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Regional Growth with Spatial Dependence: a Case Study on Early Italian Industrialization

Carlo Ciccarelli* and Stefano Fachin**

Abstract

This paper estimates a conditional β-convergence model of labor productivity growth in Italy's manufacturing industry during 1871-1911, accounting for spatial dependence. The empirical evidence is based on a recent set of data at provincial (NUTS 3) level on manufacturing value added at 1911 prices, and a new set of data on human and social capital, political participation, and infrastructures. By focusing on a country and a time when the agglomeration forces and spillover effects advocated by the new economic geography were only starting to operate, we can investigate a particularly interesting case study. Our results suggest that human capital, a cooperative culture, and initial productivity in neighboring provinces can explain much of the geographical variability of productivity growth in manufacturing in nineteenth-century Italy.

JEL Classifications: R11, O47, N64
Keywords: β-convergence, manufacturing, nineteenth-century, Italy, spatial dependence, labor productivity, human capital

Contents

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1. Introduction[1]

Nineteenth century Italy, as other European countries of the time, was a backward country. It was so in many dimensions. It was just moving its first steps away from agriculture to industry, and it was characterized by particularly high illiteracy rates, especially so in Southern regions. Furthermore, crucial infrastructures, such as the railroad network, were still under construction. Still, in the decades following the unification of the country in 1861 the size and composition of the Italian manufacturing system changed considerably, as production gradually moved away from traditional activities of artisanal nature to large modern industrial plants.[2] The related mechanization of production processes fostered substantially increases in productivity, and ultimately economic growth.

In the light of the above background, this paper's aim is precisely to shed some light on the growth of labor productivity in the Italian manufacturing industry over the period 1871-1911. To this end, we estimate conditional β-convergence models for labor productivity using a recent dataset on manufacturing value added at 1911 prices at provincial (NUTS 3) level.[3] The empirical analysis is in particular enriched by a new set of control variables including human and social capital, political participation, and infrastructures. The focus on the manufacturing industry is motivated by two main reasons. The first is that despite the predominant share of agriculture on GDP in 19th century Italy, development patterns are clearly better visible in the more dynamic sectors of the economy. The second is that recent contributions (Rodrik 2011; 2013) show that the small share of manufacturing employment in low-income countries, and the slow pace of industrialization is the main reason behind the lack of (unconditional) convergence in GDP often found in the literature. By focusing on manufacturing, instead, there is robust evidence of (unconditional) convergence.[4] In this framework, the case of Italy is of particular interest in that it represents one of the few countries for which extremely detailed historical statistical reconstruction on the manufacturing industry at the regional and provincial level (essentially NUTS 2 and NUTS 3 level) are available (see Ciccarelli 2015, for a review). Further, by focusing on a country and a time when the agglomeration forces and spillover effects advocated by the new economic geography (NEG) literature (e.g., Fujita, Krugman and Venables 1999) were only starting to operate, we can investigate a particularly interesting case study.

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[1] This a completely revised version of a paper previously circulated under the title "Industrial growth and spatial spillovers in 19th century Italy". We thank Brian A'Hearn for kindly providing the data on "age-heaping", and Roberto Basile, Ugo Fratesi, the participants to the ICEEE 2015, the EHS 2015, and AISRe 2014 annual conferences for useful suggestions. We finally thank an anonymous reviewer for providing us constructive comments. The authors alone are responsible for any errors that may remain and for the views expressed in the paper. Research supported by MIUR PRIN (Programmi di Ricerca Scientifica di Rilevante Interesse Nazionale) grant 2010J3LZEN.

[2] The Breda engineering company provides a representative example of this process of modernization. Born in 1886 in Milan, it was able to celebrate in 1908 the production of its 1000th locomotive, to branch out subsequently into armaments and aircraft.

[3] NUTS stands for Nomenclature of Territorial Unit Statistics, and represents the official way of dividing Europe territory into regions.

[4] On the distribution of manufacturing productivity in the EU regions, see in particular Fingleton and López-Bazo (2003).

The empirical literature on regional growth represents, to say the least, an active field of research, and provides thus a wealth of inspiring models (for a review, see, among others, Magrini 2004; Arbia, Basile and Piras 2005; Arbia 2006; Rey and Le Gallo 2009). As noticed in Fingleton and López-Bazo (2006) the initial focus of many authors was on aspatial models of regional growth. Both endogenous growth theory and models inspired by the NEG suggest that interaction among agents leads to external effects tied to the size of the markets, and knowledge spillovers that ultimately push economic activities to agglomerate in a selected area (Fujita, Krugman and Venables 1999). Pioneering works such as Amstrong (1995) and Rey and Montoury (1999) incorporated accordingly spatial heterogeneity and dependence in regional growth analysis. Following these seminal contributions, spatial terms were often introduced in a rising number of empirical growth exercises by simply augmenting a given empirical model with a spatial lag of the dependent variable (Spatial Auto Regressive, SAR) or of the error term (Spatial Error Model, SEM). Works such as Anselin and Rey (1991) provided then the statistical criteria to select the more appropriate model.[5] The need for more structural or theory-driven empirical growth models with spatial effects led to important contributions such as Niebuhr (2001), Ying (2003), López-Bazo, Vayá, and Artís (2004), Dall'erba and Le Gallo (2008), Piras, Postiglione, and Aroca (2012). These studies are characterized by the inclusion of both the spatial lag of the dependent variable and control variables $\mathbf{X}$ within a conditional β-convergence framework. While these works refer to different time periods and countries, they essentially conclude, a point relevant to our study, that labor productivity growth of a given regional economy is affected by that of neighboring regions. In this paper, following the approach by Fingleton (2001; 2004), López-Bazo, Vayá and Artís (2004), and Egger and Pfaffermayr (2006), we assume that externalities across Italian provinces were caused by technological diffusion and pecuniary externalities. We consider, to use the words of Fingleton and López-Bazo (2006), "spatial dependence of substantive type" (spatial lag and spatial cross-regressive) while spatial error models are deliberately not considered.

The rest of this paper is structured as follows. Section 2 describes the spatial conditional convergence model, and provides a brief review of the determinant of growth suggested in the literature. Sections 3.1 and 3.2 describe the main quantitative features of the new dataset, and illustrates the spatial distribution of both labor productivity in the manufacturing sector and socio-economic variables used as controls in the empirical exercise. Section 3.3 presents the empirical findings. Our conclusions are summarized in Section 4.

2. Modeling growth in space

The economic model here considered is the growth model with across-region externalities due to knowledge diffusion as presented in López-Bazo, Vayá and Artís (2004). Following the neat derivation in Fingleton and López-Bazo (2006), y_{it} represents average value added per worker, or labor productivity, in region i at time t.

