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# WORKING PAPER SERIES

## GLOBALIZATION AND INNOVATION IN ADVANCED ECONOMIES

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# GLOBALIZATION AND INNOVATION IN ADVANCED ECONOMIES [1]

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**PRELIMINARY DRAFT**

## 1. INTRODUCTION

The globalization of product markets has characterized the evolution of the world economy since the last decade of the XX century. The entry of new countries in the international markets has changed dramatically the international division of labor. Substantial changes have been taking place in the labor markets of advanced countries along the same time interval. The introduction of a new wave of directed technological change strongly biased in favor of higher levels of skill intensity in advanced countries has paralleled the globalization of product markets. We argue that these three processes took place at the same time and parallel each other as they are three aspects of the same process of structural change. This paper contributes the analysis of the effects of higher levels of international integration of product markets on the factor markets of the economies that participate to international trade shaped by the new globalized product markets and implements an explicit and direct analytical relationship between the changes in international product markets, the related changes in domestic factor markets and the direction and typology of technological change.

In so doing we rely upon the localized technological change approach as a tool to integrate the Schumpeterian frame of analysis with the induced technological change tradition that has received, not by chance, new attention in the recent years. The induced technological change approach

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enables to appreciate the effects of the changes in factor markets upon the rate and the direction of technological change. As a matter of fact the empirical evidence of the main advanced capitalistic economies shows substantial cross-sectional and longitudinal variance of the output elasticity of production factors. Such changes in the output elasticity of production factor can take place only because of the introduction of technological changes that have affected the production functions. Hence the variance in the output elasticity across countries and industries, within countries, is a clear indicator of the variety of technologies at work within the same sectors and can be interpreted as the consequence of the introduction of biased technological changes that have changed the basic characteristics of the production process.

The persistence of such static and dynamic variance, both within and between economic systems, is a clear clue that technological change is far from being neutral, as it is currently assumed. This evidence has received very little attention (Hall and Jones, 1999). Explicit attempts to dismiss the relevance of the international evidence can be recorded (Caselli and Feyrer, 2007).

Almost no attention has been paid to the interindustrial variance both within and among countries. Yet the interindustrial variance of the output elasticity of production factors is even more intriguing than the international variance because of the substantial homogeneity, or at least lower heterogeneity, of the factor markets. The conditions of capital and labor markets vary within a country, across different manufacturing sectors, much less than across countries in the international economy.

This paper explores the variance of the output elasticity of labour in twelve manufacturing sectors of the main OECD economies in the years 1995-2006 and elaborates an interpretative framework based upon the merging of the classical inducement hypotheses with the Schumpeterian literature enriched by the retardation hypothesis. Our approach articulates and tests the hypothesis that the direction of technological change is influenced by the dynamics of the innovation process. Specifically we argue that technological change is skill-biased when product innovations prevail and capital intensive when process innovations play a major role. To do so we apply the localized technological change approach that accounts explicitly for fixed capital. In so doing we generalize the argument elaborated by Acemoglu (2002) who in fact, uses a simplified approach that considers only the choice between

skilled and unskilled labor and does not include the consideration of fixed capital.
Once the importance of specific product markets is identified, it becomes also clear that only sectoral analyses are able to appreciate the different mechanisms which lay behind the inducement hypothesis, while such differences would be lost in aggregation when country-level analyses are performed (Acemoglu, 2003, 2006, 2010; Blanchard, 1997).

The remainder of the paper is organized as it follows: Section 2 elaborates the interpretative framework and presents the hypotheses. Section 3 presents the empirical evidence. The conclusions summarize the main results and explore the implications both for economic analysis and economic policy.

## 2. THE INTERPRETATIVE FRAMEWORK AND THE HYPOTHESES

### 2.1. GLOBALIZATION AND FACTOR MARKETS

The effects of the entry of new labor abundant countries in international product markets can be easily analyzed within the framework provided by the well-known Hecksher-Ohlin model. The integration of new labor abundant countries in international product markets can be portrayed as an increase in the size of the production frontier of labor-intensive products. The consequence is straightforward as it consists in the change in slope of the isorevenue, due to the reduction of the relative price of labor intensive products, the consequent reduction in the equilibrium output of labor intensive products in capital abundant countries and a new international division of labor based upon higher levels of specialization of capital abundant countries in capital intensive products (Grossman and Helpman, 1990, 1991, 1994).

Such changes in the international product markets brought about by the globalization affect sharply not only the structure of the trading economies but also their internal labor markets. The higher levels of integration of the product markets have in fact the direct effect to change the relative costs of production factors. More specifically it is clear that the entry of new suppliers based in labor abundant countries with low wages has the direct effect to increase the relative cost of labor in capital abundant countries.

In an integrated, open economy the slope of the isocost cannot be any longer determined by the ratio of internal wages to internal capital user costs. The slope of the isocost within the factor markets of an open economy is in fact sharply influenced by the relative levels of internal factor costs with respect to the average levels of the factor costs in all the domestic factor markets that interact and become interdependent because of the open access to the international product markets.

The entry of new low wage, labor abundant competitors in global markets at the same reduces the slope of the isorevenue, hence changes the conditions for the international division of labor and the specialization of countries, and changes the relative conditions of the domestic factor markets.

The appreciation of the notion of relative isocost, as distinct from the absolute isocost enables to assess directly the effects of the changing conditions of international product markets upon the domestic factor markets of each country that participates into the global economy.

The new institutional conditions that have been consolidating since the last decade of the XX century have opened the international product markets to firms based in huge, labor abundant economies. Much literature has explored the effects of globalization upon the division of labor and the specialization of countries participating to international trade. Less attention has been paid to assessing the effects of globalization of factor markets.

The entry of the new labor abundant economies into the global economy had the direct effect to reducing the average unit wage within the globalized labor markets so that the isocost of advanced countries becomes steeper. Firms based in capital abundant countries could face these relative changes in the new globalized factor markets either by means of textbook substitution moving upon the existing maps of isoquants towards higher levels of capital intensity or, following the induced technological change approach, by means of the introduction of new technologies that help them to cope with the new product and factor markets.

The introduction of technological change and the consequent increase of the levels of total factor productivity can play a crucial role in this context. The negative effects of the entry of new, huge, labor abundant ad low wage countries in the global economy can be contrasted if and when advanced countries were able to increase their total factor productivity.

