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Entrepreneurship and Global Competitiveness in Regional Economies: Determinants and Policy Implications

Chapter 2

GLOBALIZATION AND DIRECTED TECHNOLOGICAL CHANGE AT THE FIRM LEVEL. THE EUROPEAN EVIDENCE[1].

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Abstract

This chapter aims at exploring the effects of globalization on technological change by focusing on the determinants of the direction of technological change at the firm level of analysis by following the induced technological change approach implemented by the localized technological change hypothesis. In the empirical analysis, we proxy the direction of technological change by means of the changes in the output elasticity of capital and analyze how it is affected by the changes in factor market costs and firms' attributes for a panel of 1113 companies listed on UK and the main continental Europe financial markets for the period 1995-2003. We find that small firms are more likely to introduce capital intensive technological changes while large firms will introduce skill-intensive technological changes. Our model provides a clear analytical framework that interprets the growing skill intensity of the advanced economies as the result of the introduction of new technologies induced by the growing globalization and biased by the characteristics and the types of innovation strategies of the firms. In so doing, the chapter adds to the existing literature in that it first explores the effects of globalization upon factor markets and, second, it investigates the effects of the direction of technological change within a microeconomic perspective.

1. Introduction

Globalization has characterized the world economy since the last years of the XX century. A large literature has explored systematically the effects of the entry of new countries in international markets and has shown how deeply this changed the product markets. The relative prices of labor-intensive products fell dramatically and forced the exit of firms based in advanced countries, specializing in traditional final goods. The new supply of labor-intensive products crowded out large portions of the economic systems of advanced countries. This adjustment took place by means of both structural and technological change. Much attention has been paid to the dynamics of structural change in terms of decline and exit of old manufacturing sectors and increased specialization in service and high-tech sectors (Grossman and Helpman 1990, 1991, 1994).

Less attention has been paid to the consequences of globalization on technological change. The entry in international markets of new competitors based in labor abundant countries has changed in depth not only the product markets but also the factor markets. The relative costs of production factor changed dramatically, as much as the relative prices of products. Specifically the last decades have witnessed a sharp increase in the factor markets of advanced countries of the wages of unskilled labor not only in absolute terms, but mainly in relative terms. The entry of new competitors based in labor abundant countries, in fact, had the indirect effect to increasing the relative wage in advanced countries and making the slope of the isocost much steeper (Monte, 2010). The increase of the relative cost of unskilled labor had three effects: i) the exit of labor intensive activities unable to react to these changes and to cope with the conditions of both product and factor markets, ii) the substitution of labor intensive techniques with more capital intensive ones, iii) the inducement of major technological changes.

Quite surprisingly the relationship between globalization and the direction of technological change has received little attention. The recent revival of the induced technological change approach may be considered an implicit acknowledgement of the growing awareness of the implications of the drastic changes brought about by globalization not only in product, but also in factor markets (Antonelli and Fassio, 2011).

The empirical evidence contrasts the expectations based upon the traditional inducement hypothesis, and more generally the predictions based upon the Heckesher-Ohlin theory. The traditional induced technological change hypothesis contends that the increase of wages should push firms to a form of hyper-substitution by means of the introduction of new technologies characterized by a larger output elasticity of labor. These expectations meet and augment the predictions based upon the Hecksher-Ohlin framework of analysis that suggest that advanced, capital abundant countries exposed to higher levels of competition from labor-abundant countries should specialize in capital-intensive products with an increase of the capital intensity of production processes. Recently, Zeira (1998) has represented the traditional argument that technological change is usually characterized by higher levels of capital intensity. The analysis of the trend of economic change at the aggregate level does not support these hypotheses and contrasting evidence has been gathered. Quite the opposite, in fact, there is growing evidence that technological change introduced since the last decade of the XX century is skill-intensive, and more generally labor-, rather than capital-intensive.

There is large and growing evidence at the aggregate level that technological change introduced in the last years has been characterized by a strong bias directed towards the more intensive use of skilled labor, instead of fixed capital as usually expected. The debate has concentrated on both the determinants and the effects of such a directionality of technological change at the aggregate level (Acemoglu, 1998). The direction of technological change has been interpreted as a result of the effort to identify and appreciate the relative abundance of a production factor such as human capital, that had not been fully acknowledged in the previous analyses.