[5] See Gibbons and Overman (2012) for a critical review of the literature, Halleck Vega and Elhorst (2015) for a comprehensive overview of the strengths and weakness of different spatial econometric model specifications in terms of spillovers effect.

$$y_{it} = A_{it} k_{it}^{\tau_k} h_{it}^{\tau_h} \tag{1}$$

In Equation (1) labor productivity is a function of the average level of physical and human capital per unit of labor k_{it}, and h_{it}, and the state of technology A_{it}; τ_k and τ_h represent internal returns to physical and human capital. Knowledge spillovers, this is an essential point, enter then the model by assuming that the technological level of each region depends on that of neighboring regions:

$$A_{it} = \Delta_t (k_{\rho it}^{\tau_k} h_{\rho it}^{\tau_h})^{\gamma} \tag{2}$$

where Δ_t is an exogenous component with a growth rate equal to g, $k_{\rho it}$ and $h_{\rho it}$ denote the physical and human capital-about ratios in the neighboring regions, and γ measures the externalities across economies.

Fingleton and López-Bazo (2006) show that in case of positive spatial externalities the steady state level of output per unit of effective labor will depend positively on the stocks of physical and human capital in neighboring regions, and then derive a growth equation representing the dynamics around the steady state. The equation, reported below, will be the base of our empirical study:

$$\mathbf{g_y} = c - (1 - e^{-\beta t}) ln(\mathbf{y_0}) + \mathbf{X}\delta + \phi ln(\mathbf{W y_0}) + \gamma \mathbf{W g_y} + \epsilon \tag{3}$$

In this equation the term $\mathbf{g_y}$ represents the growth of output per unit of effective labor, β is the rate of convergence, $\mathbf{X}$ the conditioning or control variables, $\mathbf{W}$ the spatial weight matrix capturing the interactions among regions, $\mathbf{Wg_y}$ and $\mathbf{Wy_0}$ respectively growth and initial productivity level in neighboring regions.

Before proceeding further, a remark in order is that while equation (3) provides a fundamental theoretical basis of our estimates, using it for a time and country like nineteenth century Italy requires to keep clearly in mind that the actual relevance of the spatial components is a matter to be assessed empirically. To a large extent this also applies to the $\mathbf{X}$ control variables, which potentially determine provincial steady states. Needless to say, a large literature has been devoted to the individuation of these control variables. Economic growth theory, and in particular the branch on endogenous growth models, points to human capital as a one of the key engines of growth (for a review see, e.g., Krueger and Lindahl 2001). According to Aghion and Howitt (1998) the relation between human capital and growth can be essentially evaluated from two different perspectives. The first one (see, e.g., Lucas 1988) considers the accumulation of human capital over time as a determinant of sustained growth; the second one (see, e.g., Romer 1990) considers instead human capital as a stock generating innovations, contributing thus to a country's ability (especially so in case of latecomers) to imitate and adapt new technology. Essentially the first approach extends the concept of capital to embrace human capital, while in the second the link between human capital and sustained growth passes through technological progress.

A related branch of the literature, relatively less developed, links economic growth to social capital, perhaps a more slippery theme. According to Temple (2001, p. 58), much in line with Putnam, Leonardi and Nanetti (1993, p. 167), "social capital can be thought of as capturing such things as the extent of trustworthiness, social norms, and participation in networks and associations." Of much interest here, Temple (2001, p. 89) notices that it is generally difficult to discriminate among alternative approaches using macroeconomic data at the national level and that studies at the local (regional or provincial) level can be more informative. The study by Guiso, Sapienza and Zingales (2004) provides an important example for the case of Italy.

The third branch of the literature that is relevant to our research relates economic growth to infrastructures. Already about half a century ago Eckaus noticed that "the stock of social capital available to region is regarded in the current development literature as one of the most important determinants of the growth potential of a region (Eckaus 1961, p. 288). Decades later the seminal work of Aschauer (1989) provided quantitative evidence on the positive effect of public infrastructures on U.S. total factor productivity. A recent and detailed survey on the topic is given in Romp and de Hann (2005). Turning to the Italian case, studies at the sub-national level include, among others, Picci (1999), and Cannari and Chiri (2003). The more recent Bronzini and Piselli (2009), which consider the relation between R&D, human capital and public infrastructure accounting for regional spillovers in Italy's regions between 1980 and 2001 is particularly close in spirits with the aim of our research. The study by Ciccarelli and Fenoaltea (2008), of more historical nature, provides time series evidence on social overhead capital in the regions of 19th century Italy, and is also related to our research. The relevance of infrastructures on growth can be also highlighted from a policy point of view. In recent years the World Bank allocated about 20 percent of its loans to finance infrastructures of various countries, an amount greater than loans to education, and health (World Bank Independent Evaluation Group, 2007).

3. The data

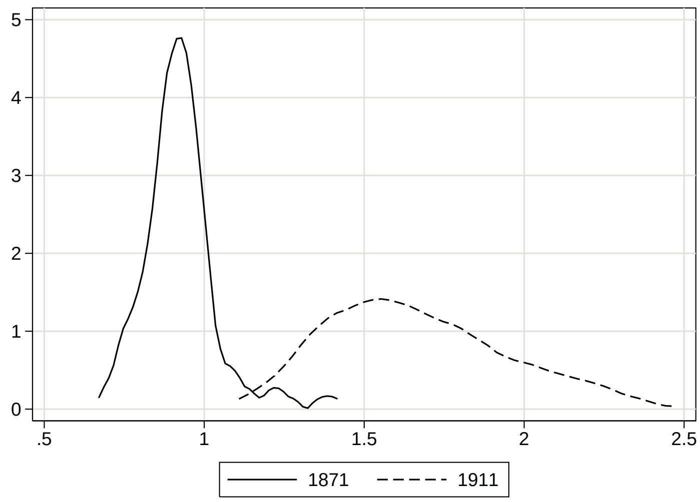
The provincial (NUTS 3) value added data at 1911 prices on manufacturing industry are those reported in Ciccarelli and Fenoaltea (2013). The control variables are instead entirely new. Gathering data at the provincial level for the 19th century is not of course an immediate task. Historical sources present their own limits, and need a careful interpretation of the figures reported. Besides that, quantitative information at the provincial level are not always available, and even studies referring to present day Italy resort in using interpolation methods to compensate for missing data on certain economic variables (see, e.g., Panzera and Postiglione 2014). It is also important to stress that in our definition of labor productivity in the manufacturing industry we only use male labor force figures in that, as it is well known, the figures from the 1871 population census tend to vastly overestimate female labor force of various southern provinces (see, e.g., Ciccarelli and Missiaia 2013).

