11. Labour productivity and technological capability: an econometric analysis on the Italian regions

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10.1. INTRODUCTION

It is widely argued in the economics literature that high technological capability is essential for economic development because it generates innovations by accelerating technological progress. Moreover, in the global economy technical knowledge is a means to compete in the global market. Using econometric analysis this chapter aims to verify the effect of technological capability on labour productivity in the Italian regions. For this purpose, I construct a new version of the labour productivity function of Sylos Labini, where the growth rate of productivity depends on three effects: the *Smith effect*, represented by the growth rate of market size that is stimulated by labour division and learning by doing; the *Ricardo effect*, represented by investment in new machinery stimulated by the growth rate of the relative labour cost (defined as the difference between wages and price of machinery); and the *knowledge effect*, introduced in this chapter, represented by variables linked to technological capability. I estimate regressions for manufacturing and consider several other variables linked to knowledge, both individually and all together. Moreover, through a dummy analysis I investigate whether the dynamics of knowledge is significantly conditioned by territorial factors.

The chapter is structured as follows. First, I present a state-of-the-art review of the literature on this topic. Subsequently, I explain the econometric model estimated with the main information of econometric analysis. Finally, I illustrate the results of the econometric analysis. Empirical evidence suggests that in the Italian regions, especially in the centre-northern regions, improvements in technological capability can positively affect labour productivity dynamics in the manufacturing sector. Compared with the original Sylos Labini function, my new version has two original elements:

the introduction of the knowledge effect into the function and the use of regional observations.

11.2. THE THEORETICAL FRAMEWORK

This chapter seeks to analyse the influence of technological capability on labour productivity in the Italian regions using the original Sylos Labini approach. After illustrating the essential role of technological capability for the production system, the different kinds of technical knowledge are defined. I then highlight the role of knowledge accessibility and of institutions on skills development. Finally, various effects of technological skills on labour productivity are described.

The relation between technological capability and productivity is a crucial issue for economic development because in the global market the enterprise can choose between two different kinds of competitiveness: *technological competitiveness*, related to investments in product and process innovations aimed at improving technological capability, and *cost competitiveness*, that mainly consists in reducing labour costs and increasing flexibility. The first kind of competitiveness is the best option from social and economic standpoints.

According to Lall (1990, p. 17), technological capability is ‘the entire complex of human skills (entrepreneurial, managerial and technical) needed to set up and operate industries efficiently over time’. According to Kim (1997, p. 4), for the developing countries technological capability is similar to the capacity to absorb and assimilate current knowledge and after to generate new knowledge (see also Lall, 2000; Von Zedtwitz and Jin, 2004). Overall, technological capability may be defined as the capability of generating, learning, disseminating and using technical knowledge to improve productivity.

According to Johnson and Lundvall (1994), there are two types of technical knowledge. *Codified knowledge* is produced and transmitted through formal channels: for example a scientific invention can be produced in a laboratory and transmitted through the acquisition of licences. By contrast, *tacit knowledge* is produced and transmitted informally. For example, a process is invented by a worker during his/her specific work and transmitted to colleagues through practical demonstrations. Within tacit knowledge, two kinds of learning may be defined: workers can learn by experience and by doing the same activity resulting from division of labour and specialization (*learning by doing*) (see Posner, 1961 and Arrow, 1962); moreover they can learn tacit knowledge embodied in physical capital by using machinery (*learning by using*) (see Rosenberg, 1982 and Arthur, 1994).

Codified knowledge can be classified into two categories: *know what*, which is codified information of key facts, and *know why*, which concerns in-depth scientific knowledge of the fundamentals of analysed facts. Tacit knowledge comprises *know how*, that is practised knowledge and competence, and *know who*, that is information able to solve specific problems to minimise the cost of acquiring new knowledge. Tacit knowledge may concern a worker's individual skills, but it can also refer to an enterprise or a professional category (such as engineers) or implicit socio-cultural knowledge if this affects the production system (Castillo, 2002).

In order to ameliorate technological capability, it is also necessary to have access to external technical knowledge (*knowledge accessibility*). In general, the results of this transmission depend on *absorptive capacity*, that is the capability at the individual or enterprise level to acquire and internalise external knowledge thanks to work experience and to previously accumulated skills (Cohen and Levinthal, 1990; Caloghirou et al., 2002).

For a firm, the complementariness between individual capacity and external collaboration is extremely important for improving absorptive capacity (Mangematin and Nesta, 1999): skilled workers can improve the firm's absorptive capacity not only with their competences, but also through interaction with other skilled workers of other firms (Rothwell and Dodgson, 1991). Transmission of external codified knowledge is easier than transmission of external tacit knowledge (Vinding, 2001). Technological transmission can be intentional (*technological transfer*) or unintentional (*technological spillover*). As regards technological transfer, transmission occurs through formal teaching and/or training, and also by distributing publications or by selling and buying knowledge-intensive services. With regard to technological spillovers, these can occur at an individual level (among people) and at an enterprise level (among firms). In the latter case, spillovers can be intra-industry, a result of industry specialisation. This may be considered a positive externality where technical knowledge developed by one firm can affect the technological accumulation of other technologically-similar firms. Knowledge spillovers can also be inter-sectoral as a result of complementary activities and techniques (Marshall, 1920; Arrow, 1962; Jaffe, 1986; Romer, 1986 and 1990; Bairoch, 1988; Fallah and Ibrahim, 2005).