Some advanced countries have been able to introduce radical innovations based upon high levels of skilled labor and generally human capital centered on the information and communication technologies (ICT). ICT were more efficient both in absolute and relative terms because of the strong intensity of human capital, a production factor that is relatively more abundant and hence relatively cheaper in advanced countries. In other words advanced countries have been able to change both the position and the shape of the map of the isoquants that represent the new technologies (Acemoglu and Zilibotti, 2001; Hall and Jones, 1999). Other advanced countries were less able to master the generation of technological knowledge and to shape its direction because of the relative scarcity of the skilled labor that was intrinsic to the new technologies and have been much less able to take advantage of the benefits stemming from the introduction of the new technologies (Caselli and Coleman, 2006; Antonelli, 2011).

While the debate on the causes and consequences of the direction of technological change has flourished with much empirical investigations at the aggregate level, little analysis has been provided on the microeconomics of biased technological change. At the firm level, the direction of technological change is not homogeneous, as it exhibits consistent differences and substantial variance across firms. So far, little attention has been paid to exploring the determinants of the variance in the direction of technological change at the firm level. No attempts have been made to appreciate the effects of the characteristics of firms, instead of countries, on the direction of technological change. Yet the direction of technological change and the bias of new technologies vary at the firm level as much as their characteristics; such as size, command of technological knowledge, and types of innovations being introduced (Scherer, 1984).

The paper aims at filling this gap. This paper adds and complements the discussion on the ambiguity in the Schumpeterian debate articulated by Scott (2009). While the Schumpeterian argument concerns the effects of product market conditions on the firms' propensity to invest in R&D and innovate, the present work analyses the effects of changes in factor market conditions on technological change taking into account, within an integrated framework the characteristics of the firms and the types of innovation strategies. Firms will respond to change in factor market costs by introducing technological changes biased either towards skill intensity or capital intensity according to the specific characteristics of their innovation processes and knowledge generation related attributes.

The paper is organized as follows. Section 2 implements the framework of analysis provided by the localized technological change approach so as to elaborate a microeconomic analysis of the determinants of the direction of technological change. Section 3 provides an econometric analysis of the hypotheses highlighted in section 2 based upon a dedicated data-base covering 1113 public companies active in 10 different sectors and 4 European economies for the period from 1995 to 2003. The conclusions summarize the results of the analysis.

2. The localized introduction of biased technological changes

The localized technological change approach provides an integrated analytical frame that enables integrating the theory of production and the theory of the firm into a broader economics of innovation. In this direction, it provides an interesting complement to the product market perspective used for linking competition and R&D investment in the Schumpeterian debate (Scott, 2009). The localized technological change approach builds upon the tradition of the induced technological change, but enables accommodating a much broader range of outcomes and determinants within the same integrated framework. Let us articulate this claim. In the induced technological change approach, technological change cannot be neutral. According to the approach established by Hicks (1932) and implemented by Ruttan (1997, 2001), technological changes are introduced by firms to face the change in the relative prices of production factors and can be considered as a form of augmented factor substitution. This line of analysis is contrasted by Samuelson (1965), who argues that the direction of technological change is induced by the opportunities to make the best use of locally more abundant factors. Following this second line of analysis, the increase of wages in labor abundant factor markets would induce the introduction of labor intensive technologies. In both versions, the induced technological change is necessarily biased, yet the direction is unclear.

The localized technological approach can be considered a qualification of the induced technological change approach. According to its original formulation, technological change is localized by the source of competence and knowledge that is acquired mainly if not exclusively by means of learning by doing, learning by using and learning by interacting. The origins of such ‘tacit’ knowledge limit the ray of possible innovations. As Atkinson and Stiglitz (1969) note, “knowledge acquired through learning by doing will be located at the point where the firm (or economy) is now operating”. The irreversibility of production factor and the switching costs that are necessary to change them root the firm in a limited portion of the space of techniques defined in terms of factor intensity (David, 1975). The blending of these elements with the Schumpeterian notion of innovation as a form of creative reaction leads to the localized technological change approach according to which firms are induced to innovate by the mismatch between their expectations and the actual conditions of product and factor markets and the limits to technical substitution (Schumpeter, 1947).