3.1 Manufacturing value added per worker

During 1871-1911 in Italy as elsewhere in Europe, a complex interaction of many economic variables reshaped substantially the structure of the industrial system. The internal mix of manufacturing changed: traditional sectors tied to the production of consumption goods (e.g. foodstuffs) reduced their share in favor of the fast-growing "high-tech" sector tied to the production of durable goods (e.g. engineering). The mechanization of production processes was also particularly pronounced; coal power was gradually replaced by hydroelectric power, also affecting industrial location, in a time when the transmission of electricity was still limited. Italy's international trade policy shifted from free-trade to protectionism (especially so after 1887), with uneven net protection guaranteed to the various industrial sectors, possibly affecting total industrial output (see, e.g., Ciccarelli and Proietti 2013).

The wide changes that occurred in the provincial distribution of labor productivity in the manufacturing industry between 1871 and 1911 are summarized by Figure 1 and Table 1. Figure 1 reports the non-parametric estimates of the density functions of labor productivity in Italy's provinces in 1871 and 1911. Both location and dispersion of labor productivity increased, reflecting technological progress and its territorial diffusion. In fact, from Table 1, panel A we

Figure 1. Labor productivity in manufacturing industry, 1871 and 1911 (thousand lire per worker at 1911 prices)[a]



[a]Non parametric kernel density estimate with Silverman (1986) plug-in smoothing parameter. Source: see text.

can see that both mean and median values of labor productivity between 1871 and 1911 grew by about 80 percent (cols. 2 and 3). Growth in the lower end of the distribution was somehow slower (see col. 1) so that dispersion, as measured by the interquartile range, doubled (col. 5). Table 1 panel B illustrates the same descriptive statistics on labor productivity by macro-areas. The predominance of North-Western provinces (those belonging to Piedmont, Liguria, and Lombardy) over those belonging to the Center/North East and the South is evident in both 1871 and 1911.

Figure 2 presents things from a spatial perspective.[6] The left hand side illustrates the geographical distribution of labor productivity in 1871. A North-South divide is evident, with northern provinces, especially those in the North-West, typically belonging to the upper part of the distribution. Of the ten

[6] A detailed map of 19th century Italy's provinces is reported in the Appendix.

Table 1. Manufacturing industry: labor productivity, descriptive statistics[a]

A. ITALY (N = 69 provinces)

	(1) min	(2) median	(3) mean	(4) max	(5) IQR
1871	0.70	0.92	0.92	1.39	0.12
1911	1.21	1.66	1.67	2.37	0.25
(1911/1871)[b]	1.73	1.80	1.82	1.71	2.08

B. MACRO-AREAS[c]

	(1) min	(2) median	(3) mean	(4) max	(5) IQR
1871 :					
North-West	0.84	1.00	1.05	1.39	0.18
Center/North-East	0.70	0.91	0.91	1.04	0.09
South	0.73	0.87	0.88	1.00	0.12
1911 :					
North-West	1.68	2.03	2.00	2.37	0.19
Center/North-East	1.43	1.69	1.71	2.20	0.17
South	1.21	1.43	1.43	1.73	0.13

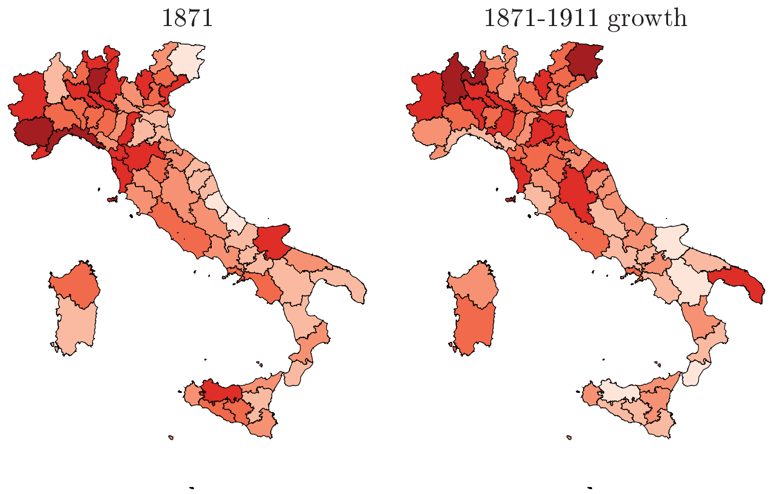
[a] Thousand lire per worker at 1911 prices. [b] The 1911/1871 row reports the (rounded) ratio of figures appearing in the preceding rows (so that for instance 1.73 = 1.21/0.70). [c] North-West = 14 provinces; Center/North-East = 30 provinces; South = 25 provinces.
Source: see text.

provinces with highest labor productivity in 1871, eight belong to the North-West, and only two and one, respectively, to the Center/North-East and the South. But there is more than that. The considerable amount of heterogeneity within both North and South reveals that the simplistic partition of the country between North and South is indeed not fully appropriate. To exemplify, within Piedmont (in the very North-West part of the map) western provinces (Turin and Cuneo) score better than eastern ones (Alessandria and Novara). The seven provinces of Sicily, to further exemplify, fall in five different intervals of labor productivity.

The map on the right hand side of Figure 2 gives a geographical representation of labor productivity growth in manufacturing. A first glance to the map suggests that dark colors are predominant in Northern provinces. However, a closer inspection of both maps reported in Figure 2 also reveals that high growth rates (map on the right hand side) tend to be associated with low initial values of labor productivity (map on the right hand side), as confirmed by a sample correlation of about -0.1.

To summarize on labor productivity, the evidence presented by Figures 1-2 and Table 1 is thus somewhat mixed. While both Figure 1 and Table 1 show increasing dispersion and point thus to divergence in labor productivity, Figure 2 suggests on the contrary convergence. However, a visual impression or a few descriptive statistics are of course not sufficient to get sensible conclusions. The

Figure 2. Labor productivity in manufacturing: 1871 (left), and 1871-1911 growth (right)[a]



[a] The maps use as class breaks the percentiles 5, 25, 50, 75, 95.
Source: see text.

topic need to be investigated appropriately within a proper statistical model of convergence. However, before presenting the estimation results of the conditional β-convergence model, the conditioning variables need to be introduced and discussed.

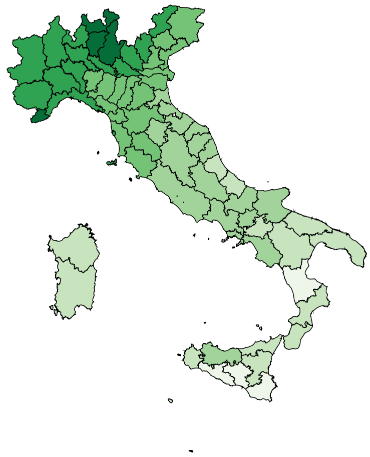
3.2 Control variables

In order to estimate the effect on manufacturing productivity growth of social participation, human and social capital, and infrastructure endowment we collected data from a wide set of historical sources ranging from population censuses, to official railways and electoral publications, to individual contributions of various scholars of the time. To increase the efficiency of our estimation procedure in some cases we resort to principal component analysis (PCA), a common way to reduce the dimensionality of the problem (for instance, it is used in a very similar set-up by Tabellini 2010).