Finally, in order to improve its technological capability, a firm needs to take part in an *innovation system* where there are developed networks between buyers and sellers, among firms, and between institutions and firms (Lundvall, 1992; Nelson, 1993; Cimoli and Dosi, 1995; Freeman, 1995; Edquist, 1997). A major advantage of networks is the reduction in information costs. The interaction and learning process among producers, suppliers, users, public authorities and scientific institutions are useful for the development of innovation capacity. In this sense, regional innovation capacity, which includes other innovation activities, regards both private and public resources and actors, and depends on the region's ability to produce new ideas and projects and commercialise new technologies (see Rosenberg and Nelson, 1994; Rullani, 1994; Sirilli, 2005). From this point of view, innovation is mainly a social process where formal and informal interaction becomes a crucial element. More specifically, institutions can improve technological capability in different ways: by increasing people skills through better education processes and higher school participation rates; by generating new knowledge through public research and development; by creating strong and cooperative relationship with firms; and by stimulating the development of networks among firms, for example through an appropriate fiscal policy (see Cimoli et al., 2006).

The influence of technological capability on labour productivity can be summarized in two main effects. The first is the *allocative efficiency effect* whereby skills permit a more efficient combination and utilization of different production factors. The second is the *diffusion effect* whereby workers with high level of skills can learn and elaborate new information by optimally combining it with their own experience and education (Nelson and Phelps, 1966; Welch, 1973; Bartel and Lichtenberg, 1987). The first effect is directly linked to implementing new technology in the production process, and can be decomposed into two effects: the *accumulation effect* concerns the introduction of new machinery (this implementation is effective if users have accumulated appropriate skills), while the *assimilation effect* regards the worker's capacity to adapt the production process to the new machinery by reorganizing roles and procedures and to translate tacit knowledge embodied in codified information that can be transmitted to others.

11.3. ECONOMETRIC ANALYSIS

11.3.1. The Econometric Model

The article develops a new version of the Sylos Labini function where labour productivity is influenced by innovations due to the dynamics of some economic variables (see Sylos Labini, 1984 and 2004; Corsi and Guarini, 2007; Guarini, 2007). In particular, two economic effects called the Smith effect and the Ricardo effect stimulate innovations thanks to accumulation of tacit knowledge.

The *Smith effect* refers to the influence of the income growth rate, considered an indicator of the market growth rate; the growth rate of income affects labour productivity thanks to increasing returns of scale generated by static and dynamic economies of scale. Static economies depend on different phenomena: the law of 'tridimensional space' (see Kaldor, 1934 and 1972; Hufbauer, 1966; Thirlwall, 2002), according to which plant capacity rises more than construction costs; indivisibility, that is some kinds of investments (for example laboratories or infrastructures) have a minimal size above which there are increasing returns (see Kaldor, 1972). Dynamic economies influence labour productivity through, for example, division of labour (see Smith, 1776; Young, 1928; see also Corsi, 1991) and learning by doing (see Posner, 1961; Arrow, 1962; Kaldor, 1962).

The *Ricardo effect* concerns the effect of the growth rate of relative labour cost, (that is the dynamic difference between wages and prices of machinery): under the hypothesis of static expectations, if the growth rate of relative labour cost increases, enterprises enhance the capital intensity of the productive process by buying in period $t-m$ machinery in substitution of labour, such that in period t productivity will increase. The m represents the period between the time at which the investment is made and the moment when there is the increase in productivity, and it depends on the type of investment. The Smith effect and the Ricardo effect are indirectly linked to knowledge; in fact, tacit knowledge is partially captured by the Smith effect through learning by doing stimulated by division of labour, and by the Ricardo effect through new technology embodied in the new machinery. Nevertheless, codified knowledge is absent in the Sylos Labini function. Hence I introduce into this function some knowledge variables to account for 'internal codified knowledge' found in internal skills, and 'external codified knowledge' transferred by buying intensive-knowledge services and consequently internalised in new skills of the manufacturing sector. In this way, external codified knowledge can lead to efficient gains in terms of the labour productivity growth rate.

The study regards the 20 Italian regions in the period 2000–2003 and draws on ISTAT[1] and EUROSTAT data (regional statistics in the Eurostat web site). The economic variables estimated are the following: growth rate of labour productivity, defined as the ratio between value added and total labour units; the growth rate of relative labour cost, defined as the difference between wages and deflator of machinery (with lag equal to 4). The first knowledge variable is the growth rate of 'number of tertiary graduates in Mathematics, Science and Technology (MST) per thousand people (age 20–29)'. This variable has an institutional importance: it is an indicator used by the European Union in its 'Lisbon Strategy 2000', a European programme aiming to build a knowledge economy in EU countries through improvements in the education and training system. The second knowledge variable is the growth rate of 'human resources in Science and Technology (ST)': according to the Canberra Manual (1995) (see OECD, 1995 and EUROSTAT metadata in the web site epp.eurostat.ec.europa.eu) a human resource in ST is 'a person fulfilling at least one of the following conditions: successfully completed education at the third level in a S&T field of study or not formally qualified as above, but employed in a S&T occupation'. The last knowledge variable is the growth rate of 'employers in Knowledge-Intensive (KI) services'. The choice of a short period for the regression analysis (2000–2003) is due to breaks in the time series of variables, caused by changes in the method of measurement (see ISTAT, 2005, 2006 and 2007). Furthermore, the knowledge variables are new in relation to economic variables. Despite the limited heuristic value of the econometric results, this chapter highlights some empirical aspects with interesting theoretical and political consequences that could be further analysed in other works.

