A SPATIAL ANALYSIS OF GROWTH AND CONVERGENCE IN ITALIAN PROVINCES: THE ROLE OF HIGHWAYS

By

Stefania Cosci (Lumsa University of Rome) and Loredana Mirra (University of Rome Tor Vergata)

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Abstract

The role of highways in reducing economic disparities is debated both in Europe and in the US. During the 60's, huge investments in highways significantly reduced the "time" run between North and South Italy. A spatial analysis of convergence is performed. Results show that the "highway effect" was significant but accompanied by a strong polarization between North and South (also emerging from nonparametric analysis). This is possibly due also to a major concentration of highway investments in the Centre-North. The change in transportation cost caused by the opening of the "Autostrada del Sole" might have generated a core-periphery pattern that later transport infrastructure policies were not able to alter.

Keywords: Highways, convergence, parametric analysis, nonparametric analysis, spatial econometrics
JEL Codes: C14, C21, O18, R11, R12

1. Introduction

The role of highways in reducing economic disparities is a subject of debate both in Europe and in the United States. Transportation infrastructure is an important input for production. At the same time it shifts market areas: highway investment lowers transportation costs and the cost of commuting, affecting residential choices that may, in turn, influence the location decisions of firms and industries (Rephann and Isserman 1994). An increasing body of evidence suggests that inter-regional infrastructure investments could result in convergence or divergence. In particular, some studies concerning Europe argue that infrastructure investments may bring regional convergence to a halt (Puga 2002, Cappellen *et al.* 2003). Other studies considering the US suggest that highways raise the level of economic activity in the regions through which they pass, but often have detrimental effects on adjacent regions (Chandra and Thompson 2000; Sloboda and Yao 2008) .

Since January 2014 the EU has a new transport infrastructure policy that connects the continent between East and West, North and South. European coordinators are leading the drive to build the core network corridors which represent the strategic heart of the TEN-T. Increasing mobility levels are considered a precondition for smart, inclusive and sustainable economic growth to meet the sector's demanding carbon reduction objectives and to safeguard Europe's global position[1]. Europe is a continent characterized by pronounced per capita income disparities across states and regions. Increasing mobility levels may foster the decrease of such disparities.

The Italian case is very interesting. During the 1950s, the Italian government planned a new transport infrastructure policy aimed at connecting the country between North and South. The *Autostrada del Sole* (the "Sun Highway") linking Milan to Naples was at the strategic heart of this plan. The country is historically characterised by a huge North-South divide and Italian regional growth has been strongly affected by human geography as shaped by infrastructure (Iuzzolino *et al.* 2011). After World War II the traditional absence of interregional trade within the South, mainly caused by the lack of transport networks together with the area's peculiar geographical structure, meant that for most firms located in the South the market was strictly local, unlike the wider market faced by Northern firms. Transport infrastructure capital rose strongly in a very short period of time: almost 61% of today's highway network was opened during the period 1960-1975, compared to only 12% before 1960.

The development of the highway network represented one of the cornerstones of Italian development policy of post-war governments. The idea that an immobile nation equated to a poor nation shaped Transport Plans aimed at "planning demand ahead" in order to achieve a moving nation, and thus a rich nation (Spaggiari, 1983). The plans put huge emphasis on roads with the aim of supporting the national motor vehicle industry. The decision to favour investment in roads over railways was hotly debated in Italy[2]. During the so-called 'Italian economic miracle' the number of cars on Italian roads rose impressively. In 1969 Italy became the sixth world producer of private cars (after US, Japan, Germany, France and Great Britain) with 1.5 million private cars sold over the 'miracle' period. The length of highways opened to traffic in 1970 (3.913km) was the highest in Europe, more than France (1.303 km), Great Britain (1.000 km), Holland (800 km), Spain (335 km) and Germany (259 km). After the strong rise during the '60s and early '70s, Italian transport infrastructure capital recorded an increasingly feeble trend[3]. The share of transport infrastructures to total public capital declined from 40.3 per cent in 1980 to 33.5 per cent in 2000[4].

Did the huge road transport investment of the '60s contribute to convergence among Italian provinces? In order to give an answer to this question, this study uses both nonparametric and parametric techniques providing complementary information about the evolution of provincial per capita income disparities in Italy during the period 1951-2001. Results arising from stochastic kernel density estimation are corroborated by spatial regression analysis. The latter is performed to take in to account the presence of spatial correlation in per capita income, very often neglected in economic convergence literature, and, at the same time, to detect the presence of spatial regimes in the different decades of the Italian Post-War period. It also directly tests the so-called "highway effect", i.e. it evaluates whether the provinces that became more accessible during the '60s as a result of road infrastructure investments later saw more growth than others. The analysis extends earlier work in two main directions. This is, to our knowledge, the first work investigating empirically the role of the highway system in reducing economic disparities among Italian provinces. Most previous works consider the effect of transport infrastructure investments on total factor productivity (TFP)[5] but we are not aware of any work analysing the effect of road infrastructure investment on convergence in Italy using spatial econometric techniques. In addition, for the first time this paper tests the effect of road infrastructure on local growth using an indicator based on transport time recently published by the Bank of Italy (Alampi and Messina 2012). Works similar to this one generally consider the length of roads and highways, which is only an approximation of the change in total regional accessibility produced by the new investments since it is unable to measure the quality of the infrastructure actually built (Crescenzi and Rodriguez Pose 2012).

The paper is organised as follows. Section 2 surveys the empirical literature on the "highway effect" and on the measures of the highway endowment; Section 3 analyses per capita income convergence in Italian provinces by means of a nonparametric (i.e. distributional) approach based on stochastic kernels. Section 4 reports the results of the conditional *beta*-convergence estimation taking into account both spatial heterogeneity and spatial dependence through spatial econometrics tools testing the "highway effect". Conclusions in Section 5 highlight some of the implications for regional policies.