The rest of this section illustrates the geographical distribution of the socio-economic variables, mapped in Figure 3. For reasons of space, details on sources and methods are reported in the Appendix.

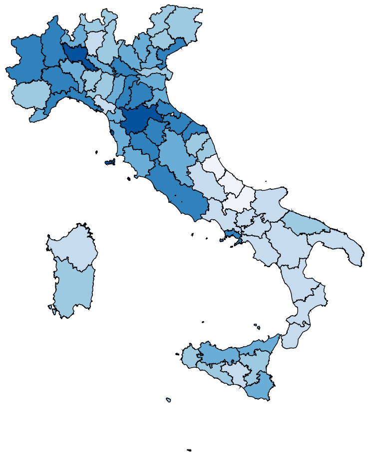
Figure 3. Control variables used in regression models (year = 1871 ca.)[a]

1. HUMAN CAPITAL

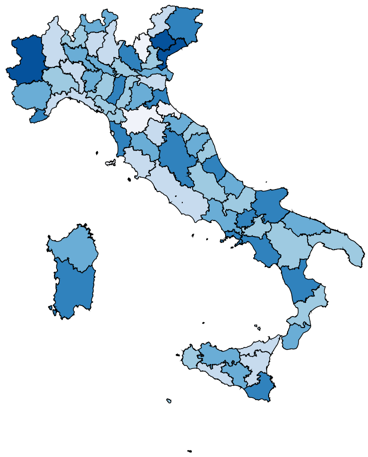


2. SOCIAL CAPITAL

2a. social participation

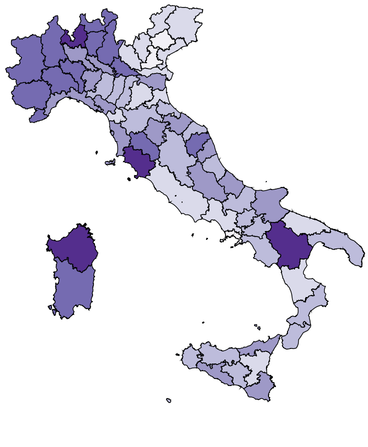


2b. political participation

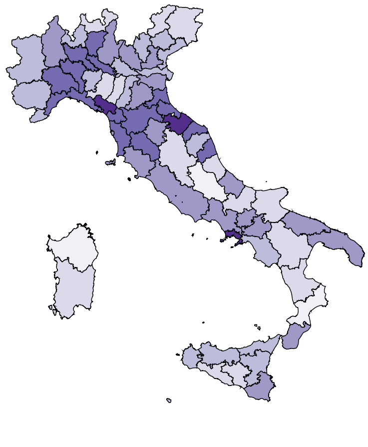


3. SOCIAL OVERHEAD CAPITAL

3a. postal offices



3b. roads and railways



[a] The maps use as class breaks the percentiles 5, 25, 50, 75, 95.
Source: see text.

Human capital. The role of human capital on economic growth during the early step of industrialization is somewhat controversial (Allen 2003, Galor 2005, Squicciarini and Voigtländer 2015). We propose an indicator of human capital that accounts for both literacy and numeracy. The human capital control used in the regression models is in particular the first principal component emerging from PCA on the logs of (standardized) illiteracy rates, age heaping, number of pupils and number of teachers in primary school. "Age heaping" (A'Hearn, Delfino and Nuvolari 2013) is defined as an estimate of the excess frequencies of population reporting age in round numbers. This phenomenon is obviously in an inverse relationship with the numeracy of the population. Hence, age heaping and illiteracy rates measure the education level of the population, while number of pupils and teachers measure the size of the education sector. Figure 3, panel 1, show that a North-South divide in term of human capital is clearly evident. Interestingly, selected provinces of Lombardy and Venetia (both part of the Austro-Hungarian Empire till 1866) score particularly well. At the opposite side of the distribution, provinces of southern Sicily performs instead poorly.[7] With few exceptions, the geographical distribution of human capital (Figure 3, panel 1) resemble closely the distribution of labor productivity growth in 1871-1911 (Figure 2). The unequal geographical distribution of human capital in 19th century Italy was well known to contemporaries at the point that Einaudi (1959, p. 198), in his positive evaluation of the State education policy carried over by Italian policy makers of the time noticed that "it was more useful to spend money in the making of a secondary education system in Northern Italy [than in Southern Italy] to avoid wasting the fruits from primary education there well established".[8]

Social capital. The social capital controls is here divided in two groups: (i) social participation; (ii) political participation. The first group includes the number of published newspapers and magazines (used also by Helliwell and Putnam 1995), and membership of mutual societies (both suitably standardized by the population size); the second group includes the number of voters (per 100 registered voters) in the local and national elections of mid-1860s and 1870. PCA suggests to keep these two groups separated, so that we constructed a social participation variable as the simple average of the number of newspapers and magazines titles and membership of mutual societies, and a political participation variable as the simple average of the number of voters (per 100 registered voters) in the local and national elections of mid 1860s and 1870. To better frame the role of social capital in 19th century Italy it seems important to recall some basic facts on the matter. First, the age of mass-press was only moving its first steps and the shift from elite to mass culture was far to come. Our sample includes nevertheless more the a thousand titles including newspaper, magazines, and other publications. Second, in Italy as elsewhere[9] only adult

[7] For reasons of space, provincial maps on elementary variables used to build the human capital index (illiteracy rates, age heaping, number of students, and number of teachers in primary school in 1871) are not reported. They are available upon request.

[8] The finding that the Sondrio and Porto Maurizio, far from representing the prototype of modern economies, performed so well according to the human capital index here proposed came admittedly as a surprise to the present writers. In the lack of better explanation, after judiciously double checking the sources and methods behind the result, the above finding appears classifiable within the "data oddities" category.

[9] See, for instance, Goldstein (1983, p. 4), reporting the percentages of population en-

males were enfranchised to vote. Of these adult males, mostly were landowners or belonging to some other well-off category. As a result, only some two percent of the population was involved in elections. One could further argue, perhaps legitimately, that in the lack of universal suffrage electoral participation correlates weakly with social participation. Third, welfare state was then very limited; and in the lack of public programs, mutual societies constituted effective tools to provide to its members insurance against various individual risks (such as those related to unemployment, health conditions, and retirement). We finally note that while the maps illustrated in Figure 3, panel 2a (on social capital) and Figure 2 (on industrial value added) present similar spatial patterns, with Southern provinces relatively colorless, Figure 3, panel 2b point to political participation as a variable distributed rather uniformly over the country.