I estimated the labour productivity function for the manufacturing sector by considering the Smith effect, Ricardo effect and the knowledge effect of technological capability. First, the knowledge effect was estimated for each single variable and then several variables were considered together. The regressions, in the general version, are the following:

$$prod_{it} = \alpha + \beta y_{it} + \gamma c_{it-4} + \delta_1 l_{it} + \varepsilon_{it} + \mu_i + \tau_t \qquad (11.1)$$

$$prod_{it} = \alpha + \beta y_{it} + \gamma c_{it-4} + \delta_2 h_{it} + \varepsilon_{it} + \mu_i + \tau_t \qquad (11.2)$$

$$prod_{it} = \alpha + \beta y_{it} + \gamma c_{it-4} + \delta_3 s_{it} + \varepsilon_{it} + \mu_i + \tau_t \qquad (11.3)$$

$$prod_{it} = \alpha + \beta y_{it} + \gamma c_{it-4} + \delta_4 l_{it} + \delta_5 s + \varepsilon_{it} + \mu_i + \tau_t \qquad (11.4)$$

where *i* refers to the Italian regions and *t* is the year considered. As regards the economic variables in all the regressions, $prod_{it}$ is the growth rate of labour productivity, y_{it} is the growth rate of income, $c_{it\text{-}m}$ is the growth rate of relative labour cost where $m = 4$. According to an analysis by Sylos Labini (2004, pp. 56–8), this lag can represent the time for firms to react to the increase in relative labour cost by buying new machinery and the time needed for this new physical capital to improve labour productivity. As regards the knowledge variables, l_{it}, ,h_{it}, and s_{it} represent growth rates of, respectively, graduates in MST, human resources in ST and employers in IK services. With regard to the coefficients, α is the constant for all the observations, $\beta, \gamma > 0$ represent respectively the *Smith effect* and the *Ricardo effect*, $\delta_1, \delta_2, \delta_3 > 0$ represent, respectively, the knowledge effect of l_{it}, h_{it}, and s_{it} in regressions (11.1), (11.2), (11.3) and $\delta_4, \delta_5 > 0$ the knowledge effect respectively of l_{it} and s_{it} in regression (11.4). Finally, ε_{it} is the white noise variable, μ_i is the individual effect that can be deterministic (Fixed Effect model) or stochastic (Random Effect model), τ_t represents the time deterministic effect. Four models were estimated: results are shown for the Pooled Ordinary Least Square model (OLS), where $\mu_i = 0$, for the Random Effect model (RE) where $\mu_i \neq 0$ is stochastic, for the Fixed Effect model (FE) where $\mu_i \neq 0$ is deterministic, and for the Least Absolute Deviation model (LAD) where the weight of outliers is reduced by using the median regression. It may thus be verified that all estimates are robust with respect to the outliers. The LAD model is used in various regional analyses concerning human capital (see for example Basile et al., 2003 and Nuzzo, 2006).

As a preliminary analysis, I tested the endogeneity of valued-added relative to labour productivity. In the productivity function of Sylos Labini, income is an independent variable, but the income identity has as components labour productivity and employment.[2] Due to the combined variations in the variables, there may exist a bi-directional relationship between labour productivity and income, hence income may not be stochastic. If this is statistically considerable, it can distort the value of the coefficient of the Smith effect. I therefore tested the statistical significance of endogeneity.[3] After finding that endogeneity in the estimated regressions is not significant,[4] I chose the model by comparing OLS, RE, FE and LAD. Further, I tested whether the time shocks are statically significant and I found that they are insignificant, hence $\tau_t = 0$. In general, for each regression the following assumptions were verified: normal distribution of residuals, the nullity of expected value of residuals, homoscedasticity, no autocorrelation of residuals, and no stochasticity of exogenous variables. The econometric diagnostic is presented in Tables 11A.4, 11A.5, 11A.6, 11A.7 and 11A.8 (see the Appendix). In Tables 11A.6, 11A.7 and 11A.8, there is a synthetic description of all variables of regressions about mean, minimum and maximum value, standard deviation (between, within, overall).

11.3.2. Descriptive Analysis

A descriptive analysis at regional and international level of indicators and variables linked to technological capability is provided to understand the position of Italy. Various studies have shown Italy's lag vs. advanced countries in human capital accumulation and also in the competitive advantage generated by public and private investment in education. For example, a study by SVIMEZ compares the Italian situation with that of other major countries. In 2002 in Italy the percentage of young people (age 20–24) who had completed upper secondary education was 46.3 per cent (42 per cent in the South and 51.4 per cent in the Centre-North). This is lower than the values for the Czech Republic (87.9 per cent), Slovak Republic (86 per cent), Poland (81.6 per cent) and Hungary (71.4 per cent). In the south of Italy 11.1 per cent of the population are university graduates, contrasting with 36.3 per cent in Japan, 38.1 per cent in the United States and 32.5 per cent in Sweden (Bianchi et al., 2006).