The localized technological change approach can be summarized as it follows. When unexpected changes in product and factor market conditions take place, firms try and react with the introduction of new technologies. Substantial irreversibilities reduce the possibility of firms to adapt to changes in relative prices by means of the traditional technical movements in the existing map of isoquants. In order to reduce the switching costs stemming from the need to cope with changes in the relative costs of inputs in factor markets, firms consider the opportunity for searching and generating new technological knowledge and introduce new technologies that enable them to fit in the new product and factor markets. The active introduction of technological change and hence the change in the map of the isoquants becomes an alternative to the passive adaptation consisting in technical changes upon the existing map of isoquants. When factor costs change, specifically wage increase, the textbook firm would simply adapt to the factor markets conditions by means of the traditional substitution along existing isoquants reaching the new equilibrium point identified on the old isoquant by the slope of the new isocost. In the localized technological change approach, firms are rooted in the space of techniques by relevant irreversibilities and switching costs that limit their mobility in the space of techniques. Technical substitution is complemented by the introduction of technological changes aimed at limiting the changes in the factor intensity upon which the learning process and the accumulation of competence are based (Antonelli, 2003 and 2008).

The localized technological change approach enables to appreciate the characteristics of the firms and their role in determining not only the rate, but also the direction of technological change. Our basic claim is that there is a strong matching between the characteristics of the innovation processes and the types of technological changes being introduced. Relevant differences among firms can be identified with respect both to the characteristics of the production process, their ability to generate technological knowledge and to their capability to exploit it. Let us consider these aspects in turn:

Firms with high levels of tangible and intangible capital intensity are more likely to experience high levels of switching costs. Hence, we can expect that for the same change of labor costs, firms with higher levels of capital intensity will try and react with the introduction of localized technological changes that enable them to remain upon the original isocline so as to reduce the changes in factor intensity. As a result, they will introduce skill-intensive technologies that enable them to use more expensive and skilled labor. More specifically, we can argue that large firms, able to command the generation of technological knowledge and its exploitation, will be able to introduce a fully localized technological change that enables them to stay along the original isocline that links the origin to the old equilibrium so as to keep the same technique, defined in terms of factor intensity. In this case, technological change will be skill intensive: the firm will be able to retain higher levels of employment, with respect to equilibrium conditions reached by means of the sheer substitution, with higher levels of human capital that match the higher wages. Localized technological change is inherently skill-intensive (Shapiro and Stiglitz, 1984; Vaona and Pianta, 2008).

Small firms—those with lower levels of capital intensity and that are less able to command a strong knowledge base, enabling them to actually introduce new original technologies--are more likely to rely upon technological knowledge embodied in new vintages of capital goods provided by upstream industries. These firms will react with the introduction of capital intensive process innovations so as to increase the output elasticity of their production process as in the induced technological change tradition.

Insert Table 1 about here

Appropriability conditions help understanding the choice of large firms in favor of skill-intensive product innovations and conversely the reliance of small firms upon capital-intensive process innovations. Large corporations and new, science-based firms can rely upon the credible enforcement of intellectual property rights and specifically upon patents to increase the appropriability of the rents stemming from the introduction of their technological innovations because of their strong content in terms of originality and priority. Large firms can rely upon the actual enforcement of intellectual property right regimes and can afford the risks of introducing major product innovations that enable them to move along the original isoclines. Small firms active in traditional industries can take much less advantage of intellectual property rights: the application to patent offices is quite expensive and the screening process, based upon the search for originality and priority of the technological content discriminate incremental innovations. The lower appropriability conditions favor the introduction of process innovations and lead to the selection of technologies directed towards a stronger intensity of fixed capital (Rothwell and Dodgson, 1994).

We can now articulate the hypothesis that firms can be characterized according to a set of attributes that qualify the likelihood that they will introduce more skill-intensive or capital-intensive technological changes. Table 1 provides a synthesis of the main issues and contrasts of the two groups of firms according to their size, the features of their innovation process whether based upon scientific knowledge or localized skills (Acs and Audretsch, 1988 and 1990; Rothwell and Dodgson, 1994).

The capital-intensive bias can be considered as the result of the typical innovation process that characterizes smaller firms with low wages and low levels of capital intensity. Their size limits the access to managerial skills and hence the foresight of broader technological opportunities. These firms rely upon the introduction of process innovations.