Social overhead capital. A detailed quantitative analysis of social overhead capital in Italy's regions (NUTS 2) from 1861 to 1913, including reference to historical sources, is given in Ciccarelli and Fenoaltea (2008). Here, dealing with provinces, the quantitative information is inevitably more limited. We define infrastructure capital so to include local and national roads, railroad extension (all measured in linear km's per square km of provinces surface, as in Capello 2009b), and the number of post offices (standardized by the population size). It is here important to stress that a consistent part of the Italian railroad network was built after 1871 (the extension of the Italian network was of roughly 6,400 kms in 1870 and 15,300 in 1910)(Istat 1958 HS, p. 137).[10] Beside roads and railroads, ports were also a relevant component of the national endowment of infrastructures given the importance of costal shipping, and more generally water transports. Accordingly, we collected data[11] and used them in the early exploratory analysis. However, given that major ports were simply absent from the vast majority of Italian provinces, these controls turned out to be irrelevant and were thus dropped from the models.

Following PCA results, the proposed regressions include the simple average of (standardized) roads and railways, and, as a separated variable, the number of post offices per 100.000 habitants. The two variables are illustrated in Figure 3, panels 3a-3b.[12]

Table 2 complements Figure 3 by reporting Moran's I spatial autocorrelation coefficient applied to the same set of variables. It emerges that the rule is constituted by (positive) spatial autocorrelation. The latter is particularly high for education, but also sizeable for industrial growth and post offices. As expected, the exception to the rule is instead represented by the political participation variable, as we failed to reject the null of no spatial autocorrelation.

franchised for lower legislative chambers in various European countries between 1815 and 1915.

[10]References to the historical sources listed in the Appendix are henceforth indicated with HS.

[11] The historical source Ministero di Agricoltura, Industria e Commercio (1872 HS), reports for instance detailed information on to the economic activity of major ports (Genoa, Messina, Leghorn, Palermo, Naples, Venice, Catania, Ancona, Brindisi, and Cagliari).

[12] The high number of post offices in the province of Potenza, notoriously a backward part of the country, represents an unexpected finding. In the lack of better explanation, after judiciously double checking the sources and methods behind the result, the above finding appears, once again, classifiable within the "data oddities" category.

Table 2. Spatial autocorrelation: Moran's I[a]

	$\mathbf{g_y}$	$\mathbf{y_{71}}$	Education	Social part.	Roads & rails	Post offices	Political part.
Moran's I	0.34	0.28	0.85	0.31	0.30	0.55	-0.09
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.84

[a]p-values, Ho: no autocorrelation (1-tail test). Moran's I evaluated with a spatial weights matrix W based on the 5 nearest neighbors. $\mathbf{g_y}$ = 1871-1911 labor productivity growth; $\mathbf{y_{71}}$ labor productivity in 1871.

Source: see text.

3.3 Estimation results

This section presents the results of the empirical estimation of the conditional β-convergence model for manufacturing productivity growth a la López-Bazo, Vayá and Artís (2004).[13] Our empirical model, discussed in section 2.1 (see in particular Equation 3), is represented by the following equation:

$$\mathbf{g_y} = c - (1 - e^{-\beta t})ln(\mathbf{y_{71}}) + \mathbf{X_{71}}\delta + \phi ln(\mathbf{W}\mathbf{y_{71}}) + \gamma \mathbf{W}\mathbf{g_y} + \epsilon \tag{4}$$

where the 69×1 vector $\mathbf{g_y}$ denotes the 1871-1911 growth of provincial value added at 1911 prices per worker in the manufacturing industry, $\mathbf{y_{71}}$ its initial 1871 value, $\mathbf{W}$ a 69×69 spatial weights matrix, and $\mathbf{X_{71}}$ a matrix of control variables. The latter includes the 1871 values of the human capital (Edu), social participation, (Soc), post offices, ($Post$), and road and railways (RR) variables.[14] Equation (4) can be formally seen as a Spatial Durbin Model, a very general specification allowing for both exogenous and endogenous spatial interaction effects (see e.g., Halleck Vega and Elhorst 2015). Although LeSage and Pace (2014) argue convincingly that the key point of spatial modelling is the proper interpretation of spatial effects, rather than the choice of the spatial weights matrix by itself, our data require spatial contiguity to be modelled in an especially careful way. This for two main reasons: first, the rather small average dimension of the spatial units (average population less than 400.000 in 1871); second, the complicated geographical structure of the country, with 23 per cent of the surface officially classified as plains, 42 per cent as hills and 35 per cent as mountains.[15] We accordingly estimated model (4) by Maximum Likelihood using various spatial weights matrices. More precisely:

1. binary weights, with provinces defined as neighbors only if their administrative centers are closer than a cut-off distance. We estimated models with cut-off at 100, 150, 200 and 250 kms, but here for reasons of space we will report only the two extreme cases (100 and 250), describing briefly the intermediate ones;

[13] According to the so called Verdoorn's Law, not considered in this paper, productivity growth is determined by the growth rate of output. Empirical tests of the Verdoorn's Law for the case of Italy's regions are discussed in Capello (2009a).

[14] The choice of using the initial (1871) level of the control variables aims at reducing the problem of endogeneity that might potentially affect estimation results.

[15] At current borders, which include territories differing by less than 5 per cent of the surface from those of the 1871-1911 borders.

2. exponentially declining weights: $w_{ij} = e^{-d_{ij}}$, with cut-off at distance d_{ij}=250 kms;

3. inverse distance weights: $w_{ij} = d_{ij}^{-1}$ with cut-off at 250 and 500 kms (here reported only the former);

4. gravity weights: $w_{ij} = d_{ij}^{-2}$ with cut-off at 250 kms;

5. $k-$nearest neighbors (knn), with $k = 5, 10, 15$ (here reported only $k = 5$ and $k = 15$).

Following standard practice binary matrices (cases 1 and 5) have been row-standardized. Distance-based weights (cases 2, 3, 4) have been instead standardized diving by the maximum eigenvalue of the matrix, so to retain their interpretation in terms of distance decay (Halleck Vega and Elhorst 2015). Finally, in the cases of binary weights with cut-off smaller than 250 kms the sample is reduced to 67 provinces, as the distance between the administrative centers of the two provinces of Sardinia is 210 km. Remarkably, specifications search on the basis of individual significance tests led to preferred specifications essentially similar for all spatial weights matrices, thus lending support from this perspective to LeSage and Pace (2014).

The preferred specifications are reported in Table 3, and the main points can be summarized as follows. First of all, the fit is roughly similar across models, although slightly better when the simplest weights matrix (binary weights, cut-off at 100 kms) is used. The heteroskedasticity and spatial autocorrelation diagnostics are always largely not significant, confirming that the spatial heterogeneity of productivity growth is adequately captured, independently by the shape of the spatial weights matrices. Second, in all cases the spatial lag of the dependent variable turned out to be not significant. Accordingly, the estimates reported are computed by OLS. Third, the own starting levels of productivity and of the conditioning variables (human capital, Edu, and social participation, Soc) have always significant effects, with coefficients of practically the same dimension across the various models. More precisely, the estimates of the coefficient of $\ln(\mathbf{y_{71}})$, referring to the initial level of labor productivity, are between -0.62 and -0.56, implying estimates of the β parameter (see Equation 4) between 1.5 and 1.8 percent.[16] This interval is remarkably close to the value of two percent, often considered, after Barro and Sala-i-Martin (1991), a benchmark value in convergence studies applied to modern economies.