Inter-regional classifications show two different results. With regard to graduates in MTS and humans resources in ST, Italian regions are divided into two parts, 'the Centre-North' and 'the South' with all central-northern regions occupying the top positions, while all southern regions are lower down (see Table 11A.1 in Appendix). By contrast, concerning employers in knowledge-intensive services, the ranking differs from the macro-area classification: some southern regions are in the top positions and some central-northern regions are lower down. For example, Calabria is third, Sicily is fifth, while Marche is 19th and Veneto is the last. As regards graduates in MTS, Italy is below the average of 25 European Union countries, although the gap narrowed between 2000 and 2004 (see Table 11A.2 in Appendix). Moreover, in this regard there is a 'southern Italian problem': this variable for southern Italian regions is half the average of 25 European Union countries. With respect to human resources in ST and employers in IK services, Italy is ranked lower in the first variable (25th) than in the second (15th), and the southern gap is also worse in the first variable (28th for the south and last for the islands) than in the second (16th) (see Table 11A.3 in Appendix).

These data show that the Italian situation is critical, since the competitiveness of the economic system, represented by the growth of labour productivity, also depends on the growth of human capital. Indeed, according to an OECD empirical study (OECD, 2006), the level of education strongly affects the increase in productivity: a country with a 1 per cent higher level of education than the international average can achieve levels of productivity which are 2.5 per cent higher than those of other countries.

11.3.3. The Results

The analysis shows that the original Sylos Labini regression is verified: the coefficients that represent the Smith effect and the Ricardo effect are significant and positive (see Table 11.1). The Smith effect is the main effect with a coefficient that is double that of the Ricardo effect. According to the results, at the dynamic level, tacit knowledge embodied in the machinery and represented by the Ricardo effect and tacit knowledge accumulated by learning by doing and by using and represented by the Smith effect are both econometrically important for increasing labour productivity.

Table 11.1. Regressions of original Sylos Labini function

	OLS	LAD	RE°	FE
y	0.446	0.348	0.446	0.503
	(0.000)	(0.000)	(0.000)	(0.000)
c_4	0.243	0.310	0.243	0.260
	(0.011)	(0.000)	(0.010)	(0.016)
α	–0.00542	–0.00425	–0.00542	–0.00620
	(0.089)	(0.086)	(0.085)	(0.077)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.402	0.267	0.417	0.417

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

All of the variables added into the Sylos Labin regressions (that is the knowledge effect of graduates in MST, human resources in ST and employers in IK services) have significant and positive coefficients (see Tables 11.2–11.5): knowledge effect is the third most important variable in terms of elasticity, but it can explain only part of the process of labour productivity growth. With respect to the standard theoretical framework, the introduction of knowledge variables makes it possible to explicitly analyse the role of codified knowledge. The significance of variable *l* is interesting at a political level because for 25 EU countries the increase in this variable is one of the main goals of educational policy. Thus a significant and positive coefficient indicates that these institutional efforts are useful for technological and economic progress. Besides, the significance of the variable *h* could explain the importance of networks among workers at inter-sectoral and intra-sectoral level and also at areal level for labour productivity dynamics. Indeed, this variable also comprises employers in technological and scientific activities in all the sectors (see Table 11.3). Moreover, from Tables 11.4 and 11.5 it emerges that *s* is the main knowledge variable. This confirms that to increase technological capability, knowledge transmission is fundamental, especially knowledge transfer through knowledge-intensive services.

Table 11.2. Regressions with the knowledge effect of graduates in MST

	OLS°	LAD	RE	FE
y	0.481 (0.000)	0.379 (0.000)	0.481 (0.000)	0.551 (0.000)
c_4	0.200 (0.027)	0.309 (0.000)	0.200 (0.024)	0.212 (0.033)
l	0.0259 (0.001)	0.0192 (0.007)	0.0259 (0.001)	0.0289 (0.001)
α	–0.00895 (0.005)	–0.00727 (0.021)	–0.00895 (0.004)	–0.0102 (0.003)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.474	0.291	0.494	0.494

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Table 11.3. Regressions with the knowledge effect of human resources in ST

	OLS	LAD	RE°	FE
y	0.446 (0.000)	0.335 (0.000)	0.446 (0.000)	0.498 (0.000)
c_4	0.196 (0.040)	0.293 (0.000)	0.196 (0.037)	0.215 (0.047)
h	0.135 (0.033)	0.137 (0.003)	0.135 (0.030)	0.129 (0.070)
α	–0.0109 (0.008)	–0.0112 (0.000)	–0.0109 (0.006)	–0.0114 (0.012)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.429	0.300	0.451	0.450

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Table 11.4. Regressions with the knowledge effect of employers in IK services

	OLS	LAD	RE°	FE
y	0.424 (0.000)	0.406 (0.000)	0.424 (0.000)	0.472 (0.000)
c_4	0.271 (0.004)	0.309 (0.002)	0.271 (0.003)	0.282 (0.009)
s	0.133 (0.030)	0.124 (0.046)	0.133 (0.027)	0.120 (0.091)
α	–0.00933 (0.010)	–0.00823 (0.028)	–0.00933 (0.008)	–0.00958 (0.018)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.431	0.289	0.452	0.451