In such conditions capital abundant countries can cope with the changed conditions of both product and factor markets by means of the introduction of technological innovations that enable them to increase the levels of total factor productivity levels. Following the induced technological change approach we can actually argue that these changes in international product markets reflected by the consequent changes in the internal factor markets can stir the introduction of technological innovations. Technological innovations will be aimed at increasing the capital intensity of the production process via the increase of the output elasticity of capital and to increase total factor productivity. Following the Schumpeterian approach, however, firms caught in out-of-equilibrium conditions by the changing conditions of both factor and product markets might try and react by changing their technology and specifically by means of the introduction of either product or process innovations. The alternative has important implications with respect to the factor intensity of the new production process. Let us now pay attention to these aspects.

In the economics of innovation and new technology there are two strands of literature that interact very little and specialize in separate fields of investigation building upon respectively the Schumpeterian and the Hicksian legacies. Their closer interaction and integration can yield important results.

## 2.2 INDUCED INNOVATION.

The analytical core of the literature that explores the direction of technological change, recently revived by a new wave of contributions, impinges upon the well-known inducement hypothesis (Acemoglu and Zilibotti, 2001; Crafts, 2009). This literature concentrates upon the direction of technological change. It recognizes that technological change is not neutral, but rather intrinsically biased, i.e. it is either capital intensive and hence labor saving, or labor intensive and hence capital saving, as it is the result of the attempt of innovators to cope with the changing opportunities and constraints of the factor markets (Ruttan, 1997 and 2001).

More specifically we can identify and retain, within the induced technological change approach, two different arguments. According to the first the rate of technological change is determined by the changing characteristics of factor markets. The tradition of analysis that impinges upon the Hicksian reinterpretation of the hypothesis first suggested by Karl Marx, suggests that technological change is induced by changes in the relative price of production inputs in the factor markets and directed towards the increase of the factor intensity of the production factor that became relatively less expensive (Hicks, 1932; Binswanger and Ruttan, 1978). This means that the direction of technological change depends only on $\Delta(w/r)$, i.e. on the rate of change of such ratio: when this is positive it will lead to capital-intensive technological change and vice versa.

On the other hand the literature that impinges upon the contributions of Paul Samuelson (Samuelson, 1965) points out that at each point in time technological change is directed towards the most intensive use of the production factor that is locally more abundant, irrespective of the changes of its market price. An increase of wages in a labor abundant country would induce the introduction of new technologies biased in favor of a larger output elasticity of labor. In this case, hence, the only determinant of the direction of technological change is the level of $w/r$: as long as this is less than one, technological change will be labour-oriented, even if $\Delta(w/r)>0$.

The combination of these two hypotheses enables to articulate a coherent frame of analysis where factor markets play a central role to explain both the rate and the direction of technological change.

Even within the more recent literature which builds upon the induced technological change approach (Acemoglu, 2002, 2003, 2006, 2010), however, product markets are not considered as relevant and the characteristics of the rivalry among firms are not investigated. In such a way the choice on the kind of innovation introduced is only related to the changes in factor prices: whether a firm introduces a capital intensive or (skilled) labour intensive innovation, the two alternatives are assumed to be equally effective irrespective of the market in which they are introduced. For the same token this literature pays very little attention to the intrinsic characteristics of the generation of technological knowledge that enables the introduction of technological innovations.

## 2.3 THE SCHUMPETERIAN APPROACH

The literature that impinges upon the Schumpeterian legacy concentrates the analysis of determinants of the introduction of innovations upon the role of the changing characteristics of product markets, the forms of competition and the features of market rivalry among firms that prevail at each point in time. The Schumpeterian literature paid very little attention to the direction of technological change and disregards the changing characteristics of factor markets, as a major determinant of the rate of introduction of innovations.

The careful examination and integration of new and old acquisitions of the Schumpeterian literature, however, helps extracting a number of elements that can help their integration with the literature specializing in the analysis of the direction of technological change.

The notion of retardation introduced by Simon Kuznetz plays a central role in this undertaking. There is a typical sequence that accompanies and qualifies the life cycle of products and industries. New products and new industries differ substantially from old ones both on the demand and the supply side. The integration of the demand side analysis elaborated by Pasinetti with the supply side approach mastered by Kuznets enables indeed a progress as Moshe Syrquin (2010) suggests. It seems clear that the further integration within that frame of the analysis of such factors as the dynamics of competition in product markets, the features of the innovation process and the types of innovations being introduced, provides much a richer analytical framework.

The notion of retardation enables to discriminate between industries according to the role of new products. Schumpeterian competition in new industries, specializing both in modern final and capital goods, is characterized by intense rivalry based upon the sequential introduction of product innovations with typical product races. Creative imitation by newcomers and followers erode transient monopolistic rents and push innovators to introduce new generations of product innovations with growing levels of product differentiation aimed at the identification of narrower and narrower product niches. The demand is characterized by fast rates of growth sustained by the diffusion of the new products in widening and increasing groups of new consumers. Income elasticity is high and conversely price elasticity is low. The generation of product innovation is based upon labor intensive research and development activities and draws extensively upon high levels of human capital engaged in production and marketing. Low levels of standardization, continual introduction of new prototypes that command high levels of skilled labor intensity in fact characterize the production process of new products. In these industries, both the production process, the innovation process and the generation of knowledge impinge upon skilled labor intensive activities. Consequently technological change is biased in favor of the intensity of skilled labor.

On the demand side mature industries including traditional final goods and intermediary inputs, are characterized by high levels of price elasticity and low levels of income elasticity. The rates of growth of output are slow since the diffusion has already reached saturation levels: demand is typically sustained by substitution process. In these industries the penetration of import is high: the growing exposure to global competition raised by the entry of new competitors based in labor abundant countries has characterized the market dynamics in the last decades. The production process of traditional products is highly standardized with high levels of capital intensity. Competition is based on price and only firms able to reduce their production costs either with the access to cheap production inputs or new technologies can survive.