Skill-intensive technological change is to a large extent if not exclusively, the product of formal research and development activities performed intra-muros, and clearly identified with explicit procedures and protocols. Research activities are conducted by highly qualified personnel with formal doctoral training, are fed by systematic relations with the academic community and generate a flow of discoveries and original applications that can be easily protected by patents. Skill-intensive technological knowledge has a wide scope of application and can feed the introduction of such a wide array of technological innovations that it often leads to the diversification of firms and creation of new industries (Ruttan, 1997). Corporations are much more able than smaller traditional firms, to impinge upon scientific advances as a major source for technological knowledge, and do not share the limitations and the constraints of small firms with respect to local factor markets. They can source production inputs in a much larger variety of regions and countries. Large corporations can command a much wider spectrum of new possible technologies. For them, the introduction of a neutral and superior technology may then be taken into account, especially, if the shift of science-based knowledge is so important that the incentives exerted by factor costs account for a small fraction of the overall positive effects of the new technologies.

In sum, we set forth the hypothesis that in the context of rising real wages, technological change introduced by i) small firms, ii) with low unit wages, iii) relying more on tacit knowledge than on formal R&D activities, and iv) less able to appropriate the benefits of their technological innovations with patents, is more likely to be characterized by a stronger bias in favor of capital intensive process innovations. By contrast, technological change introduced by large firms with high unit wages and high levels of intensity in intangible capital, better able to command the generation of technological knowledge and its exploitation by means of the introduction of patented product innovations, will be biased towards higher levels of skill-intensity.

3. Empirical investigation

3.1 Methodology

In order to explore the determinants of the direction of technological change at the firm level of analysis, we first need to calculate output elasticities. We start assuming the two-factor Cobb-Douglas production function as follows:

$$Y_{it} = A_{it} L_{it}^{b_{it}} K_{it}^{a_{it}} \qquad (1)$$

The output produced by firm *i* at time *t* is a function of the actual levels of capital and labour employed, and of the actual technology signaled by the general efficiency parameter *A* and by factors' output elasticities.

Following Euler's theorem, we calculate output elasticities by assuming constant returns to scale and perfect competition in both product and factor markets (Link, 1987). The output elasticities of labour and capital can therefore be computed as follows:

$$b_{it} = w_{it} L_{it} / Y_{it} \qquad (2)$$

$$a_{it} = 1 - b_{it} \qquad (3)$$

where w_{it} and Y_{it} are respectively average wages per employee and value added for firm *i* at time *t*, both deflated using a two-digit industry deflator at 1995 basic prices. L_{it} is the number of employees for firm *i* at time *t*.

Following the hypotheses presented in Section 2, we can propose the equation to be estimated in the econometric analysis. Our basic hypotheses suggest that different firms will respond to change in factor market costs by introducing directed technological change biased by the attributes of their innovation routines and the basis of their technological knowledge. Following the localized technological change approach, we expect that firms stuck by high switching costs but able to complement their tacit knowledge with formal R&D activities will introduce skill-intensive technological changes. On the contrary, firms less able to generate technological knowledge, with lower levels of switching costs, will follow the induced technological change tradition and introduce capital-intensive technological change.

This leads us to model the direction of technological change, proxied by the changes in the output elasticity of capital, as a function of factor market costs and firms' attributes as follows:

$$\ln \alpha_{it} = \lambda_1 + \lambda_2 \ln \alpha_{it-1} + \lambda_3 \ln(w_{it} / w_{it-1}) + \lambda_4 \ln Size_{it-1} + \lambda_5 \left[\ln(w_{it} / w_{it-1}) * \ln X_{it-1}\right] + \sum \psi_t + \varepsilon_{it} \quad (4)$$

where $\ln(w_{i,t} / w_{i,t-1})$ and $\ln Size_{i,t-1}$ are respectively the growth rate of unit wages and deflated sales for firm *i* at time *t-1*. $X_{i,t-1}$ aims at capturing firm's attributes with respect to the generation of technological knowledge with a bundle of indicators measuring R&D expenses and intangible assets including patents. We include the interaction term between wages rate of growth and $X_{i,t-1}$, the proxy for firm's innovation and knowledge related attributes, in order to verify its impact on the directionality of technological change. The sign of the interaction term's coefficient will reveal the impact of the $X_{i,t-1}$ variable on the output elasticity of capital given the dynamics of firm's wages. A positive sign on the interaction term will tell us that, when the average wages increase, firms with high level of the $X_{i,t-1}$ variable will respond by increasing α_{it}, i.e. introducing skill-intensive technological change.

