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PRODUCTIVITY AND EXTERNAL KNOWLEDGE: THE ITALIAN CASE

Abstract

In this paper, we make use of the general notion of localised technological change, as defined in Antonelli (1999), to improve our understanding of economic growth at the national level. Traditionally, the literature on economic growth has overlooked the role of the exchange of technological knowledge as a potential growth factor because technology is thought of as not localised and appropriability rather poor. When, on the contrary, appropriability conditions are considered more robust and technological change becomes localised there is room for a market of technological knowledge at the international level.

The paper provides descriptive evidence about the evolution of total factor productivity in the Italian case and focuses attention on the role of technology payments with respect to domestic research and development (R&D) expenditures on economic growth. Explorative time series analysis conducted within a traditional growth accounting framework confirms that external knowledge, purchased on international technological markets, contributes in explaining the dynamics of domestic output growth in Italy.

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1. Introduction

Technological change is believed to be inherently localised (Atkinson and Stiglitz, 1969, David, 1975, Antonelli, 1999). This means that changes in the technical capability of the production process are limited to a certain set of characteristics: size, age, location, industrial specialisation, levels of integration and diversification, distribution and access conditions to property rights, mix of complementary and interrelated inputs, cumulated competence, skills, and factor and output market strategies of firms (Antonelli, 1999). As a result, technological knowledge tends to be localized in well-defined national, technical, institutional, regional and industrial situations, and, therefore, it may develop specific to each entity or agent involved and become costly to move and to use elsewhere. The localised character of technological knowledge increases its appropriability, that is, it reduces its spontaneous circulation in the economic system.

Within this setting it is obvious that the interaction among different learning entities and agents is supposed to play a major role in the generation of new technological knowledge. Much advance in technological and scientific knowledge is nowadays possible only by relying upon the complementarity among bits of technological knowledge generated by specialists and eventually implemented or recombined by knowledge-assemblers. Acquisition of external knowledge and its recombination with internal research and development activities and competencies proves more and more a crucial way to increase the total amount of technological knowledge each company or country can generate. The cumulative character of the scientific and technological knowledge generation process makes technological specialization and outsourcing even more necessary (Archibugi and Pianta 1992; Archibugi and Michie 1997; Archibugi and Michie 1998). Recombination, assembling, specialization and division of labour are now spreading into the organization of the production of knowledge, after much experience in the production of manufactured goods (Antonelli, 2000a). Increasing shares of R&D activities are conducted within each company but find their economic application elsewhere either in plants operated abroad by multinational companies, in other firms with which arm's length transaction schemes have been implemented, or by independent firms which buy external knowledge (Gibbons, 1994). A large empirical evidence at the company level confirms that external knowledge is a key input in the process generating technological knowledge and, as a consequence, technological change and productivity growth: innovations now draw upon more technologies than before while each technology has to draw upon more science fields than before (Pavitt 1998; Arora and Gambardella 1990 and 1994).

Less empirical research is, on the contrary, available at the international level where, following the pioonering contribution of Coe and Helpman, 1995, the main focus has been the search for free knowledge spillovers from the stocks of research and development available in other countries. This paper moves away from this path of research following a more recent body of theoretical (Fujita et al. 1999) and empirical literature (Jaffe et al., 1993, Paci and Usai, 2000a and 2000b, Keller, 2000) who stress the localised character of technological change mainly in the geographical context. Here, however, we assume a more general concept of localisation.

In particular, we make use of the general notion of localised technological change, as defined in Antonelli (1999), to improve our understanding of economic growth at the national level. Traditionally, the literature on economic growth has overlooked the role of the exchange of technological knowledge as a potential growth factor because technology is not localised and appropriability conditions are rather poor (Mankiw, 1995). When, on the contrary, appropriability conditions are considered more robust and technological change becomes localised there is room for a market of technological knowledge at the international level which might potentially represent a growth factor. As a matter of fact, there is now a better understanding of the international dimension of disembodied technology trade. Specialization of countries and the international technological trade are two facets of the same coin, one where an international market for technological knowledge is being implemented and developed. According to data on the technological balance of payments international technological transactions have been growing faster than domestic expenditures in research and development activities since the early eighties. This growing trade in disembodied technology is increasingly horizontal in that it reflects the growing specialization of firms within countries and countries at large in limited technological fields.