Schumpeterian competition in these industries is mainly based upon the introduction of process innovations. In turn process innovations stem from intense user-producer interactions between upstream producers of capital goods and downstream users that most typically produce mature goods. Process innovations are mainly embodied in new vintages of capital goods. Their introduction requires not only close interactions with suppliers but also and primarily high levels of investment. The knowledge generation opportunities stemming from user-producer interactions and the embodied character of process innovations have direct and enhancing effects on the growing capital intensity of the production process, for given levels of wages. In these industries, technological change is likely to be biased in favor of capital intensity.

The sequential analysis of the technological life cycle mastered by Jim Utterback (1994) complements and reinforces this argument. Utterback notes that technological change is characterized by sequences of product innovations that are eventually followed by process innovations. Process innovations are more likely to be introduced in a second phase of the technological life cycle after the original introduction of product innovations, when the variety of product innovations is progressively selected by competition in the product markets with the emergence of a dominant design. This process parallels the substitution of monopolistic competition based upon the introduction of new products with price competition based upon cost reductions. Competition in product market takes place mainly by means of the reduction in costs made possible by the introduction of process innovations. Technological change in mature industries that have lower opportunities to introduce product innovations is characterized by higher levels of process innovations.

## 2.4 THE LOCALIZED TECHNOLOGICAL CHANGE APPROACH

The localized technological change approach contributes these hypotheses and provides strong additional arguments that help their integration into a single frame that enables to analyze jointly the effects of both product and factor markets and to focus the intrinsic bias in favor of skill intensity, as determined by the characteristics of the process that shape the generation of technological knowledge generation and the introduction of technological innovations (Antonelli, 2003, 2008 and 2011).

In the localized technological change approach firms exposed to unexpected changes in factor markets try and cope with the changing conditions of equilibrium by means of the introduction of new technologies that minimize the changes in the factor intensity of the production process. Relevant irreversibility and limited substitutability of existing production factors limit their mobility in the space of existing techniques. Cognitive limitations contribute to localizing their scope of actions: their competence is based upon learning processes based upon the techniques, defined in terms of factor intensity, that they have been practicing. In these conditions firms try and react to the changing conditions of factor markets by means of the introduction of new technologies that enable them to remain in the proximity of the original isocline. This implies the introduction of new skilled labor-intensive technologies such that labor can be used even with new higher wages.

In the localized technological change approach, when wages increase, learning firms that rely upon technological knowledge as a major asset and a relevant competitive tool, as in the Schumpeterian traditions, in order to stay as close as possible to the original techniques that are the source of technological knowledge and competence, and hence move along an isocline defined by the original conditions of the process, will try and react by means of the introduction of new technologies, as in the induced technological change model, but will introduce labor intensive technologies rather than capital intensive ones. Firms that rely less on technological knowledge and competence will react to the increase of wages with the introduction of a new technology that is more capital intensive, hence moving towards highly capital intensive techniques. In the localized approach, technological change is always and necessarily skill-intensive. The more relevant is the role of learning as a source of technological knowledge, the more localized is technological change and hence the more skill-intensive its direction (Antonelli and Quatraro, 2011; Antonelli and Colombelli, 2011).

More specifically the localized technological change hypothesis suggests that firms, constrained by factor irreversibility but able to implement localized learning processes, try and cope with the changes of factor costs by means of the introduction of skill-intensive product innovations with high levels of human capital that can be employed efficiently with higher levels of wages. Firms that rely more upon the adoption of process innovations embodied in new capital and intermediary goods introduced by upstream producers, as opposed to the introduction of original product innovations, are more likely to follow the traditional Hicksian inducement mechanisms and react to the increase in unit wages with the introduction of capital-intensive technologies

This approach enables to combine the two coexisting traditions of the induced technological change literature so that the changes in the market price of production inputs help understanding the causes of technological change while the relative abundance of production factor explain at each point in time the direction of technological change with the Schumpeterian tradition according to which technological change is determined by the dynamics of product markets (Antonelli, 2009).

Table 1 provides a synthesis of our approach and shows how and why the direction of technological change is influenced both by the dynamics of product markets and by the characteristics of the innovation processes. Innovation in new industries is based upon new products that are being generated mainly by research and development activities and are manufactured by labor-intensive processes: technological change is biased, skilled labor and specifically human capital intensive. In mature industries the features of the generation of process innovations –i.e. the key role played by user-producer interactions-, and the features of the activities that lead to the introduction of process innovations -i.e. the investments that are necessary to acquire capital goods that embody the new processes- push innovating firms to increase the output elasticity of capital.

The traditional view according to which technological change is necessarily biased towards capital intensive technologies recently updated by Zeira (1998) applies only to mature industries where technological change is induced by the increase of wages towards capital intensive technologies. In these industries process innovations, rather than product innovations matter and competition is based mainly upon cost-reductions. On the opposite, technological change is biased in favor of skill-intensive technologies in new industries where oligopolistic rivalry characterizes the markets and new products play a key role. Their introduction is made possible by high levels of skill intensity and high wages paid to a laborforce with high levels of human capital, talent and creativity that is distinctively able to master production processes with low levels of standardization and to actively participate and contribute the generation and introduction of product innovations.

TABLE 1. TYPES OF INNOVATION, TYPES OF SECTORS AND DIRECTIONS OF TECHNOLOGICAL CHANGE

| TYPES OF INNOVATION/ DIRECTION OF TECHNOLOGICAL CHANGE | PRODUCT INNOVATIONS | PROCESS INNOVATIONS |
|---|---|---|
| SKILLED LABOR INTENSIVE BIAS | -NEW INDUSTRIES<br>-FAST GROWTH OF OUTPUT<br>-KNOWLEDGE BASED UPON HIGH LEVELS OF R&D | |
| CAPITAL INTENSIVE BIAS | | -OLD INDUSTRIES<br>-SLOW GROWTH OF OUTPUT<br>-KNOWLEDGE BASED UPON USER-PRODUCER INTERACTIONS<br>-EMBODIED TECHNOLOGICAL CHANGE |

We can now put forward our hypothesis according to which the characteristics of product markets and of the generation of technological knowledge, next to the characteristics of factor markets, play a central role in shaping the direction of technological change. Technological change in mature industries is labor saving and capital intensive because of the characteristics of the innovation process and the role played by process innovation in the price competition that characterize product markets. Technological change in new industries is skilled labor intensive and capital saving because of the characteristics of the innovation process and the role played by product innovations in the oligopolistic rivalry that shapes these product markets.

