deserves much a wider readership and systematic use. This paper uses it to explore the intertwined dynamics of technological and structural change that has been taking place in advanced economies in the decades comprised between the 20th and the 21th century. Let us recall briefly the founding arguments of the Schumpeterian notion of technological change as a form of creative reaction.

Schumpeterian firms are exposed to continual mismatches between their own expectations and the actual developments of product and factor markets. Unexpected changes in product and factor markets expose them to unbalances and to operate in out-of-equilibrium conditions that cannot be fixed in the short term. In textbook accounts of the working of equilibrium markets, firms, unable to elaborate correct expectations, would be wiped out by their competitors. In the Schumpeterian framework, instead, firms are credited with the capability to try and change their technology, so as to adapt their production conditions to the unexpected changes of the markets. Firms can react. Not all reactions, however, are deemed to change successfully their technologies. Here the crucial distinction between adaptive and creative reactions is introduced. Firms that have not access to the necessary levels of external knowledge will fail: their reaction will be adaptive. Firms that have access to high quality knowledge externalities can change successfully their technologies. Their reaction, supported by the availability of external competences and skills, will be 'creative'. Technological change and hence TFP growth take place when firms, caught in out-of-equilibrium conditions because of the mismatch between their expectations and the actual conditions of product and factor markets, react taking advantage of an economic context that provide access to external knowledge available at costs that are below equilibrium levels.

This framework has an extraordinary analytical power that can be successfully applied to the analysis of the radical structural and technological change towards the knowledge economy that has characterized the advanced economies in the last decades. Such a phenomenon is to be considered the result of the creative reaction of advanced economies to the threats of globalization, with the aim to make the most effective use of their strong knowledge base as a key input and as a source of competitive advantage (Antonelli, 2008 and 2011).

The starting point can be found in the opening of international product and eventually factor markets that took place in the second part of the 20th century. The increasing levels of wages and the reduced flexibility of the use conditions of labor force experienced in many advanced economies pushed many firms to globalize with the delocalization of most labor-intensive phases of their production processes in order to re-import them later to serve their product markets in advanced economies (Caves, 2007 and Dunning, 2010).

The increasing weight of labor-intensive imports from labor abundant countries was the results of the merging of the interests of global corporations –as sellers in advanced countries, but producers in labor abundant ones– with those of labor abundant countries, eager to take advantage of the large domestic product markets of advanced economies. The progressive liberalization of the domestic markets of advanced economies and the strong reduction of all tariff and non-tariff obstacles to international trade undermined the competitive advantage of the manufacturing industries of advanced economies. As a consequence advanced economies were pushed to react to the increasing competitive pressure of the exports of labor-intensive industrializing countries both into their domestic markets and in the rest of the world economy (MacDonald, 1996; Kang and Lee, 2011).

Such a competitive pressure was enhanced by the liberalization of international financial markets that followed the globalization of international product markets: this deprived advanced economies of the traditional competitive advantage of industrializing countries, based upon the lower costs of capital and the better access conditions to financial markets. The liberalization of international financial markets provided, in fact, industrializing countries with the opportunity to access the sophisticated financial markets of the advanced economies and to borrow financial resources at costs that were close to the original domestic competitors. Advanced countries had to search for other sources of competitive advantage.

Firms caught in out-of-equilibrium conditions could implement a creative –as opposed to adaptive- response because of the availability of knowledge as an input at costs far below equilibrium levels. The strong knowledge base, already in place because of the progressive increase of knowledge intensity occurred within manufacturing industries, made possible the Schumpeterian creative reaction and became the main source of a new specialization (Abramovitz and David, 1996).

The large supply of knowledge externalities not only favored the creative reaction of firms but also made possible the transition away from mass production in manufacturing industries towards the new specialization in KIBS and KIM. Firms, and advanced countries at large, learnt how to take advantage and exploit the relative abundance of knowledge as an input, the advantages of increasing returns in the generation of knowledge and the sophisticated mechanism of knowledge governance already at work to direct technological change and elaborate a new specialization based upon the generation and exploitation of technological knowledge, not only as an input, but also as an output (Antonelli and Fassio, 2011 and 2014).

Advanced economies discovered to have a strong and distinctive competitive advantage in the generation of technological knowledge and learned how to exploit it with the systematic introduction of KIBS. The new competitive pressure forced them to introduce radical technological and structural changes directed at making the best and most effective use of their strong knowledge base as the main output and input upon which they could build a long-lasting and exclusive competitive advantage, exploiting its relative abundance and low relative cost in their domestic economies and its low international mobility. The strength of their local knowledge base provided advanced economies with the opportunity to gain a new competitive advantage specializing in the generation of KIBS (Boden and Miles, 1999; Doloreux and Shearmur, 2012; Muller and Doloreux, 2009).

Knowledge intensive activities are in fact strongly routed. The generation of knowledge is a highly localized process rooted in the web of interactions and complementarities of a variety of agents and institutions that impinge upon high levels of cumulability with the existing stock of prior knowledge and complementarity of efforts between the agents that participate in the process. For these reasons technological knowledge is a scarce and idiosyncratic resource that only a few countries –with high levels of stocks of technological knowledge embodied in skills, human capital and a dedicated institutional set-up that make possible the flow of the necessary knowledge interactions- can command (David, 1993; Antonelli, 2011).