The paper is structured as follows. Section 2 provides the general theoretical background on the nature of technological knowledge and summarizes the recent acquisitions about the localized character of technological knowledge. Section 3 gathers the empirical evidence; it provides descriptive evidence in the Italian case about the evolution of total factor productivity and focuses attention on the role of technology payments with respect to domestic research and development (R&D) expenditures. Explorative time series analysis conducted within a traditional growth accounting framework confirms that external knowledge, purchased on international technological markets, contributes in explaining the dynamics of domestic output growth. In the conclusion the general results are summarized and put in perspective.

2. The analytical background

The traditional view of technology, as information, is being increasingly challenged by recent developments of the Schumpeterian approach which stress the distinction between information and knowledge: the former is an input in the production of the latter. A growing number of authors, working in this tradition, have challenged the traditional view of technology as a pure public good, arguing that especially technological knowledge, as distinct from scientific knowledge, has a strong proprietary character. In fact it is largely excludable and its use is partly rival. In particular, technological knowledge tends to be localized in well-defined national, technical, institutional, regional and industrial situations, as a consequence it may develop specific to each country, industry, region, firm and individual or team of individuals and consequently costly to move and to use elsewhere[1]. The localized character of technological knowledge increases its appropriability and, as a result, reduces its spontaneous circulation in the economic system (Geroski, 1995). Each unit of technological knowledge can be created, used and exchanged only by means of specific competencies acquired by firms, now viewed as learning organizations, within a larger framework which includes a whole array of complementary and interrelated units of knowledge generated by other firms, universities and research institutions (Antonelli, 1999). The capability to innovate, consequently, appears to be strongly conditioned by both access to available technological information and learning opportunities, and by the accumulation of tacit knowledge both internal and external to each firm. Technological information, the competence of each firm and the technological communication conditions within technological and regional innovation systems represent the three basic inputs in the creation process of new knowledge. New technological knowledge is the result of a complex process of creation of new information building upon the mix of competence acquired by means of learning processes, the acquisition and recombination of external technological and formal internal R&D activities. External disembodied knowledge plays a major role in this setting. Such external knowledge contributes to the internal production of knowledge by means of the recombination of bits of technological information which are re-organized and applied to different settings than those originally conceived, and often implemented

[1] There has recently been a growing body of empirical literature on the stickiness of knowledge across firms and space, see for example Jaffe et al, 1993 for the United States and Paci and Usai (2000a) for the European regions.

with formal co-operation between firms with their own R&D laboratories or between firms and universities.

Rarely can new knowledge, even when it consists mainly of the results of scientific 'top-down' undertakings, be reduced to a simple set of instructions which can be acquired without any interaction with the first producers. Both codified and tacit technological knowledge can be acquired much more easily by means of direct and intimate relationships between researchers. Since technological knowledge tends to be highly specific and is embedded into the background and experience of each innovator and hence highly idiosyncratic, it is costly if not impossible to use elsewhere. As a result, communication conditions, as well as spatial and technological proximity, become very important. The transfer and adaptation of localized technological knowledge from one country, industry, region or firm to another involves specific costs which are affected by the quality and effectiveness of the communication channels within the innovation system and between innovation systems. External disembodied knowledge, in this approach, in order to be successfully assimilated and implemented, requires dedicated activities. External technological knowledge without dedicated user-producer relations is very expensive in order to be actually implemented: re-engineering costs may amount to a substantial share of the original research costs (Lundvall 1992; Cohen and Levinthal 1989, 1990). Because of its quasi-private character, technological knowledge can be traded and exchanged in market places, especially when implemented by an institutional set-up which makes the exchange reliable for both parties. Arm's length transactions implemented by long-terms contract, technological clubs, joint-ventures, equity-agreements, direct foreign investments, interlocking directorates can help the establishment of international markets for technological knowledge (Williamson 1985; Archibugi and Michie 1997).

As a result, technological knowledge can no longer be stylised only as an output: it is also an input in the generation of further knowledge. Two dimensions of technological knowledge as an input are relevant: knowledge externalities and rent (or pecuniary) externalities. The latter applies when customers can purchase bits of knowledge at lower costs; the former, instead, assumes that externalities are directly available to agents without any purposed effort. In the knowledge externality approach, knowledge generated by each firm or country cannot be fully appropriated by the innovator and therefore 'spills' into the environment and generates important externalities. Other innovators can take advantage of the knowledge available in the economic environment without any specific market transaction: no exchange takes place and technology transfer is realized without any contractual interaction and no prices are actually paid. Clearly the analyses of such knowledge externalities are consistent and coherent with the Arrovian tradition of analysis of technological knowledge. The implicit assumption is in fact that knowledge externalities apply because of the public good nature of technological knowledge, its low levels of appropriability and non-excludability and durability. This approach provides the basic theoretical framework for the empirical analyses recently extended to the international counterparts of technological spillovers (Park 1995; Coe and Helpman 1995; Engelbrecht 1997; Frantzen 1998 among others). Such empirical analyses try to measure the effects of the technological knowledge generated elsewhere on the evolution of technological change and productivity experienced by each country. Traditionally this approach consists of a growth accounting exercise on a cross-section of countries, where the stock of R&D expenditures in the rest of the world are related to the output growth of any single country together with its domestic R&D expenditures. Along this line of empirical analysis the main focus has been the search for the proper 'filter' to apply in order to evaluate the correct amount of technological knowledge spilling. Following the pioonering contribution of Coe and Helpman (1995), flows of trade have been generally considered a reliable indicator of the exposure and commercial proximity of each country to the technological opportunities generated by each other country.