In sum, the integration of the Schumpeterian literature enriched by the retardation hypothesis with the two strands of literature of the induced and localized technological change approach, respectively, enables to articulate a comprehensive and yet coherent interpretative model according to which the direction of technological change towards increasing levels of output elasticity of labor is the combined result of typical Schumpeterian forces such as:
1) the rates of growth of output and employment,
2) R&D intensity,
coupled with the inducement mechanisms represented by:
3) the levels of unit wages,
4) the rates of increase of wages.

## 3. THE EMPIRICAL EVIDENCE

### 3.1 THE DATA

In order to test our hypothesis concerning the determinants of the evolution of the labour and capital output elasticities we use data proceeding from the OECD STAN database and OECD data on the BERD Business Expenditures on Research and Development. Both data are aggregated at the two-digit sectoral level. Based on the availability of data we have been able to build a fairly balanced panel of 16 countries[2] and 17 sectors covering the time span between 1995 and 2006. We chose to stick to manufacturing sectors in order to have a more homogeneous sample of industries. We ended up with 272 units of observation for whom we have data for 12 years.

[2] The countries are: Austria, Canada, Czech Republic, Denmark, Germany, Greece, Hungary, Italy, Japan, Korea, Netherlands, Norway, Portugal, Slovenia, Spain, United States. The sectors included are listed in Table (4).

In order to test our hypotheses concerning the dynamics of output elasticities we start by assuming that each sector's economy can be represented by a Cobb-Douglas production function with constant returns to scale.

$$Y_{it} = A_{it} L_{it}^{\beta} K_{it}^{\alpha} \quad (1)$$

Following Euler theorem we have computed (and not estimated) output elasticities using STAN OECD data, by assuming constant returns to scale and perfect competition in both product and factors markets. For each sector in our database we hence consider the labour and capital elasticities to be equal to the labour and capital shares on value added, computed as:

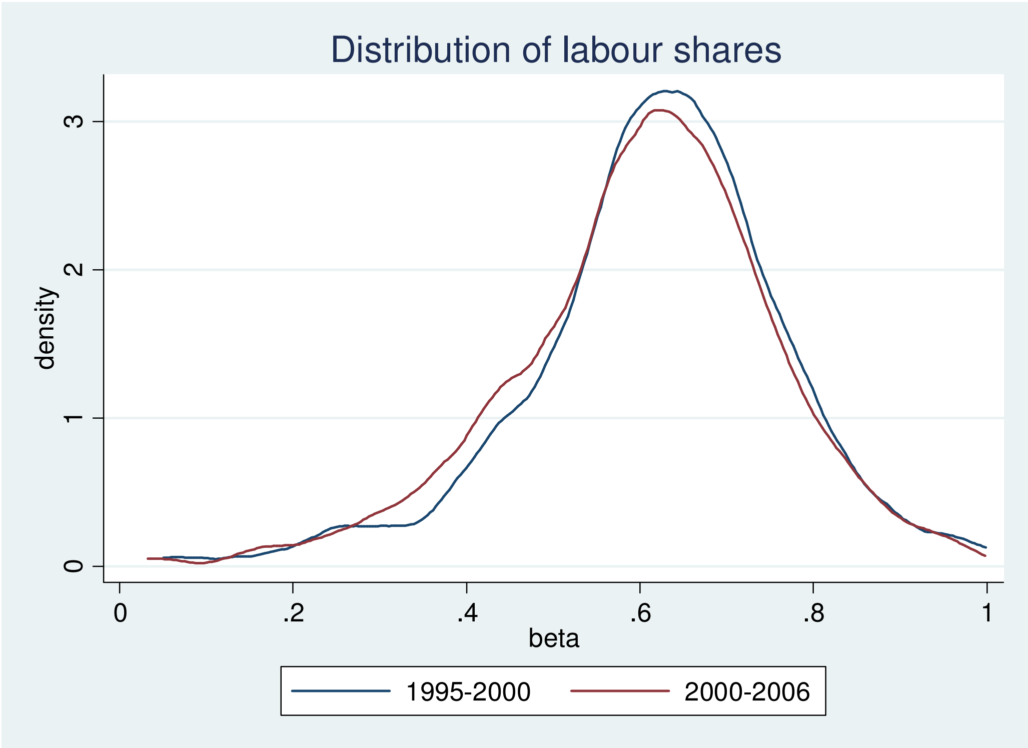
$$\beta_{it} = (w_{it} L_{it})/Y_{it} \quad (2)$$

$$\alpha_{it} = 1 - \beta_{it} \quad (3)$$

Where $(w_{it} L_{it})$ is the labour compensation within each national sector and $Y_{it}$ is the total value added for each sector at time t.

A first glance at the distribution of the labour output elasticities in Figure (1) allows appreciating the great level of heterogeneity which characterizes the variable, thus confirming the importance of focusing our analysis on the differences rather than the similarities of output elasticities. Figure (1) also allows to appreciate the relative stability across time of the distribution of the labour output elasticities. Specifically we notice that along the decade under analysis the variance of the labour output elasticities does not decline at all, we only observe a gradual shift towards lower values of the variable itself.

FIGURE 1.




Now, before introducing a formal test of the hypothesis spelled out in Section 2 we will present some aggregate features that link the evolution of the sectors with the dynamics of the output elasticities of labour and capital.

In Figure (2) we distinguish between high and low tech sectors[3], in order to show the different dynamics of the two groups of sectors. We expect the low tech sectors to represent what we have previously called mature sectors, with a slow growth of output, while the high tech sectors are supposed to be more dynamic with higher rates of growth of employment and production value. Figure (2) confirms our hypothesis. The first graph on the top left shows the dynamics of the average yearly growth of production value (in constant terms) for the two groups of sectors: although the overall dynamics of growth display similar cyclical patterns, the high tech sectors have always grown more than the low tech ones. The latter in some years have even experienced a decrease of the total amount of production.

[3] In Table (4) are listed the sectors belonging respectively to high and low tech.