The inclusion of the lagged dependent variable in the model requires dynamic estimation techniques. Moreover, we have a large N and small T panel data set where there may be arbitrarily distributed fixed individual effects. Following the literature on dynamic panel estimators (Arellano and Bond 1991; Blundell and Bond 1998; Bond 2002), the model is thus estimated using the generalized method of moments (GMM) methodology. In particular, we use the first-difference GMM. In this approach the predetermined and endogenous variables in first differences are instrumented with suitable lags of their own levels. First-differencing the equations eliminates a potential source of omitted variable bias in estimation.

3.2 Dataset and variables description

In this paper we use a panel dataset of firms publicly traded in UK, Germany, France and Italy. For all the countries, the period of observations goes from 1995 to 2003. Our prime source of data is Thomson Datastream. We pooled the dataset by adding also information on firms' patent applications at the European patent office. Finally, we included information at the industry level from the Groningen Growth and Development Centre[2].

Our final dataset consists of a balanced panel of 1113 active companies. Sample firms operate in all sectors of the economy and have been classified according to the Groningen Growth and Development Centre 10-sector classification which is based on the ISIC revision 3 one. As Thomson Datastream use the ICB industry classification at the four-digit level, in Appendix A we provide the sectoral concordance used to link the three classifications.

Appendix B reports the sample distribution by country and industry. Manufacturing covers about 41% observations in UK, 52% in Germany, 48% in France and 50% in Italy. Finance, Insurance, and Real Estate companies are also highly represented in our sample (about 27% observations in UK, 29% in France, 24% in Germany and

[2] These data were originally published and described in Van Ark (1995).

31% in Italy), while each of the other economic groups includes around or less than 10% observations in each country.

The dependent variable included in our model is the output elasticity of capital computed according to equations 2 and 3. Table 2 shows the sample distribution of production factors elasticities by year. The series highlights a convergence of α and β in the period analysed. As far as the explanatory variables are concerned, $lnSize_{it-1}$ is the logarithm of firm's sales. The growth rate of unit wages is computed as the log ratio between w_{it} and w_{it-1}, where the unit wage is the total cost of wages paid by the company divided by the number of employees. We further include the interaction term between the growth rate of unit wages and three firm's innovation related variables. First, the variable $lnR\&D_{it-1}$ is computed as the log ratio between research and development expenses and sales for firm *i* at *t-1*. Second, the variable $lnIA_{it-1}$ is the ratio between the book value of intangible assets and total assets in logarithm. The book value of intangible assets is taken by firms' balance sheets and includes goodwill, patents, copyrights, trademarks and also other expenses such as organizational and capitalized advertising cost. Goodwill represents assets arising from the acquisition of other companies and is measured as the excess cost paid for the assets purchased over the book value ascribed in the acquiring firm's balance sheet. Finally, $Patents_{it-1}$ is a dummy variable taking value 1 if the firm holds at least a patent. These variables should capture effectively the variance across firms in terms of capability to command the generation of technological knowledge and reflect the traditional partition on high and low tech activities (See Table 1). Descriptive statistics are presented in Table 3.

Insert Tables 2 and 3 about here

4. Results

The results of the econometric estimations are shown in Table 4. The results of the post-estimation tests are included in Table 4. AR(1) and AR(2) are tests for first-order and second-order serial correlation. Sargan is a test of the over-identifying restrictions for the GMM estimators. As expected, negative first-order serial correlation is found in the Arellano-Bond AR(1) test. As discussed in Arellano and Bond (1991) the first-order correlation in the differenced residuals does not imply that the estimates are inconsistent. Indeed, the Arellano-Bond AR(2) test indicates the validity of instruments. Finally, the validity of lagged levels dated t-3 as instruments in the first-differenced equations is not rejected by the Sargan test of overidentifying restrictions.