2. Related literature

2.1 The "highway effect" and convergence:

Transport investments are usually thought to benefit lagging regions but there is a strong debate on their wider economic effect (Brocker and Rietveld 2009). Transport infrastructure improvements do not always secure a more even pattern of regional economic development. In his seminal work Aschauer (1989) argues that differences in the stock of public infrastructure are the main cause of differences in productivity and national output. According to the literature on "transport-induced agglomeration effects", transport improvements can significantly raise the strength of agglomeration economies (Eberts and McMillen 1999, Graham 2007).

In contrast with the literature quoted above, some studies do not find a positive effect of transport infrastructure on local growth. Some authors argue that the direction of causality in Aschauer's regressions is not clear (see Gramlich 1994 and Vanhoudt et al. 2000), since causality does not run from public investment to growth, but rather the opposite way. New Economic Geography models (Krugman 1991, Fujita *et al.* 1999 and Puga 2002) argue that the development of transport infrastructure has both positive and negative effects. While it does give firms in less developed regions better access to inputs and markets of more developed regions, it also makes it easier for firms to supply poorer regions from a distance.

Duranton and Turner (2012) estimate the effects of interstate highways on the growth of US cities. They suggest that the creation of interstate highways reduced per capita income disparities among US cities and find that roads had been allocated to cities, in part, as a response to negative population shocks[6]. They address the fundamental simultaneity problems that plagued previous studies (Chandra and Thompson, 2000; Michaels, 2008) by relying on plausibly exogenous development such as the gradual expansion of the US interstate system.

According to the results of the meta-analysis by Melo et al. (2013), the effect of transport infrastructure on output in European countries is much lower than in the US[7]. Consistent with these results Crescenzi and Rodriguez-Pose (2012), estimating the effects of highways investments on growth in 120 regions of 11 EU15 countries between 1990 and 2004, find that the impact is well below what could be expected with respect to the prominent role it is assigned in EU regional development strategies.

Several studies analyse the effect of public capital accumulation on Italian economic growth[8]. Ferri and Mattesini (1997) use kilometres of road per square kilometres, together with the ratio of highway kilometres to total kilometres of roads, to test the effect of public infrastructures on Italian provinces' economic growth during 1970-90. They find a significant positive relationship between highway endowment and provincial growth for Italy as a whole but a non significant relationship for the Centre-North and the South when examined separately.

An empirical analysis by CERTeT and Università Commerciale Bocconi (2006) considers the effect of the localization of a highway tollgate on the respective municipality's growth[9]. The majority of the tollgates were opened in Italy during the '60s and '70s (219 and 192, respectively)[10]. The study finds that municipalities where a tollgate had been introduced grew in the following period more than others in the same province.

2.2 The "highway effect" and accessibility

The studies quoted in the previous paragraph use infrastructure stock data which does not take into account the network character of transport infrastructure: transport infrastructure essentially changes accessibility to markets for both producers and input suppliers. Crescenzi and Rodriguez Pose (2012) emphasize that the kilometres of highways say little about the different quality and condition of the roads. Some important aspects that presumably affect accessibility, like the number of lanes or the level of congestion, cannot be identified. The increase in the length of highways is only an approximation of the services provided by new transport infrastructure investments. Tollgates form an interaction point between the highway network and the local economic system, and so the number of tollgates can be considered a better proxy of the "highway effect" than kilometres of highway. Nevertheless, it does not take into account the network character of transport infrastructure. Accessibility measures, when available, are highly affected by relevant infrastructural bottlenecks, by the quality of the infrastructure actually built and by its integration with other modes of transport [11].

A recent study of the Bank of Italy (Alampi and Messina 2012) provides an index that uses transport time as an instrument to measure infrastructural endowment at the provincial level. This index may help in analysing the impact of the Italian highway programme of the '60s as it is based on the concept of potential market, that is an area's capacity to have access to relevant markets (Messina 2007 and 2009)[12]

Alampi and Messina (2012) define and calculate two different road infrastructure indexes: one based on car transport time (I_i^{car}) and one based on truck transport time (I_i^{truck}) for 1970, 1980, 1990, 2000 and 2008. These indexes give precious information at a detailed geographical level on the accessibility impact of highway improvements in Italy over a long period of time.

3. The Italian Nord-South divide: a nonparametric analysis of provinces' per capita income during 1951-2001

As stated above, Italy represents an interesting case study as it is historically characterised by a huge Nord-South divide. Italy's per capita income dynamics in the decades that followed the relevant Italian highway investments of the '60s is analysed at a provincial level by means of nonparametric techniques. The results of the stochastic kernel analysis are presented in Figure 1[13]. The analysis uses data on Italian provincial per capita value added obtained by the Istituto Tagliacarne. Italian provinces correspond to Eurostat NUTS-3 level; some descriptive statistics are shown in Table 1. Over the period considered (1951-2001)[14] the total number of provinces changed as new ones were created, therefore the sample includes only 88 administrative units, some of which are the result of an aggregation[15].