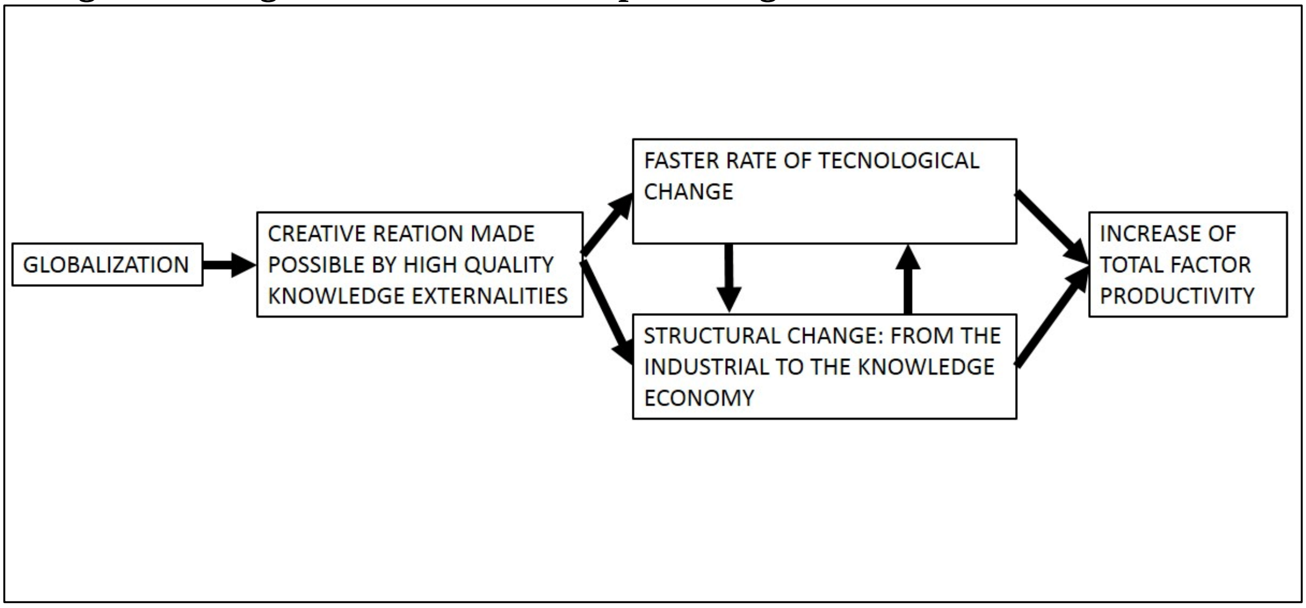
Knowledge tacitness and its limited appropriability require that sophisticated mechanisms of governance of knowledge transactions-cum-interactions both among firms and between the business sector and the public research system take place, so as to make possible the generation and exploitation of knowledge as an economic activity based upon the necessary levels of the division of labor, specialization and exchanges among research units with different incentive mechanisms. Such sophisticated systems of governance are the result of long term historic processes that include public research activities along with business firms and make possible to feed the reciprocal relations between scientific and technological knowledge that cannot be easily imitated and reproduced by other countries (Geuna, 1999; Chesbrough, 2003).

The intrinsic tacitness of technological knowledge has one additional very important consequence: the new complementarity between KIBS and a new KIM industry. The foundations of this new complementarity are found in three factors: i) the transfer and repeated use of knowledge are possible only if and where dedicated interactions between users and producers take place; ii) geographic proximity plays a crucial role in supporting dedicated interactions, which are characterized by the advantages of proximity both in geographic and cultural terms. Agents operating at distance across countries of different languages and cultural traditions have much larger problems in participating into the dedicated interactions that are necessary to access existing knowledge and to learn how to use it again as an input; iii) tight personal relations are necessary to convert scientific knowledge generated by the public research system and especially by universities into technological knowledge.

The crucial role of user-producers interactions in the generation of new technological knowledge becomes a powerful mechanism to retaining and implementing a small but highly KIM industry in advanced countries (Von Hippel, 1998). The mass off-shoring of all the manufacturing industry would clearly weaken the quality of knowledge user-producer interactions in advanced countries. The mass off-shoring of all the manufacturing industry would quickly erode the knowledge base of advanced countries and undermine their own new source of competitive advantage. The advantages of proximity in knowledge user-producer interactions would migrate to the countries of destination. The new complementarity between a large array of KIBS industries and a smaller but highly KIM industry in advanced countries is a key component of the new knowledge economy.

The mechanism at work was characterized by the typical self-reinforcing dynamics of feedback for which the strong knowledge base of advanced economies is at the same time a cause and a consequence of the process. The specialization in knowledge based activities of advanced economies was the result of the relative and comparative abundance of knowledge generating activities in their economies and yet caused the further increase in the division of labor and the enhancement of the mechanisms of knowledge generation at work in advanced economies.

FIGURE 1. Flow chart of the system dynamics of technological and structural change stemming from the creative response to globalization



Summing up the results of the analysis carried out so far, we can articulate the sequential system dynamics represented in Figure 1 where we identify three nodes:

i) The increased competitive pressure of the exports from newly industrializing countries undermined the traditional specialization in mass manufacturing industries of advanced countries and stirred the reaction of firms, caught in out-of-equilibrium conditions by the rapid change of both product and factor markets. Their creative reaction -as opposed to ‘adaptive’- was made possible by the strong knowledge externalities stemming from the large stock of technological knowledge and the size of the current R&D activities and led to a substantial increase of the pace of technological change.

ii) The quality of the knowledge base became itself a supporting factor that helped directing the gale of technological changes towards the introduction of new innovative routines specializing in the generation of technological knowledge. The working of increasing returns at the system level in its generation, together with the endowment of sophisticated knowledge governance systems, helped the identification of knowledge as the strategic resource – both as an input and an output per se- upon which to build a new competitive advantage and a new specialization. The fast increase of the extent of the market for knowledge helped the rapid growth of KIBS industries. The creative reaction of firms led to a new specialization characterized by the combination of a much smaller KIM industry complemented and supported by an array of KIBS industries that became the new core of the economic system with the final effect of accelerating a major structural change and the transition from the industrial economy to the new knowledge economy.

iii) When and where the reaction to globalization was 'creative' favoring the faster introduction of technological innovations and the creation of a new specialization based upon a small but highly productive manufacturing industry coupled with a strong array of KIBS, countries could foster technological change and hence obtain relevant increases of TFP. The creation of KIBS industries enabled to sustain TFP growth of the entire economic system.

