



# Determinants of long-run regional productivity with geographical spillovers: The role of R&D, human capital and public infrastructure<sup>☆</sup>

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## ABSTRACT

In this paper we estimate the long-run relationship between total factor productivity, R&D, human capital and public infrastructure between 1980 and 2001 across Italian regions. We take advantage of recent developments of panel cointegration techniques that control for endogeneity of regressors to estimate cointegration vectors. Empirical evidence shows that there exists a long-run equilibrium between productivity level and the three kinds of capital; among them, human capital turns out to have the strongest impact on productivity. Regional productivity is found also to be positively affected by R&D activity and public infrastructure of neighboring regions. Finally, results of the Granger-causality tests support the hypothesis that human capital and infrastructure Granger-cause productivity in the long-run while the opposite is not true; only for R&D stock is the bi-directional causality found.

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## 1. Introduction

It is widely known that the Italian economy is affected by strong territorial disparities. GDP per capita in the South is around 60% of that in the Centre and North, labor productivity is about 80%. Even though during the last decade the economic gap between the two areas has narrowed slightly, differences in standards of living among Italian regions remain profound. In the face of this evidence, it is understandable why regional growth is still at the centre of empirical research, and how reducing regional disparities remains a central

question in Italian economic policy. The persistence of geographical disparities in Italy motivated also this paper that investigates further the determinants of regional productivity.

There is a broad consensus among economists, favored by the flourishing endogenous growth theories, that research and development (R&D) and human capital are two of the most influential forces capable of boosting productivity (Romer, 1990; Lucas, 1988). The link between productivity and R&D stock has been investigated in several empirical studies since Coe and Helpman's (1995) seminal paper (see e.g. van Pottelsberghe de la Potterie and Lichtenberg, 2001; Frantzen, 2002). This essential framework has been extended by including human capital in the empirical setting (Coe et al., 1997; Engelbrecht, 1997, among others). On the other hand, a different strand of research has also pointed out that public infrastructure can play a central role in promoting economic growth, since it raises the availability of resources and enhances the productivity of existing ones (see e.g. Aschauer, 1989; Fernald, 1999; Destefanis and Sena, 2005).

Despite the fact that the literature on growth determinants encompasses a large body of studies there has been no empirical research that assesses the role of these three productivity sources together. If all these factors affect productivity and interact with each other, their contribution can be properly measured only within a unified framework. If one of the relevant inputs is omitted,

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estimations of elasticity of the other factors are bound to be biased (Frantzen, 2000).

In this paper we try to fill this gap. We assess the role of the technological knowledge, as measured by the stock of R&D capital, the human capital, and the stock of public infrastructure, in enhancing the Total Factor Productivity (TFP) of Italian regions over the period 1980–2001. Our contribution to empirical literature on regional growth lies also in the investigation of geographical spillovers. Given the small scale of our territorial units we consider the interplays among regions potentially relevant, thus we test whether, and to what extent, the factors enhancing productivity in one region can also affect the productivity in the neighboring regions. We hope that our analysis, ranking the forces according to their relative importance in driving regional productivity, can provide some useful insights to design regional policies attempting to narrow territorial gaps.

Unlike the majority of empirical models, we focus on the level of the variables instead of on growth rates. As Hall and Jones (1999) have argued, the investigation of the level may be a more natural research question since differences in the level of productivity or income reflect differences in welfare, and growth rates are studied only for their effect on the level of variables. In addition, by estimating models in growth rates information on the relationships between the levels of the variables are lost. However, the estimation of a model in which the variables are in level poses the well-known problem of spurious regression if the variables are  $I(1)$  and are not cointegrated. We handle this question by taking advantage of the recent panel cointegration techniques, that allow us to explore long-run relations controlling for omitted or unobservable factors through time and regional fixed effects. Moreover, as Temple (1999) pointed out, endogeneity of the regressors and reverse causality can bias the results of the econometric estimates of growth models such as ours. In order to deal with these issues we use an appropriate estimator that controls for endogeneity of the regressors as well as for autocorrelation of the error term (Pedroni, 1996, 2000). Next, we carry out Granger-causality tests in the error correction models to verify both the long and the short-run causality.

With respect to the majority of similar works based on panels of countries, this paper takes advantage of the sub-national perspective that reduces the weakness of cross-country analyses, plagued by the scant cross-country comparability of data on education systems, R&D expenditures and infrastructure.