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Table 11.5. Regressions with the knowledge effect of graduates in MST and employers in IK services

	OLS	LAD°	RE	FE
y	0.458 (0.000)	0.371 (0.000)	0.458 (0.000)	0.521 (0.000)
c_4	0.229 (0.067)	0.365 (0.000)	0.229 (0.008)	0.234 (0.017)
l	0.0258 (0.000)	0.0219 (0.007)	0.0258 (0.000)	0.0288 (0.001)
s	0.133 (0.034)	0.183 (0.007)	0.133 (0.018)	0.118 (0.069)
α	–0.0128 (0.001)	–0.0139 (0.001	–0.0128 (0.000)	–0.0135 (0.001
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.529	0.327	0.529	0.528

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Tables 11.6, 11.7 and 11.8 concern dummy analysis where the knowledge effect is studied with respect to the territorial classification ‘Centre-North and South of Italy’ which is used by international and national institutions for regional policies. The results confirm that a ‘southern problem’ exists with regard to the economic effectiveness of technological capability. Descriptive analysis showed that the South is behind the Centre-North in relation to the dynamics of *l* and *h* variables, but for the *s* variable there is no such dual system. Econometric analysis shows that the specific knowledge effect of Italy’s southern regions is not significant. Instead, the specific knowledge effect of the centre-northern regions is significant and positive. As shown by Tables 11.6, 11.7 and 11.8, the coefficients of the southern dummy interaction term are not significant, while the coefficient of knowledge variables, which in this dummy analysis represents the Centre-North, is significant and positive.

Table 11.6. Dummy analysis with the knowledge effect of graduates in MST

	OLS	LAD	RE°	FE
y	0.501	0.345	0.501	0.539
	(0.000)	(0.000)	(0.000)	(0.000)
c_4	0.230	0.371	0.230	0.215
	(0.010)	(0.000)	(0.008)	(0.030)
l	0.0290	0.0262	0.0290	0.0310
	(0.000)	(0.000)	(0.000)	(0.000)
dumsud	–0.00544	–0.00662	–0.00544	0
	(0.460)	(0.354)	(0.458)	.
*dumlsud**	–0.0367	–0.0197	–0.0367	–0.0420
	(0.211)	(0.455)	(0.207)	(0.243)
α	–0.00541	–0.00440	–0.00541	–0.00765
	(0.133)	(0.215)	(0.129)	(0.060)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.500	0.327	0.533	0.527

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; * dummy interaction term; °is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Table 11.7. Dummy analysis with the knowledge effect of human resources in ST

	OLS	LAD	RE°	FE
y	0.482	0.317	0.482	0.509
	(0.000)	(0.000)	(0.000)	(0.000)
c_4	0.203	0.289	0.203	0.195
	(0.032)	(0.000)	(0.029)	(0.067)
h	0.226	0.139	0.226	0.237
	(0.006)	(0.004)	(0.005)	(0.013)
dumsud	0.000502	–0.00607	0.000502	0
	(0.949)	(0.173)	(0.949)	.
*dumhsud**	–0.224	–0.0250	–0.224	–0.238
	(0.065)	(0.707)	(0.061)	(0.083)
α	–0.0118	–0.00815	–0.0118	–0.0119
	(0.022)	(0.007)	(0.020)	(0.008)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.460	0.328	0.494	0.494

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; * dummy interaction term; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Table 11.8. Dummy analysis with the knowledge effect of employers in IK services

	OLS	LAD	RE°	FE
y	0.474	0.311	0.474	0.515
	(0.000)	(0.001)	(0.000)	(0.000)
c_4	0.275	0.468	0.275	0.259
	(0.004)	(0.000)	(0.003)	(0.015)
s	0.206	0.106	0.206	0.230
	(0.014)	(0.266)	(0.012)	(0.020)
dumsud	–0.00576	–0.00985	–0.00576	0
	(0.379)	(0.209)	(0.377)	.
*dumssud**	–0.164	–0.0696	–0.164	–0.233
	(0.178)	(0.597)	(0.174)	(0.104)
α	–0.00791	–0.00360	–0.00791	–0.0103
	(0.072)	(0.492)	(0.068)	(0.010)
N	80	80	80	80
F	(0.000)	(0.000)	(0.000)	(0.000)
R^2	0.451	0.304	0.486	0.480

Notes:
N: number of observations; *F*: Fisher; R^2 means adjusted R^2 for OLS and LAD models and overall R^2 for RE and FE models; p-values are in parentheses; * dummy interaction term; ° is the model chosen on the basis of tests in Tables 11A.4 and 11A.5.

Although in the period 1996–2004 the labour productivity growth rate was higher in the southern regions than in the centre-north, these econometric results suggest that the competitiveness of the southern regions in this period was not based on technological capability in the manufacturing sector (the analysis concerns only this sector), but mainly on an increase in private investment and tourism attractiveness. One of the main policy goals is to reduce both the technological capability gap between Italy and EU countries and between southern and centre-northern Italian regions. Only if the technological capability developed positively affects labour productivity can all Italian regions become winning competitors on the global market and enjoy long-term economic growth (see Barca, 2006).