3. THE EMPIRICAL EVIDENCE

3.1 The model

In order to empirically test our hypotheses we adopt a country-level perspective. We believe that this is a suitable way to investigate the dynamics of structural change within advanced economies. Indeed most of the factors that induced the change in the productive structure of countries can only be analyzed at the country level. Tariff regimes, which influence the openness to trade of national economies, are stipulated between countries. On their turn tariff regimes influence the dynamics of product markets and the degree of penetration of foreign competition, which is the main inducement effect for the creative response of firms.

As Figure (1) shows, our theoretical framework can be described as a sequence of causal relationships where the increasing international integration of factor and product markets due to globalization lead to creative reactions by firms, to the increasing specialization in KIBS and ultimately to the growth of TFP. In order to test this specific type of process we have specified a model articulated in a sequential system of three equations: i) a patent equation; a KIBS equation; and iii) a TFP equation. This procedure should allow us to avoid the typical endogeneity problems related with the estimation of causal effects.

The patent equation

The first equation concerns the creative reaction of firms to unexpected shocks in factor and product markets induced by globalization. Firms are induced to react creatively to the mismatch between their expectations and the actual market conditions by means of technological change. The possibility of a creative reaction by firms will depend crucially on the availability of external knowledge in the system. We proxy this effort by means of the number of patent applications.[2] The

[2] We are well aware that patents indicators have some limitations as proxies of innovative activity: in some sectors patents are not considered by firms as an important source of profits from new products (Cohen at al., 2000). Moreover

main feature of a patent is the novelty of its content with respect to the previous technology: for this reason we believe patents are a good proxy of the ability of firms caught in out-of-equilibrium conditions to react creatively to the mismatch between expectations and actual market conditions through the introduction of actual innovations.

In our setting three factors affect the ability of firms to react creatively: a) the knowledge externalities stemming from the existing stock of technological knowledge; b) the country-level endowment of knowledge embodied in the researchers employed in Research and Development (R&D) activities; c) the level of openness to trade of a country, which induces firms to react creatively. In the first equation the pace of technological change, proxied by the number of patent applications, is explained by the overall stock of patents, by the amount of R&D activities and by the level of openness to trade:

$$PAT\,\mathrm{int}_{it} = a_0 + a_1 STOCKpat_{it-1} + a_2 RES_{it-1} + a_3 \left(EXP_{it-1} / IMP_{it-1} \right) + \eta_i + \lambda_t + \varepsilon_{it} \qquad (1)$$

where *i* denotes country and *t* denotes the year. We choose to adopt a specification in which variables are expressed in intensities over total employment, in order to avoid any possible country-size effect in our estimates. *PATint* is (the log of) the number of patent applications per person employed *STOCKpat* is (the log of) the cumulated stock of patents per person employed, *RES* is the number of researchers per thousand of employment and *EXP/IMP* measures the level of openness to trade of a country as a ratio between exports and imports: the higher the level of imports (and hence the lower the ratio) the greater the mismatch between national firms' expectations and actual market conditions, due to competition from foreign countries. All the independent variables are one-year lagged, as a first attempt to reduce the possible problems of endogeneity due to reverse causality. We control for country effects (η_i) and common time trends (λ_t) through the use of country and time dummies. The idiosyncratic error term in equation (1) is denoted by ε_{it}.

The KIBS equation

Our hypothesis is that the technological effort put forward by firms exposed to a mismatch between their expectations and the actual market conditions led to the increasing specialization of advanced economies in (KIBS). This was due again to the increasing level of integration of markets induced by the globalization. In order to measure this effect we introduce our second equation in which the weight of KIBS in each national economy is explained by: a) the level of technological effort put forward by the firms (as proxied by patents), and b) the degree of openness of a

patents are usually a better proxy of the technological effort of large firms, rather than small firms (Patel and Pavitt, 1994). Therefore not all the technological efforts of firms can be proxied by patents. However patents are still considered as one of the most reliable proxy of the technological activity of firms and countries (Furman et al. 2002).

country to foreign trade. Moreover our hypothesis is that manufacturing activities and KIBS are only partial substitute and that for small shares of KIM activities the two activities are instead complementary: therefore we introduce the share of manufacturing activities and its squared term to control for this effect. In order to have a proxy for the level of labor productivity we also include the level of income per capita (*INCOPC*) in order to control for the proximity to the frontier of economic advance.[3]

$$KIBS_{it} = b_0 + b_1 PAT\,\mathrm{int}_{it-1} + b_2 OPEN_{it-1} + b_3 MANU_{it-1} + b_4 MANUsq_{it-1} + b_5 INCOPC_{it-1} + \eta_i + \lambda_t + u_{it}$$
(2)

In equation (2) *KIBS* denotes the share of employment in Knowledge Intensive Business Services, *PATint* is (the log of) the number of patent applications per person employed, *OPEN* indicates the share of trade (import and export) over total GDP, *MANU* denotes the share of employees in manufacturing sectors over total employment and *MANUsq* indicates its squared term. *INCOPC* indicates income per capita. Again η_i and λ_t are the usual country and time effects while u_{it} is the idiosyncratic error term.