Results show that there exists a long-run equilibrium between the productivity level and the three kinds of capital; among them, human capital turns out to have the strongest impact on TFP. Regional productivity is found to be positively affected also by R&D activity and the public infrastructure of neighboring regions. Finally, results of the Granger-causality tests support the hypothesis that human capital and public capital cause productivity in the long run while the opposite is not true; only for R&D capital stock is the bi-directional causality found.

The remainder of the paper is organized as follows. In the second section we discuss the theoretical background and the related empirical literature. In the third and fourth sections we present the empirical model and the econometric strategy. The results of the econometric exercises are reported in section five, while some extensions, together with the robustness checks and some summarizing remarks, are discussed in the final two sections.

## 2. Theoretical framework and related literature

### 2.1. R&D, human capital and productivity

Influential developments in theoretical endogenous growth models have emphasized the key role of R&D efforts in driving technical progress and productivity (Romer 1990; Grossman and Helpman, 1991). The rationale is that technological knowledge, created and accumulated through R&D activity, enhances the production and diffusion of

innovations, and then promotes productivity growth. A vast literature spurred by the work of Coe and Helpman (1995), mostly focused on cross-country data, has empirically demonstrated the positive impact of R&D on productivity; see among others: Coe et al. (1997), Xu and Wang (1999), van Pottelsberghe de la Potterie and Lichtenberg (2001), Frantzen (2002).

In this paper we transpose this theoretical approach to a regional context. It is worth noting that using a regional setting is not simply a change of geographical scale. By testing if regional R&D is important to explain regional growth we are implicitly assuming that technological knowledge has a localized scope. We consider this a plausible hypothesis. Proximity can encourage the circulation of ideas and the transmission of information and learning, thanks to face-to-face contacts and social interaction. Moreover, the role of proximity becomes crucial when the knowledge is tacit and so non-codifiable. A wide range of theoretical and empirical studies on localized learning have demonstrated that geographical proximity matters in transmitting knowledge (for a review see: Audretsch and Feldman, 2005). In this paper we share the same view. We assume knowledge has a regional dimension and, to take account of potential spatial (inter-regional) spillovers, we also assess whether regional productivity is affected by knowledge accumulated in proximate regions, assuming that the greater the distance between regions, the smaller the spillovers will be. From the policy view this has an important policy implication. If learning has a localized scope, the location of public or private research centers will impact on local development. On the other hand, if geographical spillovers have a substantial role the benefits of investment in R&D will spread across regions and the choice of location of R&D activities will have only a marginal influence on regional disparities. Therefore, policy-makers should take this aspect into account in designing regional development policies.

Another primary source of economic growth emphasized by the literature is human capital (see e.g. Lucas, 1988; Stokey, 1991). It is argued that the level of education drives growth because it increases the ability to adapt and implement existing technology or to create new technologies. Subsequent theoretical analyses have emphasized the strategic complementarities between human capital and R&D activities. Redding (1996), for instance, builds a model in which investment in human capital made by workers and R&D efforts made by firms are complementary and interdependent, so that they jointly determine the growth equilibrium. In this vein, several empirical papers have placed human capital next to R&D as an explanatory variable of productivity, to avoid omitted variables bias and to measure its impact on growth (see Coe et al., 1997; Engelbrecht, 1997, 2002; Xu and Wang, 1999; Frantzen, 2000; Crispolti and Marconi, 2005, among others). We follow this stream of research and assume that human capital is an additional factor able to affect regional total factor productivity.<sup>1</sup>

### 2.2. Public infrastructure and productivity

Economists and policy-makers have pointed to public sector infrastructure as a fundamental element in the strategy of regional development policies. They claim that infrastructure provides valuable facilities to private sectors, increasing the availability of resources and contemporaneously improving the productivity of existing ones (Munnell, 1992). For example, the construction of a new highway can reduce transport costs by lowering shipping times and the use of vehicles; similar arguments apply also to water systems, electricity or other public capital goods. Public capital may also affect growth indirectly, since by raising the rate of return to private capital it can stimulate private investment expenditure. Theoretical models that describe the productivity-infrastructure link include Arrow and Kurtz

<sup>1</sup> An alternative way to take human capital into account would be to consider it as an augmenting factor of labor productivity, as in Bils and Klenow (2000). We test for this specification in the robustness section.

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