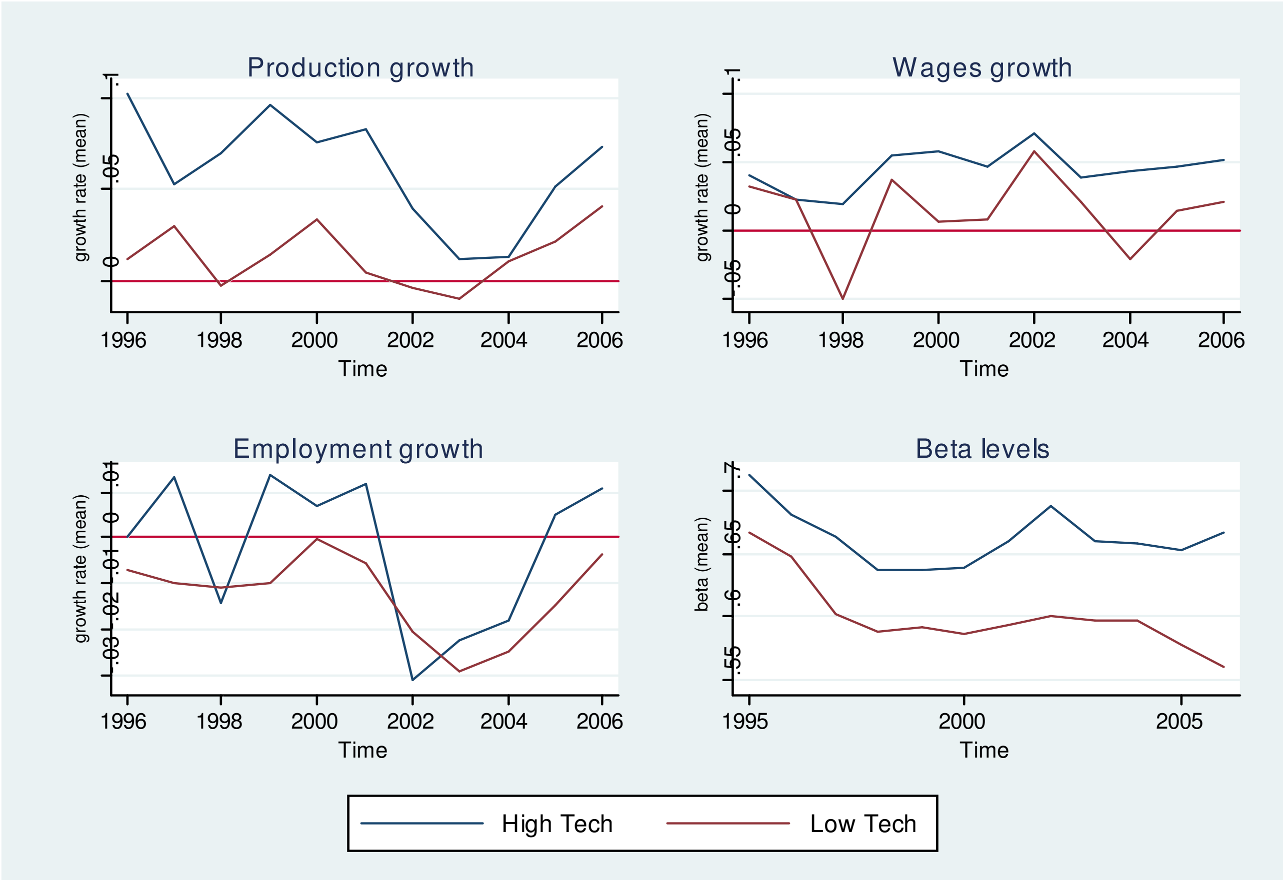
In the top right diagram instead the time series of the growth of average wages have been reported: again we can see than on average the growth of wages in the high tech sectors have been higher than in the low tech sectors. The bottom left graph in Figure (2) shows that even if in new industries, such as the high tech sectors, wages have increased more than in mature industries, (represented by low tech sectors) still employment has increased more in the former than in the latter. Even if 2002 has shown a steep decline of employment in high tech sectors (due to the dot com bubble burst in 2001) we notice that in general employment growth has constantly been higher in high tech rather than in low tech sectors, where, instead, growth rates have been always negative along the whole time span considered.

Such a dynamic provides a first confirmation to our hypothesis about the induced nature of technical change: in new industries the growth of wages does not lead to technical substitution of labour with capital, but rather induces increasing levels of (skilled) labour intensity, giving its relative abundance.

When industries are new and wages increase hence innovation efforts will be mainly biased towards labour-intensive technological change: this is confirmed by the higher levels of labour output elasticities in high tech sectors with respect to low tech sectors, as it is shown in the bottom right graph of Figure (2). While during the decade under consideration the low tech mature industries have seen a continuous decrease of the levels of the labour output elasticities, high tech sectors have maintained higher levels of labour output elasticities and have kept such values more or less stable over the years.

There seems to be hence a clear difference in the type of dynamics at work between new and mature industries: the former experience positive rates of growth of wages, positive growth of employment and higher levels of labour output elasticities, the latter instead tend to decrease employment (even though wages do not increase extensively) and direct towards capital intensive types of innovations. These findings confirm once more the need to include capital-intensive technological change among the possible direction of the innovative efforts of firms, and not only skilled and unskilled labour-intensity (Acemoglu, 2002).

FIGURE 2.