A more technology-aware effort has been recently made by Verspagen (1997) which attempts to estimate the actual effects of knowledge spillovers using a notion of technological proximity based upon technology flows matrices. In this direction another interesting work is that of Marchionatti and Usai (1998) who use imported capital goods to weight foreign R&D expenditure in their attempt to capture the effects of external technological change on Italy's growth and to study their dynamics in the postwar period. Finally, another relevant recent contribution is Keller (2000), who investigates whether knowledge spillovers are global or local using the methodology developed for regional analysis (Jaffe et al., 1993) in the international context as in Coe and Helpman (1995). Results show that there are strong localisation effects in determining the availability of technological knowledge across different countries.

All in all, it is clear that the current empirical approach is mainly referred to knowledge technological externalities where, with the exception of Marchionatti and Usai (1998), no active behaviour by economic agents is assumed. In this latter work, as a matter of fact, there is an explicit interaction which allow customers to acquire, on the one hand, some embodied technological knowledge through the purchase of capital goods; and, on the other hand, some more tacit disembodied knowledge through the contact with their producers. Following this work, and in the light of the empirical evidence which shows the increasing flows of transactions in disembodied technologies, in this paper we test empirically if next to knowledge externalities there appear important rent externalities. Such externalities being the result of opportunities for reflective customers to actually purchase disembodied technological knowledge at costs that are presumably lower than those of internal production and with important positive effects in terms of the general efficiency of the knowledge-generation-process.

According to our line of analysis, we clearly presume that such rent externalities matter and, likely, more relevant than knowledge externalities: technological information does not necessarily flow automatically within economic systems but requires the understanding and application of specific knowledge. The active participation of sellers and customers is required: the assistance of sellers is often necessary. The purchase of technological knowledge from third parties and the related technological outsourcing and technological specialization which technological trade makes it possible, have clearly positive effects in terms of the general efficiency of the innovative process: firms can concentrate on the limited technological fields where they have relevant competence and rely upon external knowledge for complementary technologies. Reduction of redundancies and duplications are also positive outcomes of the new opportunities for technological specialization engendered by the new international trade in technological knowledge (Nelson, 1987).

Obviously the relative importance of these two different externalities in channeling external knowledge may be different depending on several factors, such as the conditions of communication, the relative distance -in both the technological and the geographical space- between firms or countries, the type of technological knowledge and others. In this perspective, for example, we believe that knowledge externalities are more likely to arise in the relationship between developed and developing countries, where the spillovers mainly concern already established knowledge. In this setting standard cross-countries studies are appropriate. On the contrary, among developed countries, it is more sensible that special efforts are made to establish and reinforce appropriability on new technological knowledge for obvious competitive reasons. This implies that specific markets for technological knowledge develop quite naturally among developed countries where parallel to goods trade, exchange of such a knowledge takes place. In this setting, countries' relative specialisation and their institutional structure as well as their history (path dependence) become relevant and time series analyses applied to single countries may be preferable.

Consequently, based on the considerations above, instead of a cross-countries study, we prefer to focus on a single country in order to examine, with a certain detail, the characteristics of its relationships with other countries in terms of knowledge and rent externalities. Following Marchionatti and Usai (1998), we consider the Italian economic postwar experience as an interesting paradigmatic case to study the influence of external knowledge on a country typically defined as an imitator in a setting which involves mainly developed economies. Formally, according to the hypotheses put forward above, this implies to focus on the estimation of a time-series aggregate production function specified as follows

$$Y = f(K, L, LTK)$$

where Y is the aggregate output of the country under study, K is the real stock of physical capital, L represents the labor inputs and LTK is the localized technological knowledge produced in the country under exam. Accordingly LTK can be specified as

$$LTK = g(R\&D\&L, EK)$$

where R&D&L are the resources invested in learning and R&D activities in the same country; whilst EK is the amount of external knowledge acquired from other countries. The innovative output LTK is, therefore, generated by the interaction between intramural resources allocated to research and learning and the external knowledge flows.