To appreciate the impact of the conditioning variables, which are measured on arbitrary scales, it is instructive to compute growth differentials between the best and worst endowed provinces. In the case of Edu these are respectively Bergamo, in Lombardy, and Syracuse, in Sicily, and we estimate the difference in 1871-1911 productivity growth due to human capital differences to be between 19.4 percent (with spatial weights $\mathbf{W} = knn-15$) and 30.2 percent (with gravity weights). The impact of differences in social participation is somehow smaller, but still sizeable. We estimate the implied differential in productivity growth between the top province, Leghorn in Tuscany, and the bottom one, Campobasso in Abruzzi, to be between 17.3 percent (with binary weights and cut-off at 250 kms) and 20.1 percent (with gravity weights). The main difference between the various models concerns the (logged) spatial lags of the 1871 productivity level.

[16] With a standard error computed by the delta method approximately equal to 0.4 percent.

This is retained with positive effects in the regressions with binary weights and in that with $knn-15$ weights (with similar coefficients), but excluded with all distance-based and $knn-5$ weights. In the unreported regressions this variable is weakly significant in two cases (binary weights, cut-off 200 kms, and $knn-10$ weights) and not significant in another two (binary weights, cut-off at 150 kms, inverse distance weights, cut-off at 500 kms). The link between productivity growth and the 1871 productivity level of the neighbors seems thus to depend on the way these are defined.

Overall, the estimates suggests convergence to different steady states essentially determined by the two conditioning variables always retained, human capital and social participation, and possibly by 1871 productivity level of the neighbors. In other terms, technological spillover effects, when present, seem to be captured by the initial level of labor productivity in neighboring provinces, and not by their growth rates.[17] To further investigate the point, we also estimated in preliminary regressions ***absolute*** β-convergence models augmented with both the growth and the initial level of productivity in the neighboring provinces. Although both these variables have the expected positive effects on the productivity growth of each province, model residuals always show extremely severe spatial autocorrelation.[18] Hence, these measures of technological spillover are not sufficient to explain spatial heterogeneity in productivity growth, and a conditional convergence model need to be considered.

Our results are consistent with the view, widely shared by Italy's economists and economic historians, that the initial value of productivity (and human, and social capital as well) affected the growth potential of the local economies. Einaudi (1959, pp. 197-198) noticed in particular that for a set of historical reasons Northern regions were characterized by "better Governments, reduced distance from prosperous nations, higher self-confidence, and a geographical location prone to rapid and fruitful economic trades". And similarly, Cafagna (1989, pp. 194-202) recalled the environmental advantages of the North including more fertile land for agriculture and hydraulic resources for motive power. Ciocca (2007, pp. 94-97) summarizes the literature and concludes that during the 1860s Northern and Southern regions were different along many dimensions, including educational levels, social participation, and respect for the rule of law, all affecting the growth potential of the two macro regions, thus supporting both Einaudi's and Cafagna's view.

[17] This finding, when considered in the light of the spatial convergence literature, is in a sense surprising. In their study on conditional convergence of labor productivity, Fingleton and López-Bazo (2006), for instance, find that the coefficient associated with knowledge diffusion across EU regions is positive, sizeable, and significant. And it is so both in the unconditional and the conditional β-convergence model. However, knowledge diffusion and technological externalities go along with an adequate absorptive capacity of the various regions, that essentially rest on the availability of human and social capital (Cohen and Levinthal 1990; Caragliu and Nijkamp 2012). Our finding about the systematic insignificance of productivity growth in neighboring provinces might just reflect the extremely low initial level of human and social capital in a large parte of nineteenth century Italy.

[18] The results of these preliminary regression are not reported for reason of space, but are available on request.

Table 3. Estimation of the growth equation with externalities across provinces[a]

<table>
<tr><th></th><th>(1)
B/100</th><th>(2)
B/250</th><th>(3)
Exp</th><th>(4)
1/d</th><th>(5)
$1/d^2$</th><th>(6)
knn-5</th><th>(7)
knn-15</th></tr>
<tr><td>constant</td><td>0.58*** (0.02)</td><td>0.58*** (0.02)</td><td colspan="4">0.55*** (0.01)</td><td>0.59*** (0.02)</td></tr>
<tr><td>$\mathbf{Wg_y}$</td><td>–</td><td>–</td><td colspan="4">–</td><td>–</td></tr>
<tr><td>$\ln(\mathbf{y}_{71})$</td><td>−0.62*** (0.10)</td><td>−0.58*** (0.10)</td><td colspan="4">−0.55*** (0.10)</td><td>−0.56*** (0.10)</td></tr>
<tr><td>$\ln(\mathbf{Wy_{71}})$</td><td>0.43*** (0.14)</td><td>0.41*** (0.24)</td><td colspan="4">–</td><td>0.47* (0.26)</td></tr>
<tr><td>Edu</td><td>0.34*** (0.07)</td><td>0.32*** (0.07)</td><td colspan="4">0.39*** (0.07)</td><td>0.29*** (0.09)</td></tr>
<tr><td>Soc</td><td>0.54*** (0.13)</td><td>0.51*** (0.14)</td><td colspan="4">0.56*** (0.14)</td><td>0.52*** (0.13)</td></tr>
<tr><td>Pol</td><td>–</td><td>–</td><td colspan="4">–</td><td>–</td></tr>
<tr><td>$Post$</td><td>–</td><td>–</td><td colspan="4">–</td><td>–</td></tr>
<tr><td>RR</td><td>–</td><td>–</td><td colspan="4">–</td><td>–</td></tr>
<tr><td>R^2</td><td>0.63</td><td>0.59</td><td colspan="4">0.57</td><td>0.59</td></tr>
<tr><td>$LogLik$</td><td>79.17</td><td>78.73</td><td colspan="4">77.23</td><td>78.89</td></tr>
<tr><td>AIC</td><td>−148.35</td><td>−147.46</td><td colspan="4">−146.45</td><td>−147.79</td></tr>
<tr><td>BP</td><td>6.65 (0.16)</td><td>5.28 (0.26)</td><td colspan="4">4.45 (0.22)</td><td>4.86 (0.30)</td></tr>
<tr><td>LM^{lag}</td><td>0.03 (0.87)</td><td>1.04 (0.31)</td><td>0.06 (0.80)</td><td>0.18 (0.67)</td><td>1.02 (0.31)</td><td>0.09 (0.76)</td><td>0.36 (0.55)</td></tr>
<tr><td>LM^{error}</td><td>0.37 (0.54)</td><td>1.16 (0.29)</td><td>0.53 (0.47)</td><td>0.15 (0.70)</td><td>0.61 (0.43)</td><td>0.09 (0.72)</td><td>1.06 (0.30)</td></tr>
</table>