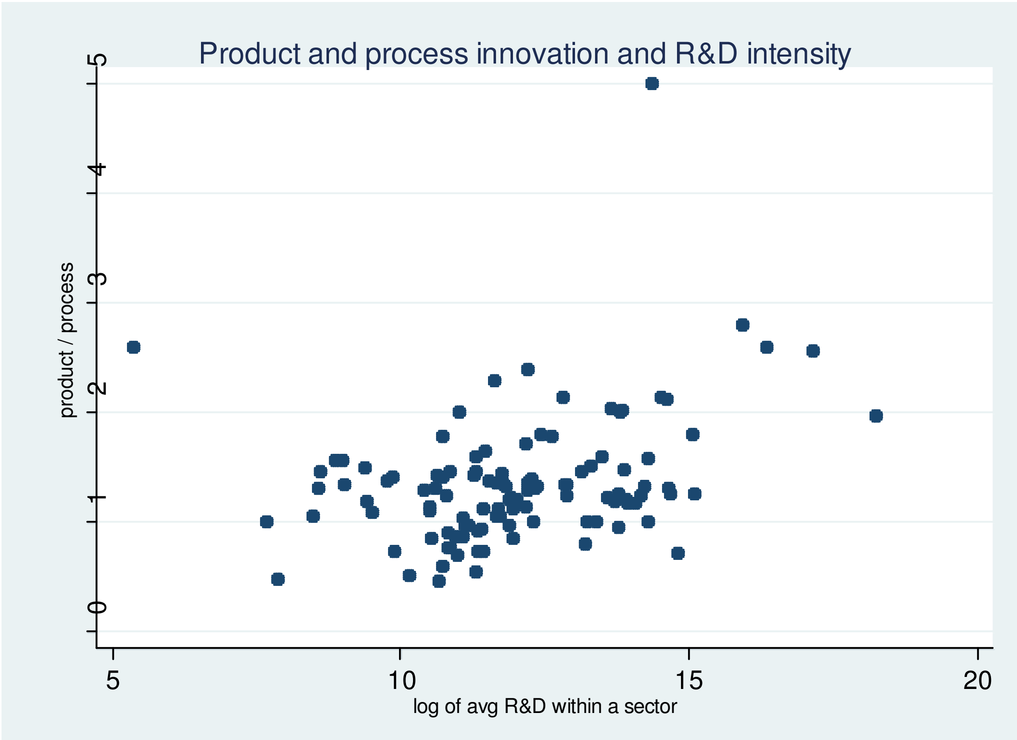

One last confirmation of the hypotheses put forward in the previous section concerns the ways through which innovation is directed towards labour or capital intensive technologies. Here we draw from the Schumpeterian framework on product markets and hence we rely upon another source of data that proves to be especially useful for our aim. We use harmonized data from the Community Innovation Surveys 4 which refer to the period 2002-2004: the data are available for 8 European countries[4] and for all the manufacturing sectors at the two-digit level of aggregation (14 sectors overall). We are able to retrieve for each sector the shares of surveyed firms which declared to have introduced product as opposed to process innovation. At the same time for each sector we are able to compute the average R&D intensity, i.e. the overall expenditures in R&D divided by the total number of firms included in the survey.

[4] Belgium, Czech Republic, Denmark, Estonia, Italy, Norway, Slovenia, Spain

In Figure (3) on the vertical axis is the ratio of the share of firms which declared to have introduced product innovations on the share of firms which declared to have introduced process innovations[5]; on the horizontal axis instead is the sectoral level of R&D intensity.

A simple scatter-plot allows to appreciate a positive relation between the intensity of R&D and the prevalence of product innovation.

FIGURE 3.




Such a finding provides further robustness to our previous Schumpeterian hypothesis according to which new industries will direct towards labour-intensive product innovation, while mature industries will insist on capital intensive process innovation. Indeed considering that in Figure (3) new industries are well represented by high tech sectors and mature industries correspond to low tech sectors (in fact the classification used to define high

[5] On the vertical axis we hence have: $Product/process_i = \frac{\%\ of\ firms\ introducing\ product\ innovation_i}{\%\ of\ firms\ introducing\ process\ innovation_i}$, where $i = sector$. Instead on the horizontal axis R&D intensity is computed as $R\&D\ intensity_i = \ln\left(\frac{\sum_n R\&D\ expenditures_{in}}{n}\right)$ where n is the number of firms in each single sector.

and low tech sectors is based on the R&D intensity, i.e. BERD over value added), it becomes clear that new industries will be those on the right of the horizontal axis of Figure (3) and hence will also have a higher ratio of product to process innovation.

## 3.2 THE MODEL

We are now able to propose a structural model in which we can test through econometric analyses whether the dynamics of labour output elasticities are a function of the variables we have already specified in the previous sections. In accordance with the Schumpeterian framework outlined so far we have proposed that the growth of output elasticities of labour is positively related with the growth of a sector, that in this section we proxy with the growth of employment. For the same reasons we also expect the intensity of R&D expenditures to influence positively the growth of the labour output elasticities. Besides, following the localized technological change hypothesis, we assume that both the increase in wages and their absolute levels have a positive effect on the rates of growth of labour output elasticities. Lastly, according to the hypotheses on the globalization of product markets spelled out in the previous section we expect the growth of imports to have a negative effect on the output elasticties of labour. We thus introduce a model aimed to test these relationships:

$$\ln\left(\frac{\beta_{it}}{\beta_{it-1}}\right) = a_1 + a_2 \ln(\beta_{it-1}) + a_3\, ln\left(\frac{L_{it}}{L_{it-1}}\right) + a_4\, ln\left(\frac{w_{it}}{w_{it-1}}\right) + a_5\, ln(w_{it-1}) + \\ + a_6\, ln\left(\frac{RDint_{it}}{RDint_{it-1}}\right) + a_7\, ln\left(\frac{IMPO_{it}}{IMPO_{it-1}}\right) + u_i + \eta_t + \varepsilon_{it} \qquad (4)$$

All variables are taken from the OECD data included in the STAN and BERD databases. $L_{it}$ is the total number of person engaged within a national sector in year t, while $w_{it}$ is the average wage in each national sector for each year and is computed by dividing the sectoral data on labour compensation by the number of person employed within the sector. $RDint_{it}$ is computed as the ratio of the flow of private R&D expenditures on the value added of each national sector. $IMPO_{it}$ instead is the percentage growth of total imports within each national sector. The complete model also includes the lagged level of the dependent variable which in this case is added as a further control, to capture the presence of any mean reversion effect. The error term is decomposed in $u_i$, $\eta_t$ and $\varepsilon_{it}$, which indicate respectively sector's specific, time specific and idiosyncratic shocks. The model is estimated through panel data analysis adopting the fixed effect estimator, which allows for arbitrary correlation between the regressors and the sector's specific error term.