Table 1: Descriptive statistics of per capita income (value added) in the 88 Italian provinces (logs)

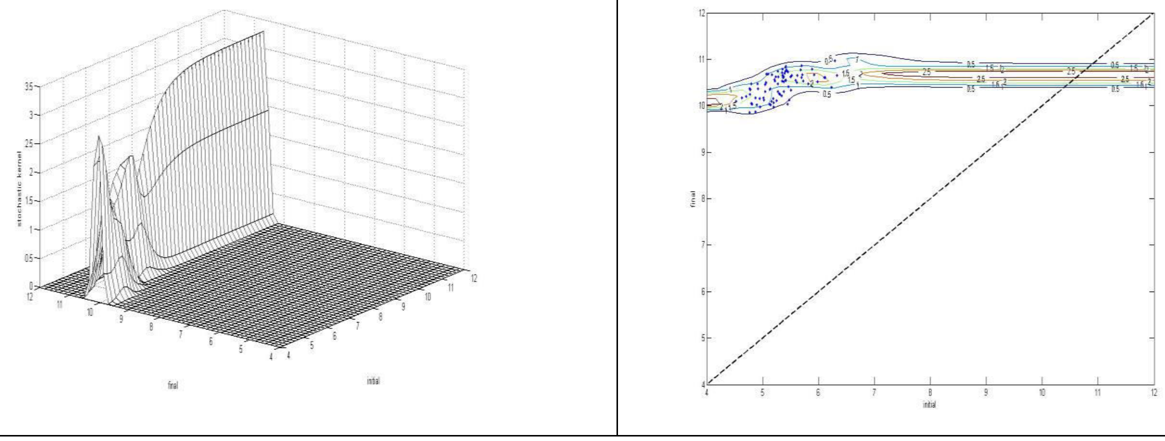
Year	Obs	Mean	Std. Dev.	Min	Max
1951	88	5.30	0.38	4.53	6.33
1961	88	6.12	0.30	5.42	6.79
1971	88	7.06	0.25	6.43	7.56
1981	88	7.07	0.34	6.43	9.16
1991	88	8.94	0.30	8.35	10.25
2001	88	10.00	0.25	9.49	10.65

Descriptive statistics in Table 1 show a fast growth of the mean per capita income completed with a fall in its standard deviation during the '50s and '60s (the years of the "Italian Miracle"), and a stagnation of the mean per capita income together with a rise in the standard deviation during the '70s-'80s, the years of the oil shock. During the following two decades per capita income increased and the standard deviation fell.

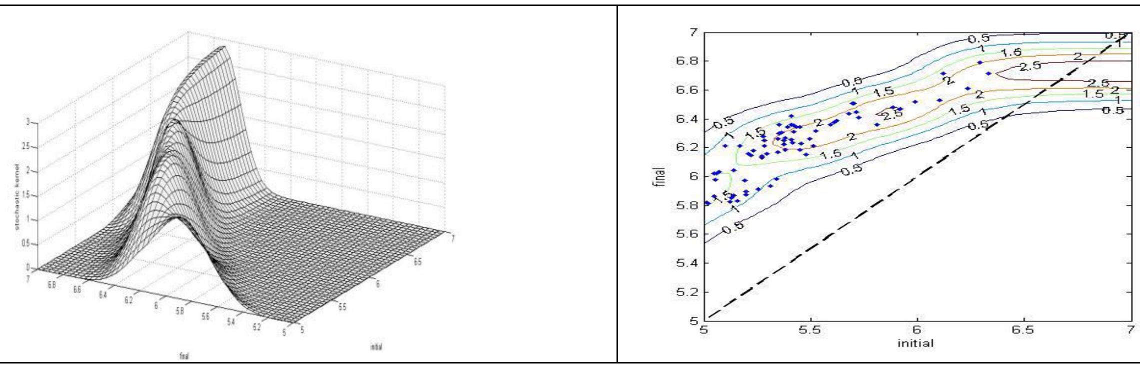
The nonparametric analysis of convergence shows the evolution over time (from time t to time $t + k$) of the per capita income distribution. It is a sort of transition probability matrix with continuous classes of income [16].

With reference to the analysis of income convergence, stochastic kernel density shows persistence of income if the bulk of the distribution lies along the main diagonal, and convergence if the distribution appears to collapse around a single value at time $t + k$. Figure 1 reports the evolution of per capita income dynamics of Italian provinces from 1951 to 2001. The stochastic kernel referring to the whole period 1951-2001 shows a significant convergence process, but a particular feature in the distribution can be seen. Higher income provinces in the contour plots tend to clearly converge (the distribution appears to collapse around a single value) while for a significant part of lower income provinces the distribution suggests that the convergence process is not yet complete. Graphically this can be noticed in the part of the kernel distribution (signalled with the dashed circle) which is not parallel to the horizontal axis, but rather to the main diagonal. Stochastic kernel densities referred to the decades of the so-called “Economic Boom”, i.e. 1951-61 and 1961-71, suggest a process of convergence, since a large part of the distribution tends to rotate becoming almost parallel to the horizontal axis. In contrast, the shape of the kernel for 1971-81 clearly shows two peaks where the greatest part of observations are concentrated. This can be interpreted as the building up of two convergence clubs. One group of provinces, initially with lower per capita incomes (Southern provinces), tends to converge to a lower steady state while the other group, with a relatively higher initial per capita income (Northern and Central provinces) seemingly converges to a higher level of income. This occurs also over 1981-1991. Finally, the kernel for 1991-2001 is significantly concentrated along the main diagonal, indicating strong persistence of income. The graph also in this case shows the presence of two different groups of observations.