We first regress the log output elasticity of capital on its lagged value. As shown in column 1, the coefficient on the lagged value of alfa is smaller than 1. Hence, the smaller the value of the elasticity of capital at *t-1* the higher is its value at time t. There is convergence for sample companies in the period under scrutiny towards the substitution of labor with capital.

Insert Table 4 about here

Results in column 2 show that the localized hypothesis according to which irreversibility of inputs and switching costs limit the mobility of firms in the technique space is fully confirmed: an increase in the cost of labor has a negative effect on the output elasticity of capital. In order to retain the stability of factor intensity firms are induced to direct technological change towards an increased use of skills.

Yet, we are interested in the determinants of the direction of technological change. The negative sign on the variable controlling for firm size (column 3) reveals that while large firms introduce skill-intensive technological change, small firms introduce more capital intensive technological change, i.e. they increase more the output elasticity of capital at time *t*. This is in line with our expectations.

In order to verify the hypothesis that firms can be characterized according to a set of attributes that influence the direction of technological change induced by the increase of unit wages, our model includes the interaction term between the growth rate of wages and firm's innovation related attributes. Column 4 to 6 report the results for $\ln(w_{it}/w_{it-1}) * \ln R\&D_{it-1}$, $\ln(w_{it}/w_{it-1}) * \ln IA_{it-1}$ and $\ln(w_{it}/w_{it-1}) * \ln Patents_{it-1}$, respectively. The interaction term between wages rate of growth and R&D expenditures at *t-1* is found to be negatively and significantly ($p<0.01$) correlated with the output elasticity of capital at time *t*. This confirms that firms investing high resources in formal research and development activities introduce a fully localized technological change in order to remain on the original isocline. On the contrary, firms that rely more on tacit knowledge and informal learning dynamics introduce more capital-intensive technological change. If we look at the terms capturing the effects of intangible assets and patents on the output elasticity of capital, we find that in both the specifications presented in column 5 and 6 the interaction terms are negatively and significantly correlated to the dependent variable ($p<0.01$). These findings confirm our hypotheses that firms better able to command the generation of technological knowledge and to appropriate the returns of their innovation activities react to an increase of unit wages by introducing skill-intensive technological innovations that enable them to move along the original isocline. In contrast, firms that cannot afford expensive knowledge generation and appropriation strategies such as, respectively, systematic R&D activities able to complement internal learning or the acquisition of other knowledge intensive companies and intellectual property rights, rely on the introduction of more capital-intensive technological change.

5. Conclusions

In this paper we have investigated the effects of globalization on induced technological change. Much analysis has explored the effects of globalization upon product markets, while much less attention has been paid to its effects upon factor markets. Yet it is clear that the entry in global product markets of new competitors, based in labor abundant countries, had major effects on the relative cost of labor in the factor markets of advanced countries. The induced technological change approach implemented by the localized technological change hypothesis enables to analyze the effects of the effects of the sharp increase in the relative cost of unskilled labor brought about by globalization upon the direction of technological change. Our basic idea is rooted in the localized technological change approach and suggests that firms' attributes influence the direction of technological change induced by changes in factor market costs. In particular, we state that firms stuck by high irreversibility of production factors try and react to the changes in factor markets by means of the technological innovations that enable them to minimize the switching costs. Large firms with high wages and capital intensity able to command the generation and the exploitation of technological knowledge react to changes in input costs by introducing skill-intensive technological changes that take advantage of the competence and tacit knowledge acquired in the original technique defined in term of factor intensity, in so doing they fully rely on localized technological knowledge. On the contrary, small firms with lower switching costs and lower intensity of technological knowledge introduce mainly process innovations embodied in new capital goods and in doing so, direct technological change towards higher levels of output elasticity of capital.

The econometric analysis has focused on a panel of 1113 public companies listed on four European countries (UK, Germany, France and Italy) in the period going from 1995 to 2003. Our findings confirm that while large companies, building on localized technological knowledge and able to implement it with codified knowledge acquired by means of formal R&D and better able to appropriate the returns of their innovation activities, are more likely to introduce skill-intensive product innovations, small firms less able conduct internal R&D activities and less able to appropriate the benefits of their technological innovations, rely more upon the adoption of external knowledge embodied in capital goods provided by upstream specialized suppliers and are more likely to introduce capital-intensive technological change.