In order to provide further robustness to our analysis we also introduce a second equation in which we test the previous relationship, but now we check the impact of the independent variables on the levels of labour output elasticities. Having an equation in levels with a lagged dependent variable among the regressors we cannot rely only on the fixed effect estimator, which is known to produce a downward bias due to the violation of the assumption of strict exogeneity (Nickell, 1981). We hence need to use a GMM procedure that allows us to exploit the availability of additional moment conditions in order to increase the efficiency of the estimator. Specifically we choose to adopt the GMM-System estimator (Blundell and Bond, 1998), which also allows us to keep time-invariant variables such as country and sectoral dummies, which are supposed to exert an important effect in our specification.
Our equation to estimate is hence the following:

$$ln(\beta_{it}) = c_1 + c_2\, ln(\beta_{it-1}) + c_3\, ln\left(\frac{L_{it}}{L_{it-1}}\right) + c_4\, ln\left(\frac{w_{it}}{w_{it-1}}\right) + c_5\, ln\,(w_{it}) + c_6\, ln(RDint_{it}) + + c_7\, ln(IMPOint_{it}) + u_i + \eta_t + \varepsilon_{it} \qquad (5)$$

In this case, in order to avoid size effects when measuring the impact of imports on the levels of labour output elasticities, we introduce the variable $IMPOint_{it}$ which corresponds to the ratio of imports on total output within each national sector.

### 3.3 THE RESULTS

In this section we provide the results for the equations introduced in the previous section, specifically equation (4) and (5). In Table (2) we present the results concerning the first equation of interest – equation (4) - in which the dependent variable consists in the growth rate from year t-1 to year t of labour output elasticities. In columns (1) to (3) we introduce gradually our regressors, without introducing the lagged dependent variable, in order to be able to check if the inclusion of the latter influences through spurious correlation the magnitude of the other regressors. We then start by measuring in column (1) the impact of the growth of employment, the growth of wages and the levels of the average wage within each sector. According to the theoretical framework put forward in Section 2.2 and 2.3 we expect a positive impact of each of these variables on the rate of growth of labour output elasticities. Column (1) confirms our hypothesis and displays positive and significant coefficients of the rate of growth of employment and wages and of the level of wages. In column (2) we introduce the growth rate of the R&D intensity expecting again a positive sign of its coefficient: the results confirm such expectation and provide an overall confirmation to the Schumpeterian hypotheses and to the induced-innovation paradigm. Finally in column (3) we introduce the growth of imports as a proxy of the competitive pressure exerted especially on mature sectors by new labour-abundant countries: in line with our expectations the coefficient of the growth of exports is negative and significant. In order to test the robustness of our specification to the presence of possible reversion-to- the-mean phenomena we also include in column (4) the lagged value of the dependent variable: as expected, there is an evident negative and significant effect. Anyway what is most interesting is that the inclusion of such variable does not affect the sign and the significance of the other variables, neither those related to the Schumpeterian hypothesis nor the ones which stem from the localized technological change framework. Column (6) of Table (2), instead, substitutes the growth of R&D intensity with the simple growth of R&D expenditures, in order to challenge the robustness of the results: although the coefficient is not significant anymore, it still displays a positive sign which tends to corroborate the previous finding about R&D intensity.

Equation (14) is tested in Table (3), first through the use of the fixed effect estimator and then through the General Method of Moments procedure, and specifically through the GMM-SYS estimator (Blundell and Bond, 1998). Column (1) and (2) display the results obtained with fixed effects. The results are very much in line with the previous findings: the growth rates and the levels of wages influence positively the level of beta, once accounted for the lagged level of the dependent variable itself, while also the growth of employment, which would typically proxy the growth of a new industry, influences positively the levels of the betas. Once we add the intensity of

R&D and the share of imports on the total production of a sector, as in column (2), we notice that while R&D intensity has a positive and significant sign, the coefficient of imports' penetration shows a positive but not significant sign, which does not totally confirm the previous finding about imports in Table (2), but does not even contradict them.

Given the well-known problems associated with the estimation of dynamic equation with the fixed estimator (Judson and Owen, 1999), we chose to proceed in our econometric analysis with a GMM-SYS estimator. The first results in column (3) confirm the presence of a downward bias in the coefficient of the lagged dependent variable when using fixed effects: in this case the coefficient of the labour output elasticity at time t-1 is quite higher than in columns (1) and (2). Furthermore the results of the estimation confirm the sign and the levels of significance of the variables in the previous specification, thus confirming the general hypotheses exposed in Section 2. The GMM-SYS estimator also allows to account for the possible endogeneity of some of the regressors and adopts a procedure which uses the lagged values of such variables in order to avoid the possibility of endogeneity bias. Since in our specification the regressors in levels (average wages, R&D intensity and the share of imports on total production) might be endogenous, due to the fact that they are contemporaneous to the dependent variable, we chose to instrument them. The results of this procedure are shown in column (4): instrumenting the variables that are suspected of endogeneity does not change the sign and the significance of the regressors. The only difference concerns the variable on import penetration, which becomes positive and significant and should probably deserve more accurate analysis.

## 4. CONCLUSIONS

Since the last decade of the XX century globalization has been emerging as a key factor of change not only of international product markets but also of internal factor markets. The entry of new, large, labor abundant countries in the internal trade arena has induced a major process of structural change. The introduction of technological change has been at the same time a major consequence and a cause of this process.

To analyze this dynamics we have attempted to merge and integrate the Schumpeterian and Hicksian literatures into the localized technological change approach to the analysis of the determinants of technological change so as to consider jointly both the effects of changes in factor markets and characteristics and changes of the product markets as relevant factors that affect the direction of technological change. Building upon these foundations we have elaborated the hypothesis that the sharp increase in the comparative levels of unit wage in capital abundant countries, brought about by the increased levels of integration of the world economy, has induced a major process of technological change characterized by the introduction of product innovations and skill-intensive technologies in high tech industries, while mature industries relied upon the introduction of process innovations and hence labor saving technologies.

According to our localized interpretative framework of analysis, product innovations supported by skill-intensive technologies are more likely to be introduced by fast-growing sectors characterized by high wages and high levels of R&D expenses. Product innovations are introduced mainly in new, fast-growing oligopolistic industries specializing in products characterized by high income-elasticity and low price-elasticity of the demand with high diffusion rates, based upon production processes with low levels of standardization privilege the introduction of product innovations. The high intensity of skilled labor in the production process and researchers in R&D activities characterize the effects of such innovation activities as mainly labor intensive.

The traditional Hicksian inducement mechanisms apply to traditional, slow-growth and price-competitive sectors, less able to fund R&D activities. Old traditional industries where the demand has reached the levels of saturation, income elasticity is low and price elasticity is high, competition is based upon price with high levels of exposure to the penetration of imports from emerging countries that have access to cheaper inputs, specialize in capital intensive production processes that are highly standardized and embody technological changes introduced by means of close interactions with upstream producers. The innovation process in these industries is characterized by the prevalence of process innovations.