11.4. CONCLUSIONS

The role of technological capability in the dynamics of labour productivity in the Italian manufacturing sector, at a regional level, was investigated for the period 2000–2003. First, I presented the theoretical framework related to the role of technological capability in the productive system and to the effect of technological capability on labour productivity improvement; the latter effect was termed the 'knowledge effect'. Secondly, I estimated this effect in a new version of the Sylos Labini labour productivity function. One of the original versions of the Sylos Labini function included the income growth rate (the Smith effect) related to static and dynamic economies of scale and the growth rate of relative labour cost (the Ricardo effect) calculated as the difference between wages and the cost of machinery, and related to the acquisition of new machinery by a firm when this kind of labour cost rises. This function is estimated by Sylos Labini only at the national level. The main contribution herein consists in introducing the knowledge effect into this function and in the use of regional observations. The knowledge variables are growth rates of: 'number of tertiary graduates in Mathematics, Science and Technology (MST) per thousand people (age 20–29)', 'human resources in Science and Technology' and 'employers in Knowledge-Intensive services'. In general, all the coefficients of the new version of the Sylos Labini productivity function are significant and positive: this means that technological capability positively affects the dynamics of labour productivity by tacit knowledge (included in both the Smith and Ricardo effects) and by codified knowledge accumulated in skills and transmitted by transfers and spillovers. Finally, dummy analysis showed that, as regards the effectiveness of technological capability at affecting labour productivity dynamics, the Italian regions are divided into two traditional areas: the specific knowledge effect of the Centre-North is significant and positive while that of the South is neither positive nor statistically significant.

APPENDIX

11A.1. Tables of Descriptive Analysis

L is the number of tertiary graduates in Mathematics, Science and Technology per thousand people (age 20–29); *S* stands for employers in knowledge-intensive services as a percentage of total employment; *H* for Human Resources in Science and Technology as a percentage of the population.

Table 11A.1. Inter-regional classifications on technological capability's indicators

	L				S				H		
		2000	2004			2000	2004			2000	2004
1	Emilia R.	9.39	14.94	1	Lazio	33.6	37.92	1	Liguria	16.60	23.30
2	Lombardia	6.88	12.39	2	Liguria	30.55	36.12	2	Lazio	19.10	22.50
3	Toscana	8.20	12.32	3	Calabria	29.74	34.11	3	Umbria	17.70	22.40
4	Friuli	4.44	11.98	4	Umbria	25.43	32.75	4	Lombardia	17.50	21.90
5	Piemonte	6.76	11.81	5	Sicilia	27.55	31.82	5	Emilia-Romagna	17.40	20.70
6	Lazio	6.75	11.66	6	Lombardia	27.05	31.58	6	Toscana	15.40	20.50
7	Liguria	10.97	11.59	7	Abruzzo	22.71	30.64	7	Marche	15.90	20.10
8	Veneto	5.97	10.13	8	Provincia Autonoma Trento	29.24	30.33	8	Provincia Autonoma Bolzano-	16.30	20.00
9	Umbria	4.94	9.83	9	Campania	29.34	30.26	9	Provincia Autonoma Trento	16.80	19.70
10	Marche	5.15	8.67	10	Valle d'Aosta/ Vallée d'Aoste	28.4	30.14	10	Veneto	16.00	19.10
11	Campania	4.27	7.22	11	Sardegna	24.55	28.98	11	Friuli-Venezia Giulia	16.00	19.00
12	Sardegna	3.85	6.92	12	Toscana	24.34	28.72	12	Valle d'Aosta	17.30	18.70

Table 11A.1. Continued

L				S				H			
		2000	2004			2000	2004			2000	2004
13	Abruzzo	5.45	6.75	13	Piemonte	25.39	28.12	13	Abruzzo	14.70	18.30
14	Calabria	3.80	6.37	14	Puglia	25.2	27.91	14	Piemonte	16.10	16.90
15	Sicilia	3.73	5.47	15	Provincia Autonoma Bolzano	23.47	27.73	15	Calabria	12.80	16.10
16	TAA	3.06	5.40	16	Molise	25.28	27.55	16	Molise	13.70	15.70
17	Basilicata	1.69	4.93	17	Friuli-Venezia Giulia	26.03	27.35	17	Basilicata	10.30	14.70
18	Puglia	2.45	4.46	18	Emilia-Romagna	25.01	27.28	18	Campania	12.50	14.30
19	Valle d'Aosta	0.37	1.57	19	Marche	23.55	26.21	19	Sicilia	12.80	14.00
20	Molise	0.62	1.29	20	Basilicata	22.33	25.61	20	Sardegna	11.20	14.00
				21	Veneto	22.98	25.47	21	Puglia	12.30	13.70

Source: ISTAT regional database ww.istat.it.

Table 11A.2. Italian position with respect to the Lisbon Strategy benchmark

	Objective in 2010	2000		2004			
Indicator		EU (25)	IT	EU (25)	IT	C–N	S
L	Increase of 15% With respect to year 2000	10.2	5.6	12.3	9.0	11.3	5.8

Note: EU: European Union, IT: Italy, C-N: Centre-North, S: South.