In conclusion, the actual levels of output a country is able to generate, under the standard control of the levels of the stocks of physical capital and labor, should depend upon both the levels of domestic expenditures in research, development and learning activities and the amount of knowledge from abroad. These arguments enable us to specify a production function as follows

$$Y = f(K, L, R\&D\&L, EK)$$

3. Empirical evidence

3.1. The international technology markets

The empirical literature on international technological spillovers, as we said above, has mainly focussed on flows of knowledge which are somewhat embodied in different means, such as manufacture, intermediate or capital goods. In this paper, on the contrary, we shift the attention towards those flows of knowledge which are disembodied and therefore mainly exchanged in specific markets. Fortunately, recent statistical work by OECD and other national statistical institutes has made available an interesting and reliable body of time-series data on international transactions in disembodied technological knowledge. The technological balance of payments is built upon the records on international technological transactions in terms of technology payments and technology receipts among a large number of advanced countries. It includes all the payments that are recorded by the balance of payments for technology transactions such as the purchase of patents, licensing agreements and related royalties, access to know-how and technical assistance [2].

According to such data, international markets for disembodied technology are growing very fast: through the eighties international transactions in technological knowledge have been growing faster than domestic expenditures in research and development activities. Data show that technology payments (TP) represent a significant and increasing share of total expenditures to acquire and implement technological knowledge and have

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[2] Much empirical analyses have shown that the flows of technology payments are influenced by the stock of foreign direct investment in each country: multinational companies use such transactions to repratriate their cash-flows (Balcet, 1990). Multinational companies however can be considered, in turn, effective channels of technological communication which are especially necessary for transactions of technological know how which can be appropriated only to a limited extent.

nowadays an order of magnitude which is coming close to that of the expenses in research and development activities of the business sector (BERD) in most countries. The analysis of the evolution since 1969 of TP with respect to R&D expenditures (figure 1) and to gross national product (figure 2) provides some interesting stylised facts which deserve some comments.

In Germany, for example, the ratio of TP to BERD has been rather stable over fifteen years around 15% and afterwards steadily increasing through the eighties and nineties up to around 40% in 1997. In the United Kingdom after many years floating around 15% this ratio is now clearly above 20%. More importantly, in the thirty years considered the relative importance of technological payments for the United States have increased sevenfold from 1% to 7% in 1997. France has remained stable around a 15% ratio.[3] In countries with lower levels of R&D expenditure intensity the ratio of TP to BERD has followed different paths. In Italy, for instance, it has gone initially downwards (from 70% in 1969) to a minimum level of 16% in the late eighties but it is now recovering its previous levels and it has stabilized around 25%. Canada has been in the vicinity of 30% for ten years and it is now oscillating around 19%.[4] Finally Japan, once a strong importer of foreign technology, has reduced the ratio of TP to BERD from a maximum of 17% in 1972 to a stable quota of 4% in the nineties due most of all to a strong expansion of R&D expenditure throughout the decades under examination.

The analysis of the evolution of this indicator since the late eighties suggests that in many traditional R&D intensive countries, such as the United Kingdom, Germany, the United States, a clear trend towards an increasing use of external knowledge has been

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[3] As for other countries, outside the G7 group we may remember Netherlands which exhibit a strong increase from 42% in 1981 to almost 200% in 1992 and Belgium which shows an increasing trend fetching 125% in 1994 from the 72% levels of 1981.

[4] Another interesting case of country which is definitely reducing its dependence upon external knowledge is Spain which has gone from 300% in 1969 to around 50% in the early nineties.

taking place. On the contrary, in less research-intensive countries we see a negative trend in the ratio of TP to BERD. The general outcome is a sharp reduction in the variance across advanced countries with some signal of convergence towards a quota of TP to BERD around 20%. This trend seems to be the result of two different evolutions. Most advanced countries have at the same time reduced their effort in domestic research and development expenditures and increased their purchase of foreign disembodied technology. In the United States the ratio of BERD to GNP has moved around 2% over this periods, while the ratio of TP to GNP increase from 0.2% to 1.4% (see figure 3). In the United Kingdom the share of BERD to gross national product declines from a top 1.6% in 1986 to less than 1.3% in 1996 while, in the same time span, the share of technology payments to national gross revenue increases from 0.2% to 0.3%[5]. In Germany the ratio of BERD to GNP reaches the top in 1988 with the high of 2.1% and then declines to 1.5% in 1997 while the ratio of TP to GNP increases from 0.2% to 0.5%. In Italy BERD over GNP has significantly increased over the years up to a maximum of 0.7% in 1993 and it is now around 0.5%, whilst TP over GNP has gone up and down but it is now stable just below 0.2 (but it was 0.1 only ten years before).