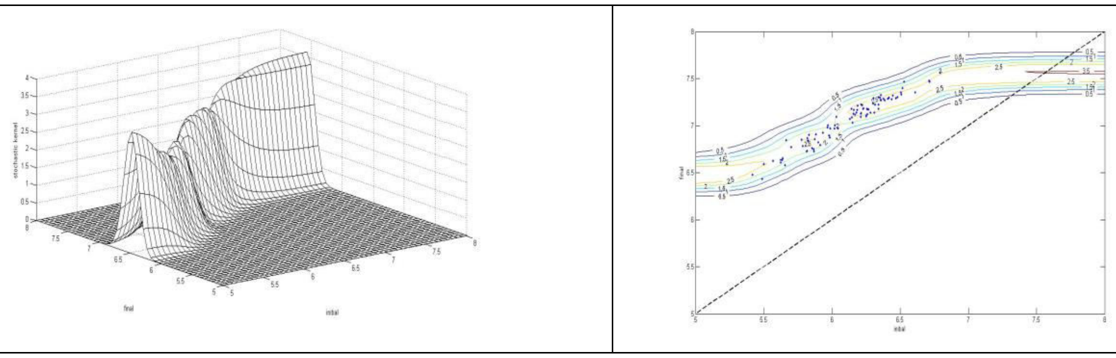
Figure 1 Stochastic kernel densities per capita income of Italian provinces



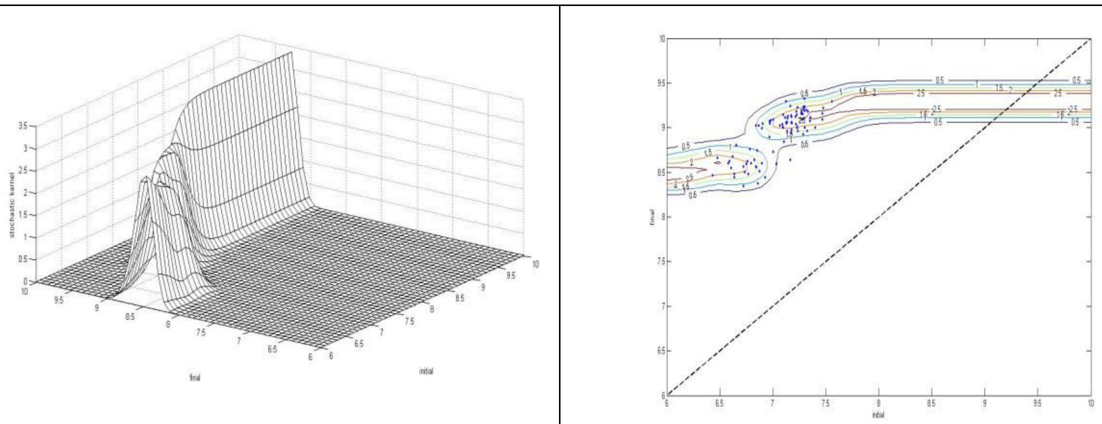
1951-2001



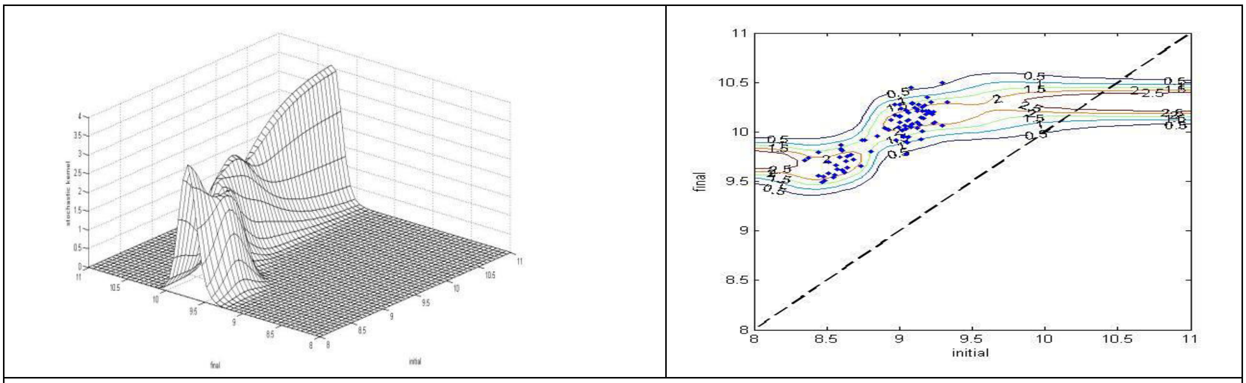
1951-1961



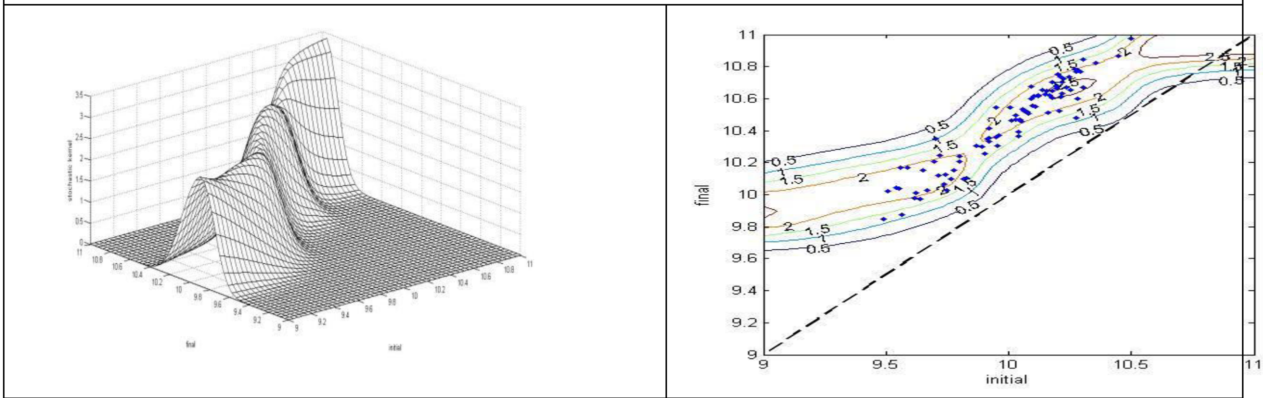
1961-1971



1971-1981



1981-1991



1991-2001

The kernels show that during the ‘70s in Italy, notwithstanding the brand new highway network, the intense Government subsidization programs in favour of Southern provinces (that had a major impulse in the late ‘60s and early ‘70s) and the fact that the oil shock affected mainly the richer and more industrialized part of the country, a strong polarisation emerged.