The TFP equation

The creative reaction of firms faced with globalization, which led to the increasing weight of KIBS, allowed for the actual increase of TFP in advanced economies. The technological change induced by KIBS had a direct impact on the increase of output that could not be explained by labor and capital. Therefore in our last equation we test the impact of KIBS on the level of TFP. Moreover we control for the other factors that are usually associated with technological change, that is the endowment of human capital, the level of expenditures in R&D and the technological effort of firms, as proxied by the number of patent applications.

$$TFP_{it} = c_0 + c_1 KIBS_{it-1} + c_2 HK_{it-1} + c_3 R\&D\mathrm{int}_{it-1} + c_4 PAT\,\mathrm{int}_{it-1} + \eta_i + \lambda_t + e_{it} \qquad (3)$$

In equation (3) the TFP indicates the level of Total Factor Productivity, *KIBS* denotes the share of employment in Knowledge Intensive Business Services, *HK* indicates the share of enrolled students in tertiary education over the total population, *R&Dint* is

[3] Income per capita is a reliable proxy for labor productivity. Labor productivity and unit wages are strictly associated as both reflect the levels of capital intensity. Both indicators are considered reliable proxies for the proximity to the international efficiency frontier. Both are fully consistent with the underlying economic model according to which structural and economic change across countries were stronger the stronger the closeness to the efficiency frontier and hence the higher labor productivity and wages. We tested a specification of our model that used,, instead of income per capita, the level of wages.. The inclusion of wages did not affect at all the results of our estimates, however the limited availability of public data on wages for most countries strongly reduced the sample for our analysis. Therefore we finally decided to use income per capita for which data availability is larger, since we consider it a good proxy for wages.

the log of the ratio of expenditures in R&D (in PPP dollars) over total employment and *PATINT* is (the log of) the number of patent applications over total employment. Besides the usual country and time effects, e_{it} is the idiosyncratic error term.

3.2 Data

We built a dataset that includes almost all OECD-member countries, that is the most advanced economies that experienced the shift to knowledge intensive activities described in the previous sections. The time period chosen for the analysis goes from 1990 to 2007, that is during the years in which the ICT revolution showed its effect on the real economy, and before the worldwide financial crisis, started in 2008. Even if the processes of production-outsourcing towards emerging economics started much before 1990, the specialization in KIBS activities was only possible after the ICT revolution of the early 90's. Therefore we claim that focusing on this limited time period allows us to identify a specific feature of the economic specialization of advanced capitalistic countries that was only possible after the introduction of ICT, and that has been radically different from the outsourcing processes occurred in the previous decades.

The number of patent applications per person employed at the country level (*PATint*) is obtained from the WIPO database, which provides the number of PCT[4] patent applications, attributing each patent to the country in which the applicant is resident. The WIPO database is very well suited for international comparison, since it provides data that are not affected by the choice of the specific national or regional patent office (as in the case of USPTO or EPO). From this viewpoint the WIPO database seems less exposed to the bias of the country of origin of the applicant. In order to check for the role of previous existing knowledge we also compute the cumulated stock of patent per person employed, following the procedure suggested by Hall, Jaffe and Trajtenberg (2005).[5]

In the paper we mainly identify knowledge-based economic activities with the KIBS. An extensive literature has dealt with the problem of the identification of KIBS among the usual sectoral classifications (Boden and Miles, 1999; Di Maria et al. 2012; Muller and Doloreux 2009). According to this literature the economic activities considered as KIBS rely heavily on professional knowledge, are themselves primary sources of information and knowledge and use knowledge to produce intermediate services for their clients' production processes. Following Freel (2006), who identifies KIBS sectors with the two-digit sectors 72, 73 and 74 of the ISIC Rev. 3 classification, we use the OECD-STAN (STructural ANalysis) Database and classify

[4] PCT stands for Patent Cooperation Treaty. A patent application filed under the PCT is called an international application, or PCT application.

[5] As in Hall, Jaffe and Trajtenberg (2005) the stock of patents was build using a perpetual inventory method with a depreciation rate set at 15%. Then we divided the stock by total employment, since our specification is in labor intensities, and we computed its logarithm, in order to avoid problems related with potential outliers. We tried alternative specifications with a depreciation rate set at 10%, with the simple level of the stock of patents (not divided by employment) and we found that our results were extremely robust to all such alternative specifications.

as KIBS the following 2-digit ISIC Rev. 3 sectors: - The renting of machinery and equipment (71); Computer and related activities (72); Research and development (73); Other business activities (74).[6] We then calculate the share of persons engaged in these sectors on the total employment of each country, as provided by STAN, and compute the share of workers in KIBS sectors (*KIBS*). Also the number of employees in the manufacturing sector comes from STAN (STructural ANalysis) Database and includes all sectors classified as "Manufacturing" in the ISIC Rev. 3. We then calculated the share of person engaged in manufacturing sectors over total employment (*MANU*).

Trade data proceed from the OECD database: specifically we collected data on the share of trade on GDP (*OPEN*) and the ratio of exports to imports (*EXP/IMP*). These measures indicate the degree of openness to trade of a country and of its capability to be competitive in the international markets. The number of researchers over thousand of employment (*RES*) was also taken from the OECD Research and Development Statistics, together with the data on the expenditures in R&D (in PPP dollars) over total employment (*R&Dint*). The share of enrolled students in tertiary education on the total population, used as a proxy for human capital (*HK*) instead comes from UNESCO data. The database also includes the level of income per capita of each country (*INCOPC*), as provided by the Penn World Tables, using the ratio of PPP dollars (in 2005 constant prices) per equivalent adult.