These data suggest that a significant reorganization of the general structure of innovative efforts has been taking place through the years: firms in advanced countries have reduced their domestic expenditures and increased their purchase of disembodied technological knowledge. Recombination of domestic and international knowledge has been becoming a common practice. The purchase of foreign technological knowledge is no longer just a sign of technological dependence and backwardness, but on the opposite, an indicator of spreading technological specialization. This analysis of the magnitude of the

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[5] In the Netherlands the share of BERD to GNP declines from 1.3% in 1986 to 1% in 1994 while the ratio of TP to GNP increases from 1% in 1986 to 1.9% in 1992

flows of resources paid by advanced countries to purchase foreign technology confirms that they should be considered an essential component, together with BERD, of the total amount of resources invested by each country in the generation of new technological knowledge. The ratio of TP to BERD in this respect seems far more interesting than the traditional focus upon the so-called 'coverage rate' i.e. the ratio of payments to receipts of the technological balance of payments.

However, we should point out that there is not just a single story to be told and that there have been different modes and examples of recombination of internal and external knowledge. Path dependence and different institutional settings may be of some relevance. This is what can be inferred by looking at the cases of Germany and Japan, both successful imitators but now following diverging paths in the acquisition of technological knowledge via international markets. Italy is also a peculiar case given that after many years of decline from the peak of 70%, the ratio of TP over BERD has grown again and it is now stable at around 25%, implying that the dependence from external knowledge is a long-run relationship.

The integration of the payments for the procurement of external knowledge, at the firm as well as the aggregate levels, into the total amount of resources invested in the search for new technological knowledge could help understanding the substantial gap in the growth accounting of technological change. The econometric evidence suggests in fact that a major inconsistency exists between inputs and outputs that is invested in the generation of technological knowledge and their return in terms of output growth. In the following section we try to address this issue by starting exploring the Italian evidence.

3.2. The Italian evidence

According to the analysis above, our basic hypothesis is that the correct measure of the efforts countries make to generate new technological knowledge should take into account also the active procurement of disembodied technological knowledge from foreign producers. Marchionatti and Usai (1998) move in this direction by using the imports of investment goods in order to filter potential foreign spillovers emerging from other countries' research and development expenditure. In that case, there is an active conduct by customers and a contact between the customers and producers, even though no attempt is made to focus, more explicitly, on the role of disembodied technology acquired through technological markets. Moreover, due to lack of long time series, they concentrate on the short run analysis, whilst here we try to unravel the long run relationships between growth and localised technological change represented by internal and external knowledge.

For this purpose an excellent data set has been built for Italy with a long time series for the technology balance of payments records. Data for technology payments are in fact available in Italy since 1963 through 1997, as well as data for business enterprises research and development expenditures. Together with standard data provided by national accounts on the figures for fixed capital, employment and gross national product they provide a 34 year long time-series.

Our purpose, as we said above, is to estimate the long run relationship between economic growth and localised technological change[6]. However, instead of estimating directly equation (3) [7], we make use of the controversial concept of total factor productivity [8]. This choice is motivated on two grounds. Firstly, on a technical ground, this allows to save degrees of freedom in a estimation setting, that of cointegration, where 34 observations

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6 A previous explorative investigation on this issue within panel of countries can be found in Antonelli (2000a).

7 As a matter of fact, in Marchionatti and Usai (1998) the whole production function is estimated in order to get direct estimates for the labour and capital coefficients. However, that procedure was possible due to the fact that they focus on the short run relationship by looking at first difference.

8 For an interesting revisitation of the debate on TFP see Hulten (2000).

are considered just sufficient. Secondly, despite TFP is a measure of our ignorance, and therefore subject to serious measurement errors, it proves also a simple and internally consistent intellectual framework for organizing data on economic growth (Hulten, 2000) which, for this reason, is commonly used in the literature. It is, in other words, a useful tool in order to ensure the comparability of our study to others in the same area.