4. Conditional *beta* convergence and the “highway effect”: a spatial approach

The conditional *beta* convergence analysis using spatial econometrics tools presented in this Section is aimed at evaluating whether provinces that became more accessible thanks to the highway investments during the ‘60s later grew more than others. This is done by introducing variables measuring the presence of highway infrastructures. Furthermore the analysis allows to rigorously test for the formation of two separate spatial regimes (Centre North and South) in Italy during the ‘70s.

4.1 Econometric specification

The spatial econometric analysis has two main goals: (1) to take into account the presence of spatial autocorrelation and (2) to test for the presence of spatial regimes. To this end, we start adopting the so-called Spatial Durbin model (SDM) which is a general model that includes, together with the explanatory variables, not only the spatially lagged dependent variable, but also the spatially lagged independent variables (Lesage and Pace, 2009; Elhorst, 2010; 2014; LeSage and Fisher, 2008). SDM takes the following form:

$$Y = WY\rho + \alpha\iota_n + X\beta + WX\theta + \varepsilon \qquad (1)$$

where Y denotes an n by 1 vector of observed per capita income growth rates (one observation for every spatial unit of the dependent variable), X is a n by k matrix of explanatory variables not including the intercept vector, represented by ι. n represents the number of Italian provinces, k is the number of explanatory variables. The matrix W is an n by n non-stochastic and non-negative spatial weight matrix. The elements of W are needed to denote the spatial dependence structure between observations. In fact, a vector or matrix pre-multiplied by W represents its spatially lagged value, ρ, β and θ are response parameters, and ε is a n by 1 normally distributed, constant variance vector of residuals with zero mean and variance σ^2. In particular, the so-called 'spatial lag' vector WY is a linear combination of per capita income growth rates from contiguous provinces[17]. It captures spatial dependence in Y and the parameter ρ specifies a measure of the impact of adjacent provinces' growth rate on the growth rate measured for a certain province i. The parameter ρ must be a scalar less than unity and in a spatial growth regression we would expect a positive value (LeSage and Fisher, 2008).

Aside from the advantage due to its generality, the choice of the SDM model has two main reasons that are based on the fact that, in spatial analysis of growth and convergence, two issues are most likely to occur. The first is the possible presence of spatial dependence in the residuals of the OLS model (Abreau et al, 2004)[18]; the second is the potential existence of unobserved factors, that is omitted independent variables that could be spatial dependent and/or correlated with one or more variables included in the model. The latter could possibly be controlled by using the initial values of the explanatory variables in neighbouring areas as proxies. The Spatial Durbin Model allows for this to be done.

Furthermore, the use of an SDM specification in the regional growth regression analysis of growth is deeply supported in economic theory. For instance, Ertur and Koch (2007), by developing an endogenous growth model with spatial knowledge spillovers, have shown how the convergence equation takes exactly the form of an SDM model, including both the spatial lags of the dependent variable (the income growth rate) and of the initial income level[19].

The Spatial Durbin model is quite a general specification since it encompasses some of the models mostly used in regional literature. In particular, imposing the restriction that $\theta=0$ leads to a spatial autoregressive (SAR) model that contains only a spatial lag of the endogenous variable from connected regions. Imposing the restriction that $\theta=-\rho\beta$ yields the spatial error model (SEM) that does not take into account the problem of omitted variables and allows spatial dependence only in the residuals. A spatially lagged *X* regression model (SLX) is obtained posing the restriction that $\rho=0$. In this very simple model independence between the regional dependent variables is presumed, but features from related regions in the form of explanatory variables are taken into account. Finally, imposing the restriction that $\rho=0$ and $\theta=0$ yields a non-spatial regression model. In the econometric analysis we select the most suitable model on the basis of hypotheses testing[20].

In order to obtain information about the spatial configuration of provincial data the standardized spatial weight matrix *W* is introduced. In this case a distance-based contiguity approach is adopted. The complete description of matrix *W* is presented in Appendix 3[21].

In our spatial growth regression which includes a spatial lag of the dependent and independent variables, a change in a single independent variable in province *i* has a *direct impact* on province *i* itself and an *indirect impact* on other provinces (refer to LeSage and Fischer 2008 for a complete discussion). This is due to the spatial connectivity interactions incorporated in spatial regression models that make an accurate interpretation of the resulting estimates more demanding. Pace & LeSage (2009) provide computationally feasible means of calculating scalar summary measures of these two types of impacts that arise from changes in the explanatory variables in the SDM.

As a final step, the two-regime Spatial Durbin Model is performed[22] to detect for the presence of spatial regimes in Italy during the period 1951-2001[23]. Also in this case OLS (in the switching regression form) is carried out to check if there is still residual spatial autocorrelation in the disturbances.

The analysis is based on an *a priori* choice testing for the presence of different paths of convergence between the Centre-North and the South[24].

Again the spatial analysis is performed selecting the most suitable spatial model among the SDM, SEM and the SLM or SLX. A Spatial Chow Wald test to detect for the presence of spatial breaks is performed (Anselin, 1988) .

4.2 The sample data

Before describing all the set of explanatory variables used in the spatial regression analysis[25] it is important to focus the attention on the description of the variables used in this conditional *beta*-convergence analysis to proxy the so-called "highway effect".