The data used to calculate the levels of Total Factor Productivity (TFP) were taken from OECD-STAN (STructural ANalysis) Database for the whole economy. The (log of) the level of TFP was calculated as in Bernard and Jones (1996) in the following way:

$$\ln(TFP_{it}) = \beta_{it} \ln\left(\frac{Y_{it}}{L_{it}}\right) + (1-\beta_{it})\ln\left(\frac{Y_{it}}{K_{it}}\right) \tag{4}$$

Following the Euler theorem and assuming constant returns to scale we calculate β as the share of labor compensation over total GDP. Y denotes real GDP, L is the level of total employment and K is the net stock of capital: all measures are taken from the OECD-STAN (STructural ANalysis) Database.[7] Real GDP and capital stock series have then been deflated by the Purchasing Power Parities deflator to obtain comparable measures in PPP dollars for all the countries in the database.

[6] We included also the sector 71 (Renting of machinery and equipment) in order not to lose too many observations, since in most cases these four sectors are aggregated together at the national level.

[7] In the case of United States and Japan, for which net capital stocks were not available in OECD-STAN, the capital stock series proceed from the EU-KLEMS database (O'Mahony and Timmer, 2009).

The final database is a fairly balanced panel of 18 OECD countries and 18 years (1990-2007).[8] In Table (1) the descriptive statistics of the variables are displayed.

3.3. The methodology

Our estimation strategy aims to address the endogeneity problems related with the estimation of our equations, as summarized in equation (4). Indeed we suspect that even if we adopted a one-year lag to avoid reverse causality issues in the estimation and even if we included country dummies to control for unobserved heterogeneity, some of the independent variables of our equations might still suffer from endogeneity problems. In panel data the main limitation of the usual OLS fixed effects estimators is the assumption of strict exogeneity, according to which the level of an independent variable today must be uncorrelated with past, present and future exogenous shocks (the idiosyncratic error term). While we believe that present and future shocks will most likely be uncorrelated with the independent variables of our model, in some case past shocks could have indeed an effect on some regressors.

The final specification of the model is structured in three sequential equations where the two key independent variables (*PATint*) and (KIBS) are dependent variables of the previous equations:

$$\begin{cases} PAT\,\text{int}_{it} = a_0 + a_1 STOCKpat_{it-1} + a_2 RES_{it-1} + a_3\left(EXP_{it-1}/IMP_{it-1}\right) + \eta_i + \lambda_t + \varepsilon_{it} \\ KIBS_{it} = b_0 + b_1 PAT\,\text{int}_{it-1} + b_2 OPEN_{it-1} + b_3 MANU_{it-1} + b_4\left(MANU_{it-1}\right)^2 + \eta_i + \lambda_t + u_{it} \\ TFP_{it} = c_0 + c_1 KIBS_{it-1} + c_2 HK_{it-1} + c_3 R\&D\,\text{int}_{it-1} + c_4 PAT\,\text{int}_{it-1} + \eta_i + \lambda_t + e_{it} \end{cases} \quad (5)$$

In the patent equation we are worried that the number of researchers (*RES*) might be correlated with past shocks of the dependent variable (*PATint*)[9]: to avoid this problem we instrument the number of researchers with their own lags in t-2 and t-3. After having estimated the coefficients of the patent equation, we exploit the sequential pattern of our equations and in the KIBS equation we instrument *PATint* with the fitted values obtained from the patent equation. Indeed also in the KIBS equation a possible endogeneity problem might exist, since the increasing specialization in KIBS activities also leads to an increasing number of patent applications, as KIBS are highly knowledge (and patent) intensive. Instrumenting *PATint* allows to avoiding this problem of reverse causality. Also the openness to trade measure in the KIBS equation is likely to be endogenous: if a country shifts its economic specialization

[8] The countries included in the database are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain, Sweden, United Kingdom and United States.

[9] A possible case for the endogeneity of the number of researchers in the patent equation could be the growth of a new and fertile field of research,that fosters a contemporaneous increase of patent applications. In the following years this might have induced the recruiting of additional researchers by private firms in order to fully exploit the opportunities offered by such new scientific field. This reaction would clearly violate the assumption of strict exogeneity because past shocks in patent productivity would be correlated with the future level of researchers.

from the production of goods to knowledge intensive business activities, by definition the amount of imported goods for consumption will increase. Therefore we instrument the variable *OPEN* with the level of openness to trade in time t-2, as well as the level of income per capita in t-2. Finally also in the TFP equation we instrument our main variable of interest, the share of employment in KIBS, with its own past levels (in time t-2 and t-3), to make sure we are not bearing the risk of endogeneity problems.

We estimate this system of three equations by Two-Stage-Least-Squares (2SLS), performed equation by equation, which is empirically equivalent to the estimation of System 2SLS (Wooldridge, 2002: 192). The 2SLS estimator is not necessarily the asymptotically most efficient estimator, for example the Three-Stages-Least-Squares estimator can, under specific conditions, be more efficient. However the 2SLS estimator has the great advantage that, in order to produce consistent estimates of the parameters of interest, it only has to verify that the orthogonality conditions hold (Wooldridge, 2002: 199; Bogliacino and Pianta, 2013). This makes it the preferred estimator for our system of equation, since we can be sure that if our choice of instruments is legitimate we will be able to consistently estimate the relevant coefficients.