In conclusion, our estimation exercise consists of regressing total factor productivity (TFP) on domestic investment either in learning and R&D activities or in external knowledge once we have controlled for the relative distance between the economy under study (Italy) and the country which is unanimously considered at the frontier of technological change (USA). Basically, the equation to be estimated, expressed in logarithms, is as follows:

$$(4)\ TFP = \beta_1 + \beta_2\ RD + \beta_3\ EK + \beta_4\ GAP$$

where RD is the gross expenditure on research and development, EK represents the external knowledge acquired from abroad[9] and GAP is a measure of technological distance proxied by the ratio of GDP per capita of Italy with respect to United States (expressed in 1990 dollars).

There are some data issues to be discussed. First, external knowledge can be proxied by different phenomena. Here, following the empirical literature started by Coe and Helpman (1995) we use the measures already used in Marchionatti and Usai (1998), that is the sum of external R&D in the major industrialised countries (G7) and the imports of investment goods. Moreover, we introduce a new measure, that is the payments of disembodied knowledge in the international markets and registered in the technological balance of payments. Secondly, as regards the TFP,

[9] It should be noted that both series have been deflated by means of a specific deflator constructed as a weighted average of the variation of the price of investment goods and of the salary in the manufacturing sector.

our estimation design consists in the construction of two measures of TFP, that is the Solow residual, based on different hypotheses about the relative importance of capital (measured by the factor share in either costs or revenue) in the typical Cobb-Douglas production function. Following Ardeni (1993), we assign α two possible values: 0.5 and 0.3 [10]. This should provide a basic test for the robustness of our result with respect to different TFP measures.

Table 1 shows some simple statistics on growth accounting for five year periods from 1960. Growth rates of GDP are reported in the first column, TFP growth rates according to the suggested values for α are in the following two columns and finally in the last two columns there appear the quotas of GDP explained by the variation of production factors. According to this simple accounting exercise, we can conclude that on average labour and capital have been able to explain about 3/4 of GDP growth. More interestingly this explanatory power has been variable through the years from 48% in the early nineties to 85% in the early eighties (taking α=0.3). Results are similar for α=0.5[11]. As a matter of fact, on average the best account of growth by means of the usual factors of production, that is labour and capital, is given when α is equal 0.3 and the average amount of explained growth over the whole period under study is 70%. The table below, however, seems to indicate that the relative importance of labour and capital has varied through the years even though without a regular trend. Note, for example, that in two periods (in 1971-75 and in 1981-85) the highest quota of explained growth, that is the lowest TFP growth rate, is attributed to the specification with α=0.5 while in

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10 Other direct estimates of capital and labour coefficients are given by Mattana (1997).

11 Other values for α (such as 0.6 and 0.7) have been implemented in order to see if the TFP was anyhow lower but the quota of explained growth declined intensely in all the periods under exam.

all the other periods the lowest TFP growth rate is attributed to α=0.3.[12]

Table 1. Italian growth accounting

	gdp growth rate	explained growth		explained growth	
		alpha=0.3	alpha=0.5	alpha=0.3	alpha=0.5
1960-65	5.22%	1.93%	2.01%	63.0%	61.5%
1966-70	6.22%	2.17%	2.86%	65.2%	54.0%
1971-75	2.78%	0.50%	0.17%	82.0%	94.0%
1976-80	4.46%	1.18%	1.68%	73.6%	62.5%
1981-85	1.51%	0.22%	0.04%	85.2%	97.3%
1986-90	2.97%	0.72%	0.99%	75.9%	66.8%
1991-95	1.16%	0.59%	0.62%	48.8%	46.6%
1996-98	1.67%	0.42%	0.58%	74.6%	65.4%

Because the series exhibit clear trends, we should estimate only equations which are cointegrated in order to avoid serious problems in the correct interpretation of parameters (spurious relationships, inconsistency and so on). Such equations have interesting statistical properties: estimated parameters are superconsistent. Once we have established that a cointegrated relationship exists this is interpreted as long run relationship between the variables and we can build on this result by estimating an Error Correction Model (ECM) which allows to analyse both short and long run dynamics. The ECM to be estimated in this case is as follows:

$$(5)\ \Delta TFP_t = \chi_1 + \chi_2\, \Delta RD_{\tau-1} + \chi_3\, \Delta EK_{\tau-1} + \chi_4\, \Delta GAP_{\tau-1} + \chi_5\, \Delta TFP_{\tau-1} + \chi_6\, RES_{\iota\,\tau-1}$$

where Δ indicates the first difference and RES_ι stands for the residual of the corresponding cointegration equations individuated by means of the cointegration test. The model above allows to

[12] This result is similar to Ardeni (1993)

take account of the delayed response implied by the lagged dependent variable, and of the speed of convergence towards equilibrium represented by the coefficient of RES, if significant and negative[13]. A general to specific procedure can be applied in order to have a parsimonious specification and, nevertheless, a clear idea of the dynamics properties of the phenomenon under scrutiny. This is particularly important in our case given that we have few degrees of freedom and that multicollinearity is likely. That is also why we do not specify the model with other lags other than one.