In particular we consider three variables: the number of municipalities where a tollgate is localised (referred to 1950, 1960 and 1970), the share of km of highways per road kilometres in 1971 (Qhigh, that is the variable used by Ferri and Mattesini, 1997) and the truck infrastructural index in 1970 ($I^{truck70}$) described in Section 2. Unfortunately the most informative index $I^{truck70}$ is not available before 1970 but the implementation of the highway plan reported in Table 2 allows to argue that this is not a problem, given that highway improvements between 1970 and 1975 are very small compared to those achieved before 1970.

Table 2 shows that the Italian highway network recorded great improvements between 1959 and 1964 with the opening of portions of the *Autostrada del Sole* (named A1) linking Milan to Naples (see Figure 2). Arguably, the highway from Salerno to Reggio Calabria, that was built between 1964 and 1972, may be considered more a large state road than an actual highway.

Table 2: Development of the Italian highway network before 1975

YEAR	
1924	The route from Milan to the lakes Como and Maggiore is opened. It is the first toll highway in the world
1956	The engineers that are going to project the new *Autostrada del Sole* visit the United States, in order to learn how to build a modern highway. The *Autostrada del Sole* is planned with a four-lane, double-carriageway structure, that becomes the standard design for all other motorways in Italy. In 1956 the pre-existing highway network is very small and characterised by a single-carriageway structure.
1959	The first important segment of the highway, linking Milan to Bologna, is opened to traffic.
1960 (1st Dec)	The segment linking Bologna to Florence is opened to traffic. This segment, crossing the Appennine mountains, is the most "revolutionary" part of the *Autostrada del Sole* as it saw the creation of a connection between the two cities, as opposed to merely the improvement of an existing route. Connections by previous mountain roads were incomparably slower.
1964 (4th Oct)	The segment linking Rome to Naples is opened to traffic. The last segment to be completed is the one between Orvieto and Chiusi in Tuscany. In 1963 the popular magazine “Quattroruote” reports the details of a heated debate that is delaying the works in Tuscany: the magazine names “Fanfani curve” a deviation (visible in Figure 2) of the highway to Arezzo (the town where the Prime Minister at that time, Amintore Fanfani, was born) not justified by geographical reasons. The highway is expected to stimulate growth in a very relevant way and this is causing many municipalities to fight for the localization of a tollgate in their territory.
1964	In addition to A1 two other important pre-war motorways are completed (the Milan-Venice and the Milan-Genoa) and other segments are added (also the first part of the Savona-Torino); the network reaches 1,630 km, i.e. 3.4 times its length of 1956.
1964	The Italian Government decides to finance the project of another highway, linking Salerno to Reggio Calabria.
1966	The segment of the Salerno-Reggio Calabria highway between Salerno and Lagonegro is opened to traffic.
1968	The segment of the Salerno- Reggio Calabria highway between Lagonegro and Cosenza is opened to traffic.
1969	The segment of the Salerno-Reggio Calabria highway between Cosenza and Gioia Tauro is opened to traffic.
1972	The last segment of the Salerno-Reggio Calabria highway (between Gioia Tauro and Reggio Calabria) is opened to traffic. The highway looks more like a large State road than an actual highway: it is a rather narrow double-carriageway road without an emergency lane.
1975	Act n. 492/1975 art.18 bis abruptly stops the building of new highways, as a consequence of the 1973 oil crisis. The highway network reaches 4,900 km. 1975 can thus be considered the end point of the Italian highways’ golden age.

Figure 2: The *Autostrada del Sole*

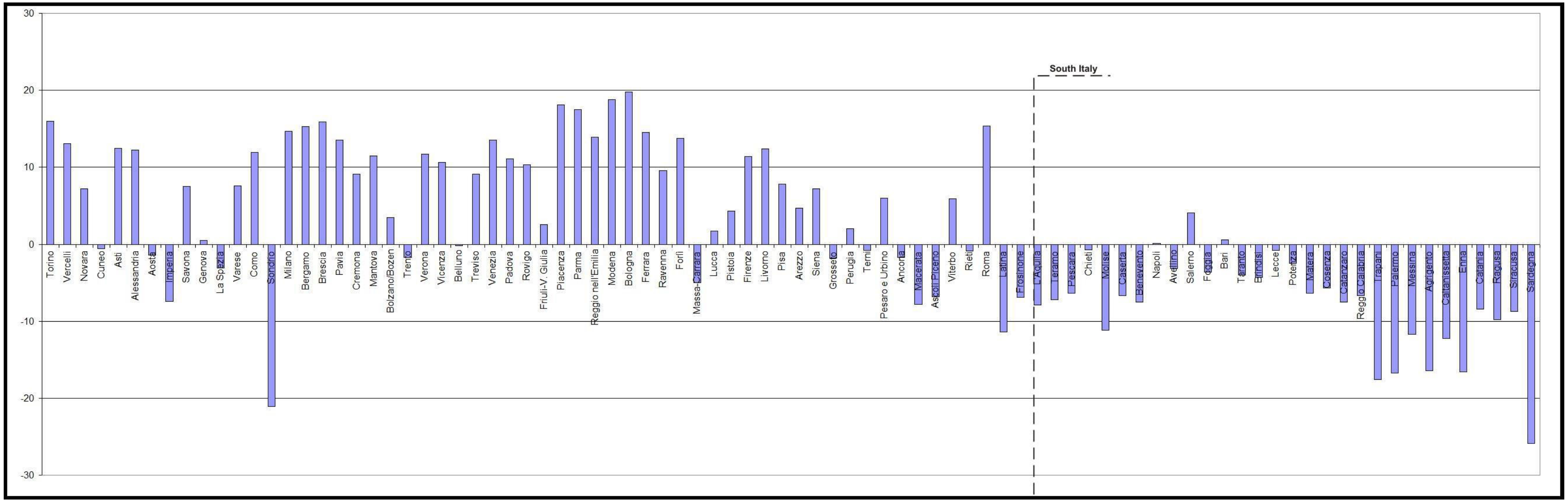
Summary statistics reported in Table 3 show that the number of tollgates per province increased dramatically during the ‘50s and ‘60s. In 1970, the index $I^{truck70}$ was much higher in the Centre-North than in the South and its standard deviation was smaller in the South. The index $I^{truck70}$ is particularly important since time distances fell in a very relevant way after the opening of the *Autostrada del Sole:* before 1964 a truck took two days to go from Milan to Naples while afterwards it took less than ten hours. The Government’s aim to make Southern provinces less peripheral was actually achieved. The correlation between the index $I^{truck70}$ and the variable share of km of highways per road kilometres (1971) is very low (0.04)[26] while the correlation between the variable $I^{truck70}$ and the variable tollgate (referred to 1970) is much higher (0.36).