Source: Ministero dell'Economia e delle Finanze, DPS Annual Report (2005), ISTAT, Eurostat, OECD PISA (Programme for International Student Assessment, 2003) data.

Table 11A.3. European classifications on technological capability's indicators

	H				H				S				S		
		2000	2004			2000	2004			2000	2004			2000	2004
1	Netherlands	31	35	16	Slovenia	19.4	23.5	1	Sweden	45.71	46.95	16	Sud (IT)	27	29.9
2	Denmark	29.9	34.9	17	Czech Republic	20.9	21.9	2	Denmark	42.13	42.32	17	Malta	29.72	29.08
3	Sweden	34	33.6	18	Centro (IT)	17.4	21.5	3	Netherlands	39.21	42.16	18	Hungary	26.5	28.47
4	Finland	33.8	33.3	19	Latvia	20.8	21.3	4	United Kingdom	39.81	42.11	19	Estonia	26.88	27.49
5	Estonia	27.6	30.8	20	Nord Ovest (IT)	17	20.6	5	Finland	37.91	40.34	20	Nord Est	24.37	26.68
6	Belgium	26.7	29.7	21	Nord Est (IT)	16.6	19.8	6	Luxembourg	35.5	39.03	21	Cyprus	25.53	26.34
7	Germany	28.2	29.4	22	Hungary	17.6	19.5	7	Belgium	37	38.6	22	Spain	24.55	26.07
8	Luxembourg	24	28.2	23	Slovakia	17.6	19.1	8	France	34.69	35.79	23	Slovakia	24.48	25.05
9	Cyprus	24.4	28.1	24	Greece	15	18.7	9	Ireland	31.76	33.49	24	Lithuania	26.19	24.96
10	United Kingdom	25.2	27.6	25	Italy	15.4	18.5	10	Germany	30.37	33.36	25	Greece	21.76	24.9
11	Austria	20.7	27.5	26	Poland	15.3	17.5	11	Centro (IT)	28.5	32.9	26	Latvia	24.76	24.6
12	France	24.1	27.1	27	Malta	14.3	15	12	Austria	28.17	31.3	27	Czech Republic	24.03	24.52
13	Ireland	20.9	27	28	Sud (IT)	12.6	14.8	13	Nord Ovest	26.93	31.04	28	Poland	:	24.32
14	Spain	21.4	24.6	29	Portugal	11.1	14.2	14	Isole (IT)	26.72	30.99	29	Slovenia	22.8	24.27
15	Lithuania	34.1	24	30	Isole (IT)	12.4	14	15	Italy	26.68	30.25	30	Portugal	19.37	22.46

Source: EUROSTAT regional database epp.eurostat.ec.europa.eu.

11A.2. Tables of Econometric Diagnosis

Table 11A.4. Tests on endogeneity

Equations	A	B	C	D	E	F	G	H
Sargan test	2.416 (0.1201)	2.061 (0.1512)	2.182 (0.1396)	1.894 (0.1687)	1.519 (0.2178)	0.477 (0.4897)	1.248 (0.2639)	0.753 (0.3856)
Wu-Hausman F test	0.09020 (0.76474)	0.06456 (0.80013)	0.05966 (0.80770)	0.00107 (0.97400)	0.00759 (0.93082)	0.03270 (0.85699)	0.20902 (0.64890)	0.03401 (0.85420)
Durbin-Wu-Hausman chi-sq	0.09484 (0.75811)	0.06880 (0.79309)	0.06359 (0.80091)	0.00114 (0.97306)	0.00820 (0.92784)	0.03582 (0.84988)	0.22841 (0.63271)	0.03725 (0.84695)

Note: In both tests of endogeneity of *y*, the null hypothesis is: Regressor is exogenous. In parenthesis I report the p-value.

Table 11A.5. Other tests

Equations	A	B	C	D	E	F	G	H
Test for annual dummies	1.54 (0.6732)	1.27 (0.2903)	0.92 (0.8201)	1.11 (0.7739)	2.55 (0.0623)	2.62 (0.4546)	1.25 (0.7407)	1.48 (0.6875)
Breusch and Pagan test for random effect	4.40 (0.0360)	2.23 (0.1353)	4.44 (0.0352)	4.95 (0.0261)	2.59 (0.1077)	4.15 (0.0417)	5.78 (0.0163)	5.91 (0.0151)
F test that all $u\_i = 0$	0.9860	0.9055	0.9883	0.9934	0.9386	0.9881	0.9982	0.9979
Breusch and Pagan test for heteroscedasticity	0.38 (0.5365)	2.71 (0.0999)	2.45 (0.1177)	2.79 (0.0949)	10.33 (0.0013)* [1.87] [(0.1719)]	2.01 (0.1558)	0.66 (0.4176)	0.73 (0.3943)

Note: OLS: Ordinary Linear Square. RE: Random Effect. FE: Fixed effect. For FE I report the F test that all $u\_i = 0$ and in parenthesis the Prob > *F*. For RE I report the Breusch and Pagan Lagrangian multiplier test for random effects and in parenthesis the Prob > *F*; * without an outlier there is no heteroscedasticity.