The implementation of the cointegration estimation procedure implies the preliminary evaluation of the stationarity of the series under exam through standard unit root tests suggested by Dickey and Fueller and Philips and Perron in order to test for their robustness given the small sample under exam[14]. Results confirm that data are non stationary and they become stationary in first difference, that is they are integrated of order one. This allows to implement Johansen's methodology in order to determine whether our I(1) series are cointegrated and, if they are, to identify the number and the nature of the cointegrating (long run equilibrium) relationships.

The results for the cointegration test for the two types of TFP ($TFP_{\alpha=0.3}$, $TFP_{\alpha=0.5}$) and the three proxies for external knowledge (technology payments, external R&D expenditures and imports of investment goods) are reported in table 2.

13 It should be also noted that an important by-product of the ECM is a simple framework for causality tests. We can easily distinguish between endogenous and weakly exogenous series, in order to exclude the possible presence of reverse causation.

14 The Augmented Dickey-Fueller test is not very powerful for small samples (such as our sample which consists of 33 observations)

Table 2 Johansen Cointegration test

		L.R. (H0=none coint. eq.)	L.R: (H0=at most one coint. eq.)	L.R. (H0=at most two coint. eq.'s)
technology	$TFP_{\alpha=0.3}$	67.88**	39.95*	16.86
payments	$TFP_{\alpha=0.5}$	64.67**	37.80*	17.48
external R&D	$TFP_{\alpha=0.3}$	85.5**	54.08**	30.21**
	$TFP_{\alpha=0.5}$	83.51**	50.54**	29.05**
imports of	$TFP_{\alpha=0.3}$	60.15*	29.43	10.96
investiment goods	$TFP_{\alpha=0.5}$	55.68*	25.8	10.89

** (*) denotes rejection of the hypothesis at the 1% (5%) significance level*

Likelihood ratio (L.R.) test indicates that for the regressions with technological payments there are two cointegration equations at the 5% level and one at the 1% level, for the ones with external R&D there are more than two equations at the 1% level and finally for the test with imports of investment goods as a proxy for external knowledge we get that there is just one equilibrium at the 5% level.

The next step is to estimate the error correction model with either one or two or more cointegrating equations. Results are not independent both on the proxy for external knowledge used and on the number of cointegration equations inserted. The most important result is that both the external R&D and the imports of investment goods do never get a significant coefficient. The imports of investment goods also show the wrong sign in the cointegrating equation[15]. On the contrary, technology payments have the right sign and a significant coefficient but only when one cointegration equation is taken into account.

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15 Similar results are obtained if we insert the interactive variable composed of external R&D multiplied by imports of investment goods as in Marchionatti and Usai (1998)

Table 3, therefore, shows the results of estimation only for the specification of ECM with EK proxied by technological payments and with one cointegrating equation, also because in the specification with two cointegrating equations, the corresponding residuals have never proved significant.

Table 3. Error correction model results

Included observations: 32		
Dependent Variable	Ä($TFP_{0.3}$)	Ä($TFP_{0.5}$)
Cointegration equation		
(GAP(-1))	-0.76	-1.15
	6.27	*15.6*
LOG(EK(-1))	0.07	0.05
	2.39	*2.43*
LOG(RD(-1))	0.06	0.05
	2.00	*2.25*
RES	-0.20	-0.06
	-4.17	*-0.39*
Ä (TFPα(-1))	0.60	0.66
	5.32	*3.22*
Ä (GAP(-1))	0.31	0.54
	3.73	*3.13*
Ä LOG(EK(-1))		0.03
		1.52
DLOG(RD(-1))	0.04	0.11
	1.29	*1.89*
R-squared	0.43	0.19
Adjusted R-squared	0.37	0.07
Log likelihood	108.72	83.99
Durbin-Watson stat	2.12	1.95

Note: t-statistics in italics

Let us start commenting results on the cointegration-equilibrium relationship. Most of TFP variation is explained by GAP which has a negative and significant coefficient which goes from -0.76 to -1.15. The role of internal and external knowledge is proved important and rather stable. The elasticity is always around 0.5 for both indicators and it is always significant.