Our model of localized technological change supported by robust empirical evidence provides a clear analytical framework and a coherent interpretation of the growing skill intensity of the advanced economies that can be interpreted as the result of the introduction of new technologies induced by the growing globalization experienced by the world economy since the end of the XX century and biased by the characteristics of the production process, the generation and exploitation of technological knowledge of the firms. More specifically, the localized technological change approach seems able to explain the bias in favor of higher levels of skill intensity as the result of an induced technological change constrained by the irreversibility and consequent large switching costs of firms with high levels of fixed and human capital intensity. The skill-intensive direction of technological change is the result of the efforts of large firms with high unit wages, able to command the generation and exploitation of technological change, to cope with the increase of the relative levels of wages of unskilled labor and competition in traditional product markets brought about the rapid increase in the integration of international product markets.

Appendix A - Sectoral concordance table

Sector name	Groningen Growth and Development Centre 10-sector database	Datastream	ISIC
Agriculture, Forestry, and Fishing	01-05	1733, 3573	45, 01-02
Mining and Quarrying	10-14	1771-1779	10-12, 13-14
Manufacturing	15-37	533-587, 1353,1357, 1737-1757, 2353, 2713-2757, 3353-3537, 3577-3726, 3743-3785, 4535-4577, 5557, 5752, 9572-9578	5,15-36
Public Utilities	40-41	7535-7577	40-41
Construction	45	3728, 2357	45
Wholesale and Retail Trade, Hotels and Restaurants	50-55	2797, 5333-5379, 5753, 5757	51-55
Transport, Storage, and Communication	60-64	2771-2779, 5553, 5751, 5759-6575	60-63, 64
Finance, Insurance, and Real Estate	65-74	2791-2795, 2799, 5555, 8355-9537	65-70, 71-74
Government Services	75-85	4533	85
Community, Social and Personal Services	90-99	5377, 5755	80,90-93

Appendix B - Firms and observations by country and industry

	UK		*Germany*		*France*		*Italy*	
	Firms	*%.*	*Firms*	*%.*	*Firms*	*%.*	*Firms*	*%.*
Agriculture, Forestry, and Fishing	5	1.68	4	0.76	3	1.63	2	1.92
Mining and Quarrying	5	1.68	7	1.33	4	2.17	0	0
Manufacturing	121	40.60	274	51.99	88	47.83	52	50.00
Public Utilities	9	3.02	24	4.55	7	3.80	8	7.69
Construction	13	4.36	14	2.66	5	2.72	4	3.85
Wholesale and Retail Trade, Hotels and Restaurants	45	15.10	35	6.64	13	7.07	3	2.88
Transport, Storage, and Communication	18	6.04	36	6.83	10	5.43	3	2.88
Finance, Insurance, and Real Estate	80	26.85	128	24.29	53	28.80	32	30.77
Government Services	1	0.34	4	0.76	1	0.54	0	0
Community, Social and Personal Services	1	0.34	1	0.19	0	0	0	0
Total	*298*	*100*	*527*	*100*	*184*	*100*	*104*	*100*

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TABLE 1. THE DIRECTIONS OF TECHNOLOGICAL CHANGE

TYPES OF INNOVATION PROCESSES/MAIN FEATURES	SKILL-INTENSIVE LOCALIZED TECHNOLOGICAL CHANGE	CAPITAL INTENSIVE INDUCED TECHNOLOGICAL CHANGE
MAIN SOURCE OF KNOWLEDGE	SCIENTIFIC DISCOVERIES	TECHNOLOGICAL KNOWLEDGE EMBODIED IN CAPITAL GOODS
KNOWLEDGE GENERATION	RESEARCH AND DEVELOPMENT	LEARNING BY DOING AND BY USING
FORM OF KNOWLEDGE	MAINLY CODIFIED	MAINLY TACIT
SCOPE OF APPLICATION	LARGE	NARROW
TYPES OF INNOVATION	PRODUCT	PROCESS & CREATIVE ADOPTION
APPROPRIATION	PATENTS	SECRECY AND TIME LAGS
EXPLORATION	GLOBAL SOURCING ON THE INTERNATIONAL SCIENTIFIC FRONTIER	LOCAL KNOWLEDGE SOURCING WITHIN CLUSTERS
EXPLOITATION	GLOBAL PRODUCT MARKETS	LOCAL FACTOR MARKETS
FIRMS	CORPORATIONS&SCIENCE BASED YOUNG FIRMS	SMALL AND MEDIUM SIZE
INDUSTRIES	HIGH TECH SERVICES AND CAPITAL GOODS	TRADITIONAL FINAL GOODS