[a] Coefficients: standard errors in brackets, ***,**,* significant at 1%, 5%, 10%
LM^{lag}, LM^{error} : spatial residual autocorrelation tests, p-values in brackets.
BP : Breusch-Pagan heteroskedasticity test, p-values in brackets.
The definition of the **W** matrix in the various columns is as follows:
cols. 1-2: B/d: $w_{ij} = 1$ if distance $d_{ij} < d$, 0 else; d = 100, 250; ($B/100$: $N = 67$);
col. 3: Exp: $w_{ij} = e^{-d_{ij}}$ if distance $d_{ij} < 250$ km,0 else;
col. 4: $1/d$: $w_{ij} = d_{ij}^{-1}$ if distance $d_{ij} < 250$ km,0 else;
col. 5: $1/d^2$: $w_{ij} = d_{ij}^{-2}$ if distance $d_{ij} < 250$ km,0 else;
cols. 6-7: $knn - N$: $w_{ij} = 1$ if j is one of the N closest provinces, 0 else

The models reported in cols. 3-6 have no spatial terms. Hence, the coefficient estimates and the non-spatial diagnostics are the same for all models.

Source: see text.

On the relation between social capital and industrial development our findings that active citizenship (press diffusion and social awareness, as measured by the diffusion of mutual societies) have a significant effect on labor productivity growth, is consistent with A'Hearn (1998), and de Blasio and Nuzzo (2009), also considering 19th century Italy. Leonardi (1995) stresses in particular that in the case of Italian South in recent decades, social norms emphasizing collective action (i.e. social capital) as a viable means of achieving societal goods are absent. Rather, the South is permeated by a culture emphasizing individual norms oriented towards short-term individual gains (on this point see also Felice 2012; 2014 and literature therein).

The relation between human capital and industrial development is instead more controversial. Di Liberto (2008) shows that improvements in literacy rates had a strong impact on the growth of Southern Italian regions in the 1960s, when the income differentials with the rest of the country temporarily shrank (on this, see Paci and Saba 1998). On a much larger scale, Gennaioli *et al.* (2013) show that education is the single most determinant of the current world regional development differentials, and Tabellini (2010) that the literacy differentials can have highly persistent effects on income differentials, up to the point that regional per capita output in the European regions at the end of the 20th century is significantly related to literacy rates of over a century before, which thus appear to be able to shape culture and institutions in the very long-run. However, the studies by Allen (2003) and Galor (2005) downplay considerably the role of human capital during the early phases of industrialization. Interestingly, Squicciarini and Voigtländer (2015), referring to the 18th and 19th centuries in France, shows that once upper-tail knowledge (proxied by city-level subscriptions to the *Encyclopèdie*) is distinguished from average human capital (basic literacy) the former is positively related with productivity growth of innovative industrial technology. In our case, referring to 19th century manufacturing in Italy, the positive and significant relation between our human capital indicator (accounting for both literacy and numeracy) and labor productivity growth constitutes one of the more robust empirical findings.

4. Conclusions

This paper considers the early development of provincial manufacturing in nineteenth century Italy. We contribute to the empirical growth literature by considering a conditional β-convergence model for labor productivity in the manufacturing industry, allowing for spatial effects in a time (1871-1911) and a country when the agglomeration forces and spillover effects advocated by the new economic geography literature were just starting to operate. The vast majority of labor force was employed in agriculture, industry was only moving its first steps, literacy rates were rising but still extremely low in the South, and essential infrastructures such as the railways network were under construction.

In this scenario, we find evidence of conditional convergence of labor productivity growth within manufacturing, once human and social-capital are accounted for. Differently from the prevailing literature referring to more recent times, our estimates suggest that labor productivity benefited from the initial level of productivity in the neighboring provinces, and not their growth rates. The result is consistent with the different growth potential of northern provinces in the aftermath of the country Unification (1861) advocated by the prevailing historical literature. The paper also shed light on the controversial role of human capital on industrial growth for past historical periods. Our results show clearly that, at least for the time period and country considered here, areas better endowed in terms of human and social capital experimented, on average, higher growth rates of labor productivity in the manufacturing industry.

Appendix

Sources and methods

This appendix documents the sources and the methods behind the provincial dataset (NUTS 3 units) used in this paper. Data on manufacturing value added are from previous research. Data on additional control variables are instead entirely new. To increase the efficiency of the estimation procedure we constructed synthetic indicators using Principal Components Analyses (PCA).

Manufacturing industry: provincial value added, 1871-1911

Manufacturing value added estimates at 1911 prices for the whole set of 69 Italian provinces, for the years 1871 and 1911, are those provided by Ciccarelli and Fenoaltea (2013). The estimates are available at `http://onlinelibrary.wiley.com/doi/10.1111/j.1468-0289.2011.00643.x/suppinfo`, last accessed June 2014.

Human capital

The data on illiterates for 1871 are from Ministero di Agricoltura, Industria e Commercio (1874–76 HS), vol. 2, Introduzione, pp. B-I. Data on primary education in 1871 (number of students, and number of teachers) are from Antonielli (1872 HS, pp. 282-283). The data on age-heaping in 1871 were kindly provided by Brian A'Hearn (see A'Hearn, Delfino and Nuvolari 2013).

The elementary variables used as inputs to the principal component analysis providing as output the human capital indicator used in the convergence models are:

1. Illiteracy rate ($Illit$)
2. Age heaping (Age)
3. Primary school pupils divided by population in the 5-12 age bracket ($Pupils$)
4. Primary school teachers divided by population in the 5-12 age bracket ($Teach$)

The last two variables measure the size of the education sector, while the first two the quality of its output (with a negative sign). The results of PCA applied to the logs of these elementary variables are reported in Table A1. The first principal component turns out to be able to explain over 80 per cent of the variance; all variables have approximately the same weights in absolute value, with opposite signs as to be expected for the first and the second pair. We thus decided to include the first principal component, labeled as Edu (Education), in the convergence regressions. The provincial distribution of this variable is illustrated in Figure 3, panel 1.

Table A1. Human capital: Principal component analysis

	Elementary variables			
	Illit	*Age*	*Pupils*	*Teach*
first PC:				
weights	-0.451	-0.521	0.524	0.500
variance explained (%):	83.7			

Source: see text.

Social capital

The data on the newspaper and magazines title are from Ottino (1875 HS), Allegato 4, "Prospetto statistico della stampa periodica, della tipografia e della libreria in Italia.", on the membership of mutual societies from Ministero di Agricoltura, Industria e Commercio (1875 HS, pp. 200-203), while on the number of voters in local and national elections of 1865 from Antonielli (1872 HS, p. 146). Election data for the province of Rome, annexed to the country in 1870, refer to the national elections of 1870 and the local elections of 1872, as reported in Direzione generale della Statistica (1873 HS, pp. 87b and 86).