Table 3: Summary statistics of the “highway effect” proxies

Variable	Obs	Mean	Std. Dev.	Min	Max
Tollgates (50)	88	0.66	2.01	0.00	14.00
Tollgates (60)	88	2.67	3.20	0.00	15.00
Tollgates (70)	88	4.22	3.68	0.00	15.00
Share of highways Km on total KM - Qhigh (71)	88	0.01	0.01	0.00	0.06
$I^{truck70}$	88	101.54	10.35	74.10	119.80
$I^{truck70}$ *Centre-North*	58	106.33	8.61	78.90	119.80
$I^{truck70}$ *South****	30	92.28	6.39	74.09	104.10

Figure 3 shows the values of the index in more detail. Most Northern provinces show values significantly higher than the mean. Only five among Central provinces have values significantly lower than the mean. On the contrary, the only province south of Rome showing a value of the index significantly above the mean is Salerno (that was linked to Naples since 1961[27] by a highway and was therefore the actual end point of the *Autostrada del Sole).*

Figure 3: The infrastructural index based on truck transport time in 1970 (*$I^{truck70}$- 100*)



Note: Italian provinces are ordered by geographical latitude from North to South. The values of the indexes are those reported in Alampi and Messina (2012) except for those referring to the provinces that had been divided in two or more provinces after 1970. Values for Vercelli, Novara, Milano, Forlì, and Firenze are therefore the average of the indexes of the provinces they include weighted by each's surface. The same methodology is used to obtain the indexes for the regions Friuli V. Giulia, Molise and Sardegna.

Other variables used in this parametric analysis[28], in addition to provincial per capita income and those proxying the highways effect, include: the illiteracy rate, the activity rate, the share of employees in the manufacturing sector, the share of employees in large firms, the density of the population, the density of bank branches, per capita telephone lines and roads length (description of variables in Appendix 5 and summary statistics in Table 4)[29].

Table 4: Descriptive statistics of the other auxiliary variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Illiteracy rate (51)	88	11.91	8.25	0.61	27.61
Illiteracy rate (61)	88	8.40	6.87	0.45	43.16
Illiteracy rate (71)	88	5.08	3.94	0.27	13.39
Density of population (51)	88	192.39	205.56	28.86	1777.02
Density of population (61)	88	204.31	245.38	30.95	2067.44
Density of population (71)	88	219.31	284.99	33.49	2316.47
Activity rate (51)	88	0.44	0.052	0.33	0.57
Activity rate (61)	88	0.41	0.054	0.28	0.55
Activity rate (71)	88	0.35	0.04	0.25	0.42
Share manuf. employees (51)	88	0.09	0.09	0.03	0.60
Share manuf. employees (61)	88	0.16	0.12	0.04	0.78
Share manuf. employees (71)	88	0.21	0.05	0.02	0.30
Share employees large firms (51)	88	0.08	0.13	0.00	0.63
Share employees large firms (61)	88	0.09	0.12	0.00	0.61
Share employees large firms (71)	88	0.13	0.13	0.00	0.67
Per capita bank branches (51)	88	0.18	0.09	0.04	0.48
Per capita bank branches (61)	88	0.21	0.09	0.05	0.51
Per capita bank branches (71)	88	0.23	0.27	0.18	1.54
Per capita telephone lines (51)	88	4.62	3.38	0.97	21.73
Per capita telephone lines (61)	88	14.40	6.45	5.04	43.99
Per capita telephone lines (71)	88	23.5	4.06	10.09	70.07
Roads (51)	88	6.53	3.52	1.45	19.50
Roads (61)	88	7.41	3.45	2.05	19.50
Roads (71)	88	11.04	4.26	4.09	20.97

4.5 Estimation results and discussion

Direct and indirect effects coming from SDM specification are reported in Table 5 together with the OLS coefficients. The results of Moran's I test on the OLS errors show evidence of residual spatial autocorrelation, confirming the need for a spatial specification for the conditional *beta*-convergence analysis. The only exception is for the period 1961-1971 where the analysis is based only on a non-spatial regression. These results are corroborated by Lagrange Multiplier (LM) tests and their robust versions used to test the OLS versus the SAR and SEM. Likelihood ratio (LR) tests used for testing the SAR and SEM versus the SDM suggest that the SDM is preferred to SEM or SAR models in all periods where a spatial specification is needed.

In the Spatial Durbin specification for the whole period 1951-2001 (column 1a) all the direct effects are significant and have the expected sign, except the activity rate and the share of employees in manufacture. The relative road endowment, measured by its length in 1951, has a positive impact on growth (direct and indirect effects are significantly different from zero at a conventional level), whereas the presence of tollgates only directly affects positively and significantly subsequent growth.