As for the ECM, we have that the cointegration equation, represented by its residual, is always negative but it is significant only in the first specification, when it is equal 0.2. Notably it is particularly significant in the specification with $TFP_{\alpha=0.3}$. Moreover, the lagged value of the first difference of the dependent variable and of the GAP are always positive and significant. As for internal and external knowledge they are always positive but not very robust: the former proves significant only in the specification with $TFP_{\alpha=0.5}$ whilst the latter never proves significant.

In conclusion, explorative cointegration analysis shows that in the Italian case disembodied knowledge acquired on international technology markets has played a role, apparently as important as that of internal R&D expenditure, on the global long run economic performance. On the contrary, external R&D and imports of investment goods do not prove to have such a role in long run growth[16]. As we have already said, this result should be interpreted as a signal that there is more to be discovered in the relationship between economic growth and disembodied techonological knowledge purchased in international markets. In particular, it should be taken as an encouraging preliminary exercise which should be followed by further tests which should attempt to prove the robustness of these results in two main direction. The former follows Verspagen (1995) in trying to look for a better specification of the production function taking into account for sectoral differences and consequently of different technological and production associations in a input-output framework. The latter should attempt to follow Keller (2000) and Paci and Usai (2000 b) in assessing the role of spatial proximity in directing and facilitating both knowledge and rent externalities.

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16 In Marchionatti and Usai, the interactive variable of external R&D multiplied by imports of investment goods (or of machinery) proved to have a significant short run elasticity in global production function even though this was especially true until the eighties.

Unfortunately data for this kind of analysis are very difficult to be collected.

4. Conclusions

Technological knowledge is in reality far more embedded and localized than currently assumed in the Arrovian tradition. International technological outsourcing is becoming an important source of new technological knowledge. Much recent empirical evidence has focused attention on international R&D spillovers as if countries could benefit from foreign R&D activities without actually purchasing technological knowledge and without any actual participation of sellers in the technological transfer. However, we believe that knowledge externalities can take place successfully if both parties, vendors and customers, are actively involved and an actual transaction takes place. International (as well domestic) markets for disembodied technological knowledge are also emerging for the diffusion of new information and communication technologies and the related changes in the organization of the production of knowledge. The international specialization of countries and the international technological trade are two facets of the same coin, one where an international market for technological knowledge is being implemented and developed. This international evidence is complemented by a large empirical evidence at the company level which confirms that external knowledge is becoming a key input in the process generating technological knowledge and eventually technological change and productivity growth . This dynamics can be considered a part of a broader process where the generation of technological knowledge is itself becoming closer to the production of goods. Exchange of technological knowledge takes part because the conditions for appropriability are now far better that currently assumed by a large traditional literature. This evidence requires a theoretical assessment and provides the background to appreciate empirically the role of external knowledge in growth accounting.

The empirical analysis conducted within a traditional growth accounting framework provides preliminary confirmation that external disembodied knowledge, purchased on international technological markets, plays a role in TFP growth in the Italian economy. Italian firms have been able to take advantage of the opportunity offered by new emerging international markets for technological knowledge to complement their internal R&D expenditures and recombine external disembodied knowledge with internal competence and formal research activities. The supply of external knowledge clearly makes it possible to acquire inputs at lower costs than those generated internally. Technological outsourcing from firms specializing in the provision of technological knowledge as well as from other 'industrial' firms willing to sell disembodied knowledge can become an important source of technological knowledge and thus adds to the general efficiency of the generation of new knowledge. Internal R&D activities remain clearly critical for the absorption of external knowledge: the relationship between internal and external knowledge has a strong complementary character which should be investigated more carefully. At the same time more investigation is needed to qualify the relationship under examination both in the technological space (Verspagen, 1997) and in the geographical space (Keller, 2000).

A new framework with important policy implications becomes evident in conclusion. Until now, the economic importance of formal intra-muros R&D conducted by firms and scientific activities conducted by universities, as the unique and single input into the generation of technological knowledge has been exaggerated. As a consequence too much emphasis has been put upon R&D policies and more generally science policies as the basic tools to sustain the rates of accumulation of new knowledge. In the generation of new technological innovations, firms rely more and more on technological communication which is conducive to the acquisition of external knowledge by means of formal interactions between themselves, sharing learning opportunities and experience, and with other established sources of knowledge. Outsourcing of research activities and the procurement of knowledge intensive business services plays an increasing role in assessing the innovative capabilities of each firm. The levels of technological procurement from other 'industrial' firms and the outsourcing of knowledge intensive business services should be accounted for when assessing the actual amount of inputs invested in the process of research and learning. The procurement of technological knowledge from third parties, both at the international level and within countries, is an important component of the general process of accumulation of new knowledge.

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