3.2. The results

Table (3) presents the estimates of equation (1), -the patent equation- which explains the level of patent per employed person. In the model we include both country and time dummies and we use White-robust (1980) standard errors. In column (1) we present normal OLS estimates in which all regressors are considered as exogenous.[10] The coefficient of the cumulated stock of patents per employed person *STOCKpat* is positive and significant, showing that the stock of prior inventions increases patent productivity (the so-called “standing on the shoulders of giants” effect). Also the coefficient of *RES* (the number of researchers per thousand of employment) is positive and significantly different from zero at 10% level. These preliminary results confirm our expectations: the availability of knowledge externalities stemming from the existing stock of technological knowledge and the endowment of knowledge embodied in the researchers allows firms to react creatively and introduce novel technologies, proxied by patents.

However we want to make sure that our results do not suffer from endogeneity problems, therefore in column (2) of Table (3) we instrument the level of researchers with its lags in time t-2 and t-3 and estimate the model with 2SLS. In column (2) the Kleibergen-Paap F-statistics, which is robust to the presence of heteroskedasticity rejects the null hypothesis of weak identification: hence the instruments are not weak. Moreover the Hansen test of overidentification of all the instruments accepts the null

[10] Since we are using the number of patent applications divided by the level of employment our dependent variable is not a positive integer and therefore we cannot apply the usual count data models.

hypothesis of exogeneity of the instruments used.[11] Our choice of instruments is hence legitimate and it will allow to obtaining consistent estimates in our model. The coefficient of *RES* in column (2) is still positive and it is also larger and more significant than in the OLS estimates. In Table (3) we also perform a heteroskedasticity-robust endogeneity test on the coefficient of *RES* to check whether the variable is actually endogenous. The test rejects the null hypothesis of exogeneity at the 5% level, indicating that the choice to instrument the number of researchers is legitimate.

Finally in column (3) we also include a measure of the openness of a country to trade, by introducing as an additional regressor the ratio of Exports to Imports *EXP/IMP*. Our expectation is that the stronger the exposure of a country to foreign competition (as proxied by trade openness) the greater will be the creative reaction of national firms and their technological effort, that we proxy with the number of WIPO patents. The level of exposure of a country to foreign competition will be higher the greater the level of imports with respect to exports. The results in column (3), in which we still control for the endogeneity of researchers, are in line with these expectations: the lower the ratio of exports to imports (and hence the greater the imports) the higher the creative reaction of firms, as proxied by the number of patents per employed person.

Table (4) presents the results of the estimation of equation (2), -the KIBS equation- which explains the level of KIBS in each OECD country. According to our theoretical framework we expect that both the openness to trade of a country (that we proxy with the share of trade over total GDP) and the creative reaction of firms proxied by the number of patents should increase the specialization of countries in KIBS. Moreover we also expect manufacturing activities to exert a substitution effect on KIBS only after a certain threshold: a small knowledge intensive manufacturing industry (KIM) should instead be complementary with the existence of KIBS.

Column (1) presents the normal OLS estimation of the model, including country and time dummies. The results show that the ratio of trade over total GDP has a positive and significant effect on the share of employment in KIBS. The same positive and significant effect is found for the number of patents per employed person. The share of manufacturing over total employment (*MANU*) is also found to be positive, while its squared term (*MANUsq*) is negative. This indicates the existence of an inverted-U relationship between the share of manufacturing and the share of KIBS in total employment: after a certain threshold the effect of manufacturing becomes negative. Looking at the two coefficients of *MANU* and *MANUsq* of respectively 0.3 and -1.3 we can calculate the level at which the effect of manufacturing share on KIBS starts to be negative and this amounts to approximately 0.11 (11%). This result is most important as it confirms that KIBS and KIM are complementary when their shares

[11] The joint null hypothesis of the Hansen J-statistics is that the instruments are valid, that is, uncorrelated with the error term and that the excluded instruments are correctly excluded from the second stage.

are close to parity. The increase of KIBS substitutes the decline of manufacturing only when the share of the former is too small and the latter exceeds approximately the 10% level. Finally, in order to control for the proximity to the frontier of economic advance, we also control for the level of wages and labor productivity, proxied by the income per capita (*INCOPC*): again we find that the coefficient is positive and significant.

In column (2) we control for the possible endogeneity of *PATint* and we exploit the sequential pattern of our system of equations: we use as instruments for *PATint* the independent variables used in equation (1), that is the stock of patents per employed person and the level of researchers per thousand of employment at time t-2. The 2SLS estimates do not change much with respect to the previous estimates. The significance of *PATint* is slightly reduced, but remains significant at the 5% level. Moreover the Kleibergen-Paap F-statistics show that the instruments are not weak and the Hansen test on overidentification indicates that the instruments are truly exogenous. In this case however we find the endogeneity problem is not relevant, since the endogeneity test over the *PATint* variable cannot reject the null hypothesis of exogeneity of the variable. In column (3) instead we instrument only the variable that measures the openness to trade (*OPEN*), as we suspect that also this variable might suffer from endogeneity problems. As instruments we use the lagged levels of openness to trade and of income per capita in time t-2. The results show that the instruments are both relevant and exogenous, providing strong support for their inclusion. The coefficient of *OPEN* is still positive and significant. The endogeneity test cannot reject the null hypothesis of exogeneity of the variable, but the p-value is much lower than in the case of *PATint*, showing that the openness to trade is probably more likely to be affected by endogeneity. Finally in column (4) we instrument both *PATint* and *OPEN* with the instruments used in the previous two specifications: also in this case we find that instruments are valid and that the coefficients of our variable of interest remain positive and strongly significant.