Table 2 – Sample production factors elasticities by year

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

$$a_{it} = 1 - b_{it} \quad (3)$$

Year	α	β	α+ β
1995	0.418	0.582	1.000
1996	0.435	0.565	1.000
1997	0.425	0.575	1.000
1998	0.438	0.562	1.000
1999	0.441	0.559	1.000
2000	0.440	0.560	1.000
2001	0.463	0.537	1.000
2002	0.448	0.552	1.000
2003	0.435	0.565	1.000

Table 3 – Descriptive statistics

	obs.	*mean*	*std. dev*	*min*	*max*
$\ln\alpha_{it}$	10017	-0.9639481	0.5818202	-7.136785	0
$\ln\alpha_{it-1}$	8904	-0.9603627	0.5752905	-7.136785	0
$\ln(w_{it}/w_{it-1})$	8893	0.0714427	0.368695	-7.142705	7.247954
$\ln Size_{it-1}$	8896	16.08716	2.772896	5.347107	23.65579
$\ln(w_{it}/w_{it-1}) * \ln R\&D_{it-1}$	2805	-0.1157062	1.304551	-28.73244	-28.73244
$\ln(w_{it}/w_{it-1}) * \ln IA_{it-1}$	6732	-0.0965345	1.128948	-35.71825	36.33765
$\ln(w_{it}/w_{it-1}) * Patents_{it-1}$	8893	0.0041039	0.1043013	-3.403005	5.505905

Table 4 - Results of first difference GMM Regressions

$$\ln \alpha_{it} = \lambda_1 + \lambda_2 \ln \alpha_{it-1} + \lambda_3 \ln(w_{it} / w_{it-1}) + \lambda_4 \ln Size_{it-1} + \lambda_5 \left[\ln(w_{it} / w_{it-1}) * \ln X_{it-1}\right] + \sum \psi_t + \varepsilon_{it} \qquad (4)$$

Dep. Var. $\ln\alpha_{it}$	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES						
$\ln\alpha_{it-1}$	0.175***	0.202***	0.241***	0.123***	0.146***	0.239***
	(0.0281)	(0.0280)	(0.0305)	(0.0312)	(0.0295)	(0.0305)
$\ln(w_{it}/ w_{it-1})$		-0.183***	-0.192***	-0.337***	-0.440***	-0.185***
		(0.0313)	(0.0332)	(0.0563)	(0.0359)	(0.0318)
$\ln Size_{it-1}$			-0.0679***	-0.0675***	-0.0669***	-0.0665***
			(0.0181)	(0.0194)	(0.0170)	(0.0181)
$\ln(w_{it}/ w_{it-1}) * \ln R\&D_{it-1}$				-0.0431***		
				(0.0164)		
$\ln(w_{it}/ w_{it-1}) * \ln IA_{it-1}$					-0.0630***	
					(0.0104)	
$\ln(w_{it}/ w_{it-1}) * Patents_{it-1}$						-0.202***
						(0.0781)
$\Sigma\psi_t$	Yes	Yes	Yes	Yes	Yes	Yes
Observations	7791	7781	7774	2365	5697	7774
Number of ID	1113	1112	1111	403	993	1111
Number of instruments	18	19	20	21	21	21
Wald Test χ^2	105.43	133.91	124.02	149.58	261.50	158.95
Prob > $\chi2$	0.000	0.000	0.000	0.000	0.000	0.000
Sargan test $\chi2$	11.97	13.62	14.57	18.54	16.60	14.58
Prob> $\chi2$	0.287	0.191	0.148	0.046	0.084	0.148
AR(1)	-7.05	-6.62	-6.66	-4.44	-5.23	-6.61
Prob> z	0.000	0.000	0.000	0.000	0.000	0.000
AR(2)	-0.95	-0.23	-0.13	0.45	0.41	-0.07
Prob> z	0.341	0.818	0.898	0.651	0.685	0.941