The elementary variables used as inputs to the principal component analysis providing as output the social capital indicators used in the convergence models are:

1. Number of journals and magazines titles per 100.000 residents ($Journals$)
2. Members of mutual societies per 100.000 residents ($Mutual$)
3. number of voters at local elections per 100 registered voters ($Local\_vot$)
4. number of voters at national elections per 100 registered voters (Nat_vot)

The results of applying PCA on the above elementary variables are summarized in Table A2. The first principal component turned out to be able to explain only half of the variance of this set of variables. As it can be seen, press diffusion and membership of mutual societies have positive weights, while the rate of participation to local and national elections negative ones: hence, there is no obvious interpretation. We thus opted for splitting this set of variables in two pairs, with the simple means of the $Journals$ and $Mutual$ (suitably standardized to have unit standard deviation) capturing Social participation (Soc) and that of voters the two elections Political participation (Pol).

$$Soc = 0.5\left(\frac{Journals}{\sigma_{Journals}} + \frac{Mutual}{\sigma_{Mutual}}\right)$$

$$Pol = 0.5\left(\frac{Local\_vot}{\sigma_{local\_vot}} + \frac{Nat\_vot}{\sigma_{nat\_vot}}\right)$$

The provincial distribution of social participation (Soc) and political participation (Pol) is illustrated in Figure 3, panel 2.

Table A2. Social capital: Principal component analysis

	Elementary variables			
	Journals	*Mutual*	*Local_vot*	*Nat_vot*
first PC:				
weights	-0.375	-0.550	0.543	0.511
variance explained (%):	46.1			

Source: see text.

Social overhead capital

The data on the local and national roads, measured in kilometers, are from Correnti (1873 HS, pp. 122-125). The data on the number of postal offices are from Direzione generale delle Poste (1873 HS, p. XLIV). The extension of the railway network by province for the year 1871 is obtained adding to the figures for 1861, taken from Ferrovie dello Stato (1911 HS) the lines opened in each province between 1861 and 1871, as reported in Ministero delle Comunicazioni (1927 HS).

The elementary variables used are thus the following:

1. Local and national roads, km's normalized by surface of the province in km^2 (*Roads*)
2. Railways, km's normalized by surface of the province in km^2 (*Rail*)
3. Number of post offices per 100.000 residents (*Post*)

The results of applying PCA on the above elementary variables are summarized in Table A3. The first principal component explains about 42 per cent of the variance of the entire set of variables, and it is positively correlated with *Roads* and *Rail* (which have almost equal weights) and negatively with *Post* (which has a smaller weight). In fact, the second PC (not shown here) is very close to the latter variable. We thus decided to split this set of indicators as well, including the post offices variable directly, and the simple mean of the *Roads* and *Rail* variables (*RR*), duly scaled, capturing communication infrastructures:

$$RR = 0.5 \left(\frac{Roads}{\sigma_{Roads}} + \frac{Rail}{\sigma_{Rrail}} \right)$$

The provincial distribution of both social overhead capital indicators, *Post* and *RR*, is illustrated in Figure 3, panel 3.

Table A3. Social overhead capital: Principal component analysis

	Elementary variables		
	Roads	*Rail*	*Post*
first PC:			
weights	0.658	0.673	-0.339
variance explained (%):	42.2		

Source: see text.

Historical sources

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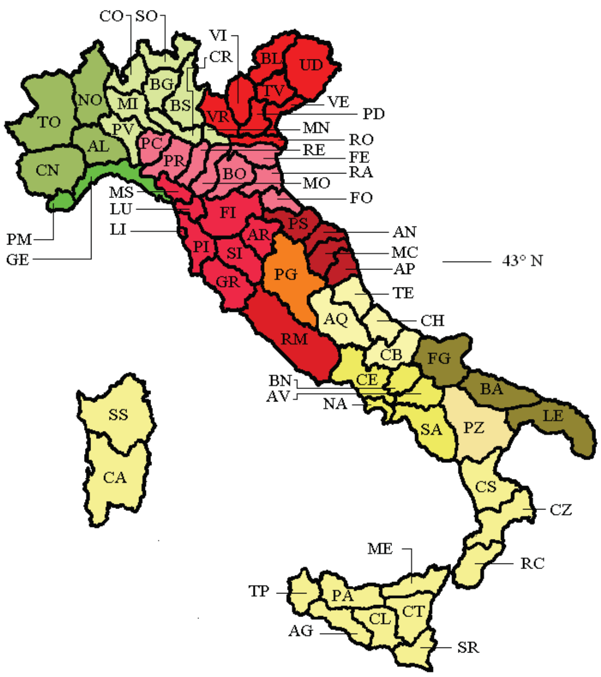
Map of Italy's provinces (1911 borders)

In the text below, the name of each region, in bold, is followed by the name (and tag) of its provinces. Different colors simply highlight regional borders.

PIEDMONT: Alessandria (AL), Cuneo (CN), Novara (NO), Turin (TO)
LIGURIA: Genoa (GE), Porto Maurizio (PM)
LOMBARDY: Bergamo (BG), Brescia (BS), Como (CO), Cremona (CR), Mantua (MN), Milan (MI), Pavia (PV), Sondrio (SO)
VENETIA: Belluno (BL), Padua (PD), Rovigo (RO), Treviso (TV),Udine (UD), Venice (VE), Verona (VR), Vicenza (VI)
EMILIA: Bologna (BO), Ferrara (FE), Forlì (FO), Modena (MO), Parma (PR), Piacenza (PC), Ravenna(RA), Reggio Emilia (RE)
TUSCANY: Arezzo (AR), Florence (FI), Grosseto (GR), Leghorn (LI), Lucca (LU), Massa Carrara (MS), Pisa (PI), Siena (SI)
MARCHES: Ancona (AN), Ascoli Piceno (AP), Macerata (MC), Pesaro (PE)
UMBRIA: Perugia (PG)
LATIUM: Roma (RM)



ABRUZZI: Aquila (AQ), Campobasso (CB), Chieti (CH), Teramo (TE)
CAMPANIA: Avellino (AV), Benevento (BN), Caserta (CE), Naples (NA), Salerno (SA)
APULIA: Bari (BA), Foggia (FG), Lecce (LE)
BASILICATA: Potenza (PZ)
CALABRIA: Catanzaro (CZ), Cosenza (CS), Reggio Calabria (RC)
SICILY: Caltanissetta (CL), Catania (CT), Girgenti (AG), Messina (ME), Palermo (PA), Syracuse (SR), Trapani (TP)
SARDINIA: Cagliari (CA), Sassari (SS)

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