In Table (5) we estimate equation (3), the TFP equation. In column (1) we present OLS estimates in which we include both the share of KIBS and the level of human capital of a country (*HK*), as proxied by the number of enrolled students over the total population. As expected both variables display positive and significant coefficients. The positive coefficient of *KIBS* in particular confirms the hypothesis that knowledge intensive business activities have a fundamental role in explaining the overall level of Total Factor Productivity of advanced economies. In order to check whether the positive coefficient of *KIBS* represents a true causal relation we instrument it with its own past levels, in order to check whether an endogeneity problem is present. The results in column (2) show that the instruments are not weak (the Kleibergen-Paap F-statistics rejects the null hypothesis of weak identification) and that they are not correlated with the equation error term, since the Hansen test of overidentification accepts the null hypothesis of exogeneity of the instruments. The size and significance of the coefficient of the *KIBS* variable, instead, is still large and strongly significant. The endogeneity test on the *KIBS* variable however suggests that the variable is truly exogenous to the error term. Even if our model includes country and time dummies that should capture most of the unobserved heterogeneity present in the error term, in column (3) we also check whether including the R&D expenditures and the number of patent applications per employed person (respectively *R&Dint* and *PATint*) affects somehow the *KIBS* coefficient, since these are factors that are also likely to affect the levels of Total Factor Productivity. The results of column (3) show that both *PATint* and *R&Dint* have an important role in explaining the level of TFP, but that the coefficient of *KIBS* is not affected by the inclusion of these additional variables, as well as the human capital (*HK*) coefficient.

4. CONCLUSIONS

This paper has analyzed process of structural and technological change that led to creation of a knowledge economy based upon the mix of a strong KIBS and a thin but highly specialized KIM industry that substituted the mass manufacturing industry at the heart of the economic system of advanced economies in the decades between the end of the XX and the early XXI century. The paper has elaborated an interpretative framework based upon the Schumpeterian notion of innovation as a creative response that can take place only when firms caught in out-of-equilibrium conditions can access relevant knowledge externalities, implemented with the analysis of technological congruence that enables to grasp the advantages of the direction of technological change towards the most intensive use of the inputs that are locally and comparatively most abundant.

The strong knowledge base in place in advanced economies could support the reaction of firms and make it creative. The increasing role of knowledge in turn became a powerful attractor directing the introduction of technological changes with a strong bias in favor of knowledge intensive activities. Increasing returns in the generation of knowledge at the system level and sophisticated knowledge governance procedures favored the identification of knowledge as the strategic input towards which it was more profitable to direct the introduction of new technologies.

The empirical evidence of the OECD countries in the years 1990-2007 confirms that the set of variables so far identified play a strong and significative role to explaining the growth of knowledge intensive business service industries and their progressive substitution of the manufacturing industry at the heart of the economic system of advanced economies

The implications of the interpretative framework elaborated through this paper and supported by strong and reliable empirical evidence are important both for economics and economic policy. With respect to economics, we claim that the interpretative framework based upon the Schumpeterian notion of innovation as a form of creative reaction that takes place when favorable external conditions are available, deserves much a broader use as it provides important tools to understand how structural and technological change are endogenous and strictly intertwined.

Our analysis has two important policy implications: i) the central role of the support to the generation and use of technological knowledge; ii) the new complementarity between KIBS and KIM. Let us analyze them in detail.

Economic policy should support as much as possible the generation of knowledge, along three main axes: a) by implementing the governance of knowledge and as a consequence the interactions between the powerful public research system and the emerging knowledge intensive business services industries; and b) favoring the dissemination of knowledge in order to increase the availability of external knowledge to favor the accomplishment of successful creative responses; c) the role of tight and localized user-producer interactions between KIBS and manufacturing is vital in the generation and exploitation of knowledge makes. The active governance of knowledge interactions-cum-transactions is necessary to implementing the division of labor and the participation of a variety of agents with different incentive mechanisms to the generation and exploitation of knowledge as an economic activity (Ostrom and Hess, 2006).

From an economic policy viewpoint it seems clear that the shift to the new knowledge economy is the result of a vital and fertile process that is able to support the increase of TFP at the system level. The attention of policy makers should be called upon the new evidence of the complementarity between the new knowledge intensive business services and a thinner but highly skill and knowledge intensive manufacturing industry. The substitution between KIM and the manufacturing industry takes place as long as the shares of the manufacturing industry are far larger than that of KIBS. After the parallel decline of the manufacturing industry to a level of approximately 10% of employment and the growth of the shares of KIBS to comparable levels, a new complementarity between the new knowledge intensive manufacturing and the knowledge intensive business services industries becomes evident. KIBS need KIM as much as KIM need KIBS to keep the knowledge generation mechanisms based upon user-producer interactions at work. This complementarity is likely to be the new source of a sustainable competitive advantage of advanced countries. The desertification of the manufacturing industry might endanger a competitive advantage based upon technological knowledge as the key input and output. From this viewpoint the mechanisms underlying the structural change analyzed by Simon Kuznets at the time of the radical substitution of manufacturing to agriculture apply only to a point.