Table 11A.6. A synthetic description of all variables of regressions: all regions

Variable		Mean	Std0. Dev0.	Min	Max	Observations
	overall	0.0022615	0.0326616	–0.1344397	0.1220996	N = 80
prod	between		0.0069282	–0.0076822	0.0131593	n = 20
	within		0.0319469	–0.1329426	0.1235967	T = 4
	overall	0.0091334	0.0399153	–0.1253071	0.1229467	N = 80
y	between		0.0159575	–0.0261865	0.0445155	n = 20
	within		0.0367186	–0.1374543	0.1194533	T = 4
	overall	0.0148882	0.0314452	–0.056781	0.0767908	N = 80
c_4	between		0.0087738	0.0043616	0.0347805	n = 20
	within		0.0302447	–0.0478236	0.0709331	T = 4
	overall	0.1482546	0.3569646	–10.543314	10.979987	N = 80
l	between		0.0706273	–0.0031419	0.2863925	n = 20
	within		0.3501784	–10.501834	20.021468	T = 4
	overall	0.0458203	0.0459467	–0.0689929	0.1659851	N = 80
h	between		0.0110604	0.0240359	0.0651038	n = 20
	within		0.0446477	–0.0644453	0.1556796	T = 4
	overall	0.0277036	0.0469494	–0.0697341	0.1706142	N = 80
s	between		0.0155529	0.0072986	0.0583314	n = 20
	within		0.0444021	–0.0810942	0.1399865	T = 4

Table 11A.7. A synthetic description of all variables of regressions: Centre-North

Variable		*Mean*	*Std0. Dev0.*	*Min*	*Max*	*Observations*
	overall	0.0017077	0.0256083	–0.0911	0.0528615	N = 48
prod	between		0.0067803	–0.0069275	0.0126578	n = 12
	within		0.0247537	–0.085407	0.0520191	T = 4
	overall	0.0017726	0.0333241	–0.0607777	0.1229467	N = 48
y	between		0.0115872	–0.0261865	0.0167189	n = 12
	within		0.0313815	–0.0716319	0.1120925	T = 4
	overall	0.0099681	0.0288002	–0.056781	0.050658	N = 48
c_4	between		0.0044091	0.0043616	0.0192484	n = 12
	within		0.0284825	–0.0527437	0.0515306	T = 4
	overall	0.1357576	0.4463792	–10.543314	10.979987	N = 48
l	between		0.0682317	–0.0031419	0.2863925	n = 12
	within		0.4414703	–10.514331	20.008971	T = 4
	overall	0.0467717	0.0448403	–0.0689929	0.134059	N = 48
h	between		0.0126245	0.0240359	0.0651038	n = 12
	within		0.0431445	–0.055604	0.1469202	T = 4
	overall	0.029266	0.042983	–0.0640328	0.1216588	N = 48
s	between		0.0146312	0.0100093	0.0543193	n = 12
	within		0.0405848	–0.0539447	0.1356442	T = 4

Table 11A.8. A synthetic description of all variables of regressions: South

Variable		Mean	Std0. Dev0.	Min	Max	Observations
	overall	0.003092	0.0415107	–1344397	0.1220996	N = 32
prod	between		0.0075318	–0.0076822	0.0131593	n = 8
	within		0.0408889	–0.132112	0.1244273	T = 4
	overall	0.0201746	0.0465486	–0.1253071	0.0993986	N = 32
y	between		0.0157474	0.0003357	0.0445155	n = 8
	within		0.0440771	–0.1264131	0.1051096	T = 4
	overall	0.0222683	0.0341845	–0.0385643	0.0767908	N = 32
*c*_4	between		0.0086401	0.0089676	0.0347805	n = 8
	within		0.0331837	–0.0368989	0.0783131	T = 4
	overall	0.167	0.1484081	–0.1324601	0.5881618	N = 32
l	between		0.0745266	0.086339	0.2814827	n = 8
	within		0.1304157	–0.2469427	0.4736792	T = 4
	overall	0.0443933	0.0482493	–0.0670109	0.1659851	N = 32
h	between		0.0088154	0.0306506	0.0561258	n = 8
	within		0.0475163	–0.0658723	0.1542526	T = 4
	overall	0.0253601	0.0529786	–0.0697341	0.1706142	N = 32
s	between		0.0175985	0.0072986	0.0583314	n = 8
	within		0.0502693	–0.0834378	0.1376429	T = 4

NOTES

1. Database is *Statistiche per politiche di sviluppo e Indicatori di contesto chiave e variabili di rottura* (July 2006). These annual data are produced by the project 'Territorial and sectoral statistical information for the structural policies 2001–2008': ISTAT builds and modifies database with 130 socio-economic regional indicators for monitoring and evaluation of the EU Support Framework 2000–2006.
2. The income identity in dynamic terms is defined $y = \pi + n$ where *y* is the growth rate of income, π the growth rate of labour productivity, *n* the growth rate of employment.
3. See Dixon and Thirlwall (1975); Rowthorn (1975); Parikh (1978); McCombie (1981); McCombie and de Ridder (1983 and 1984); Pugno (1995); Førsund (1996); Leon-Ledesma (1999 and 2000); Destefanis (2002). These studies confirm the validity of the Smith effect using different econometric techniques.
4. I use the instrumental variable method with the Hausman test, Wu-Hausman F test and Durbin-Wu-Hausman test.

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