According to the localized technological change hypothesis the bias of technological change is determined not only by the characteristics of factor markets. The bias of technological change bias is determined also by the characteristics of: i) the product markets, ii) the knowledge generation process and iii) the innovations being introduced.

Given this theoretical framework, it becomes evident that a proper analysis concerning the direction of technological change must be conducted at the sectoral level, in order to appreciate the heterogeneity of the innovative strategies implemented by firms in different product markets.

The empirical evidence supports the localized technological change hypothesis and shows that technological change in advanced capitalistic countries in the years 1995-2006 has been driven by R&D intensive sectors characterized by high levels of product innovation, increased levels of wages and skills and strongly biased in favor of the introduction of skill-intensive technologies supporting product innovations with a general increase of the output elasticity of labor. The econometric evidence, at the sectoral level, in a panel data estimate across 17 sectors in 16 advanced countries over 12 years, confirms that technological change in advanced countries has been strongly localized and biased in favor of skill-intensive new technologies significantly and positively associated with the rates of growth of output, unit wages levels and their increase, and R&D intensity.

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**Table 2. Dependent variable: $\ln(beta_t/beta_{t-1})$**

| Variables | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| $\ln(beta_{t-1})$ | | | | -0.421*** | -0.447*** |
| | | | | (0.0172) | (0.0175) |
| $\ln(LABOUR_t/LABOUR_{t-1})$ | 0.248*** | 0.334*** | 0.355*** | 0.237*** | 0.239*** |
| | (0.0373) | (0.0352) | (0.0349) | (0.0313) | (0.0323) |
| $\ln(WAGE_t/WAGE_{t-1})$ | 0.431*** | 0.417*** | 0.412*** | 0.380*** | 0.387*** |
| | (0.0191) | (0.0174) | (0.0172) | (0.0153) | (0.0158) |
| $\ln(WAGE_{t-1})$ | 0.0533*** | 0.0631*** | 0.0580*** | 0.127*** | 0.131*** |
| | (0.0132) | (0.0125) | (0.0124) | (0.0113) | (0.0116) |
| $\ln(RDint_t/RDint_{t-1})$ | | 0.0666*** | 0.0662*** | 0.0518*** | |
| | | (0.00507) | (0.00501) | (0.00447) | |
| $\ln(IMPO_t/IMPO_{t-1})$ | | | -0.142*** | -0.120*** | -0.122*** |
| | | | (0.0198) | (0.0176) | (0.0181) |
| $\ln(RD_t/RD_{t-1})$ | | | | | 0.00523 |
| | | | | | (0.00476) |
| Constant | -0.631*** | -0.770*** | -0.687*** | -1.727*** | -1.790*** |
| | (0.153) | (0.146) | (0.145) | (0.135) | (0.139) |
| Observations | 2,691 | 2,435 | 2,435 | 2,435 | 2,435 |
| R-squared | 0.198 | 0.293 | 0.310 | 0.460 | 0.427 |
| Number of id | 250 | 247 | 247 | 247 | 247 |

Fixed effect estimation. The models also include time dummies, no other time invariant dummies are included. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

**Table 3 . Dependent variable: ln($beta_t$)**

| Variables | Fixed Effects (1) | (2) | GMM-SYS (3) | (4) |
|---|---|---|---|---|
| ln($beta_{t-1}$) | 0.499*** | 0.505*** | 0.752*** | 0.716*** |
| | (0.0170) | (0.0169) | (0.0585) | (0.0650) |
| ln($LABOUR_t$/$LABOUR_{t-1}$) | 0.143*** | 0.224*** | 0.177** | 0.248*** |
| | (0.0322) | (0.0312) | (0.0717) | (0.0856) |
| ln($WAGE_t$/$WAGE_{t-1}$) | 0.253*** | 0.243*** | 0.334*** | 0.283*** |
| | (0.0173) | (0.0160) | (0.0490) | (0.0504) |
| ln($WAGE_t$) | 0.134*** | 0.141*** | 0.0525*** | 0.0947*** |
| | (0.0117) | (0.0112) | (0.0198) | (0.0265) |
| ln($RDint_t$) | | 0.0510*** | 0.0262*** | 0.0484*** |
| | | (0.00451) | (0.00660) | (0.0123) |
| ln($IMPOint_t$) | | 0.0193 | 0.0105 | 0.0637*** |
| | | (0.0126) | (0.00669) | (0.0240) |
| Constant | -1.790*** | -1.725*** | -0.615*** | -0.979*** |
| | (0.137) | (0.135) | (0.218) | (0.300) |
| Observations | 2,691 | 2,501 | 2,501 | 2,501 |
| Number of id | 250 | 248 | 248 | 248 |
| R-squared | 0.399 | 0.472 | - | |
| AR(1) | - | - | -3.699 | -3.633 |
| AR(2) | - | - | 0.362 | 0.363 |
| Hansen test | - | - | 54.90 | 195.7 |

Column (1) and (2) are estimated with the fixed effect estimator with time dummies. Column (3) and (4) are estimated with the Blundell-Bond estimator with twostep Windmeijer's correction. Industry and country dummies are included. Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

**Table 4. List of sectors included in the database, classified by technological levels**

| |
|---|
| Low-tech sectors |
| C15T16 Food products, beverages and tobacco |
| C17T19 Textiles, textile products, leather and footwear |
| C20 Wood and products of wood and cork |
| C21T22 Pulp, paper, paper products, printing and publishing |
| C23 Coke, refined petroleum products and nuclear fuel |
| C25 Rubber and plastics products |
| C26 Other non-metallic mineral products |
| C27 Basic metals |
| C28 Fabricated metal products, except machinery and equipment |
| High-tech sectors |
| C24 Chemicals and chemical products |
| C29 Machinery and equipment, n.e.c. |
| C30 Office, accounting and computing machinery |
| C31 Electrical machinery and apparatus, n.e.c. |
| C32 Radio, television and communication equipment |
| C33 Medical, precision and optical instruments |
| C34 Motor vehicles, trailers and semi-trailers |
| C35 Other transport equipment |
| Source OECD STAN (2011) |