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TABLE 1. Variables description

PATint	log of the number of PCT patent applications (WIPO) per employed person
STOCKpat	log of the cumulated stock of PCT patents (WIPO) per employed person
RES	number of researchers per thousand of employment (OECD)
EXP/IMP	ratio of exports over imports (OECD)
KIBS	the share of employment in KIBS for each country (OECD)
OPEN	share of trade on GDP (OECD)
INCOPC	level of income per capita (PENN World Tables)
MANU	share of employment in the manufacturing sectors for each country (OECD)
MANUsq	square of the share of employment in the manufacturing sectors for each country (OECD)
TFP	Total Factor Productivity (OECD)
HK	share of enrolled students in tertiary education on the total population (UNESCO)
R&Dint	log of the ratio of expenditures in R&D (in PPP dollars) over total employment (OECD)

TABLE 2. Descriptive statistics, time period 1990-2007

VARIABLE	Obs.	Mean	Std. Dev.	Min	Max
PATINT	313	4.482	1.524	-2.950	6.721
STOCKpat	317	6.123	1.760	-2.111	8.819
RES	303	6.967	2.719	2.340	17.773
EXP_IMP	311	1.036	0.227	0.522	1.902
KIBS	300	0.096	0.029	0.040	0.176
OPEN	321	0.730	0.371	0.160	1.728
INCOPC	324	0.032	0.008	0.008	0.056
MANU	317	0.174	0.042	0.099	0.287
MANUsq	317	0.032	0.016	0.010	0.082
TFP	301	11.627	0.172	11.190	12.013
HK	306	0.037	0.011	0.011	0.068
R&Dint	241	6.365	0.700	3.133	7.426

TABLE 3: The patent equation

VARIABLES	(1) OLS *PATint*	(2) IV *PATint*	(3) IV *PATint*
		RES endog	
$STOCKpat_{t-1}$	0.750***	0.750***	0.749***
	(0.147)	(0.142)	(0.141)
RES_{t-1}	0.037*	0.067**	0.065**
	(0.021)	(0.029)	(0.028)
EXP/IMP_{t-1}			-0.526*
			(0.316)
Constant	-4.759***	-3.547***	-3.191***
	(0.775)	(0.786)	(0.743)
Observations	297	279	279
R-squared	0.919	0.917	0.918
F statistic (Kleibergen-Paap)		235.079	235.079
Hansen J statistic (overidentification test of all instruments)		0.597	0.309
Chi-sq. p-value		0.439	0.5784
Endogeneity test of endogenous regressors:		3.887	3.877
Chi-sq. p-value		0.048	0.049

All models include country and time dummies. In column (2) and (3) excluded instruments are the number of researchers per thousand of employment in time t-2 and t-3. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

TABLE 4: The KIBS equation

VARIABLES	(1) OLS KIBS	(2) IV KIBS	(3) IV KIBS	(4) IV KIBS
		PATint endog	*OPEN* endog	*PATint &* *OPEN* endog
$OPEN_{t-1}$	0.030***	0.032***	0.035***	0.037***
	(0.005)	(0.005)	(0.005)	(0.006)
$PATint_{t-1}$	0.001***	0.001**	0.001**	0.001**
	(0.000)	(0.000)	(0.000)	(0.001)
$INCOPC_{t-1}$	0.748***	0.870***	0.696***	0.831***
	(0.208)	(0.203)	(0.217)	(0.232)
$MANU_{t-1}$	0.294**	0.375***	0.296**	0.386***
	(0.119)	(0.114)	(0.118)	(0.118)
$MANUsq_{t-1}$	-1.310***	-1.599***	-1.308***	-1.624***
	(0.305)	(0.312)	(0.300)	(0.323)
Constant	-0.014	0.077***	0.087***	0.075***
	(0.014)	(0.015)	(0.016)	(0.016)
Observations	286	272	274	261
R-squared	0.985	0.985	0.985	0.985
F statistic (Kleibergen-Paap)		12.135	137.139	4.490
Hansen J statistic (overid. test of all instruments)		0.104	0.654	1.011
Chi-sq. p-value		0.746	0.418	0.603
Endogeneity test of endogenous regressors:		0.336	2.445	1.7
Chi-sq. p-value		0.562	0.117	0.427

All models include country and time dummies. In column (2) excluded instruments are the number of researchers per thousand of employment in time t-2 and the stock of patents per employed person in time t-2. In column (3) excluded instruments are the openness to trade in time t-2 and income per capita in time t-2. In column (4) excluded instruments are the number of researchers per thousand of employment in time t-2, the stock of patents per employed person in time t-2, the openness to trade in time t-2 and income per capita in time t-2. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

TABLE 5: The TFP equation

VARIABLES	(1) OLS TFP	(2) IV TFP *KIBS* endog	(3) IV TFP *KIBS* endog
$KIBS_{t-1}$	2.926***	2.738***	2.624***
	(1.020)	(0.969)	(0.838)
HK_{t-1}	1.474**	1.557*	1.603*
	(0.698)	(0.822)	(0.929)
$RDint_{t-1}$			0.050***
			(0.015)
$PATint_{t-1}$			0.166***
			(0.031)
Constant	11.316***	11.618***	10.703***
	(0.053)	(0.127)	(0.298)
Observations	275	265	211
R-squared	0.922	0.919	0.943
F statistic (Kleibergen-Paap)		274.322	266.289
Hansen J statistic (overidentification test of all instruments)		0.132	1.212
Chi-sq. p-value		0.716	0.270
Endogeneity test of endogenous regressors:		0.203	0.244
Chi-sq. p-value		0.652	0.621

All models include country and time dummies. In column (2) excluded instruments are the share of employment in KIBS in time t-2 and t-3. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

TABLE 6. Countries included in the regressions

Australia	Germany
Austria	Italy
Belgium	Japan
Canada	Netherlands
Czech Republic	Norway
Denmark	Spain
Estonia	Sweden
Finland	United Kingdom
France	United States