In all the regressions relative to the period 1971-2001 (columns 2, 2a, 3, 3a, 4, 4a) growth rates are negatively influenced by the illiteracy rates and positively influenced by activity rates as shown by OLS coefficient and SDM direct effects. Road endowment shows a positive and significant SDM direct effect (column 2a) whereas for the variables tollgates and the share of highways per km^2 (Qhigh) there is no evidence of significant influence on per capita income growth (results in columns 2, 2a, 3, 3a). The variable $I^{truck70}$ affects significantly and positively provincial growth (columns 4 and 4a): the direct effect is significantly different from zero at a conventional level.

When we look at the results for the different decades we notice that the ‘50s (columns 5 and 5a) were years of relatively high convergence and spatial dependence of provincial growth rates (the spatially lagged dependent variable coefficient ρ is significant and quite high). The conditional β–convergence coefficient in the OLS and the direct effect in the Spatial Durbin model are higher in 1951-1961 than in 1951-2001. Results reported in column 6 show that during the ‘60s there is still a significant convergence process, but at a much lower rate than in the previous decade. Furthermore all the tests are against the opportunity of using a spatial model. During the ‘70s (columns 7, 7a) the conditional convergence coefficients (OLS and direct effects in SDM) are again high (above those reported in columns 2, 2a, 3, 3a, for 1971-2001) and the spatially lagged dependent variable coefficient ρ points to a significant spatial dependence among provincial growth rates.

Table 5: Conditional convergence in Italian provinces

	1951-2001				1971-2001 (A)				1971-2001 (B)			
	OLS	Spatial Durbin			OLS	Spatial Durbin			OLS	Spatial Durbin		
	Coef.	Direct	Indirect	Total	Coef.	Direct	Indirect	Total	Coef.	Direct	Indirect	Total
	1	*1°*	*1b*	*1c*	*2*	*2a*	*2b*	*2c*	*3*	*3a*	*3b*	*3c*
Constant	0.203				0.320				0.322			
	0.000				*0.000*				*0.000*			
Initial per capita VA	-0.018	-0.019	-0.006	-0.025	-0.026	-0.029	-0.012	-0.041	-0.027	-0.029	0.022	-0.007
	0.000	*0.000*	*0.334*	*0.000*	*0.000*	*0.000*	*0.847*	*0.527*	*0.000*	*0.000*	*0.809*	*0.935*
Illiteracy rate	-0.001	-0.002	0.003	0.002	-0.003	-0.003	-0.004	-0.007	0.003	-0.003	-0.001	-0.004
	0.049	*0.033*	*0.349*	*0.588*	*0.000*	*0.002*	*0.721*	*0.512*	*0.000*	*0.001*	*0.973*	*0.835*
Density of population	-0.002	-0.002	-0.007	-0.009	0.000	0.000	-0.023	-0.023	0.000	0.000	-0.019	-0.019
	0.002	*0.015*	*0.163*	*0.083*	*0.924*	*0.600*	*0.447*	*0.445*	*0.659*	*0.871*	*0.587*	*0.594*
Activity rate	0.002	0.004	-0.011	-0.007	0.024	0.020	-0.018	0.002	0.024	0.022	0.045	0.067
	0.549	*0.290*	*0.494*	*0.656*	*0.000*	*0.000*	*0.787*	*0.971*	*0.000*	*0.000*	*0.715*	*0.588*
Share manuf. employees	-0.001	0.000	-0.001	-0.000	0.000	0.000	0.004	0.003	0.000	0.014	-0.009	0.014
	0.356	*0.691*	*0.912*	*0.949*	*0.663*	*0.517*	*0.745*	*0.781*	*0.598*	*0.666*	*0.776*	*0.674*
Share employees large firms	0.001	0.001	0.002	0.002	0.000	0.000	0.008	0.008	0.000	0.000	0.018	0.018
	0.003	*0.001*	*0.230*	*0.176*	*0.838*	*0.828*	*0.417*	*0.425*	*0.783*	*0.407*	*0.544*	*0.539*
Per capita bank branches	0.000	0.001	0.010	0.011	-0.001	-0.002	-0.025	-0.027	-0.001	-0.002	-0.035	-0.037
	0.404	*0.062*	*0.045*	*0.039*	*0.307*	*0.069*	*0.560*	*0.533*	*0.357*	*0.127*	*0.608*	*0.690*
Per capita telephone lines	0.003	0.001	-0.005	-0.004	0.004	0.005	0.018	0.023	0.004	0.003	-0.004	-0.001
	0.000	*0.017*	*0.210*	*0.393*	*0.041*	*0.020*	*0.705*	*0.641*	*0.038*	*0.135*	*0.939*	*0.984*
Road infrastructural index($I^{truck70}$)												
Km of roads (Roads)	0.004	0.002	0.018	0.020	0.002	0.003	0.045	0.048	0.002	0.001	-0.001	0.000
	0.000	*0.008*	*0.005*	*0.003*	*0.213*	*0.097*	*0.458*	*0.439*	*0.105*	*0.376*	*0.964*	*0.993*
Tollgates	0.000	0.000	0.001	0.001	0.000	0.000	-0.005	-0.005				
	0.858	*0.090*	*0.718*	*0.613*	*0.280*	*0.740*	*0.416*	*0.419*				
Share of highways Km on total KM (Qhigh)									0.061	0.056	-0.386	-0.320
									0.135	*0.178*	*0.770*	*0.807*
R-squared	0.867			0.933	0.553			0.749	0.561			0.707
Rho				0.408				0.635				*0.717*
				0.021				*0.000*				*0.000*
Moran's I test (errors)				0.240				0.304				0.300
				0.000				*0.000*				*0.000*
LM(error)				28.502				45.974				44.618
				0.000				*0.000*				*0.000*
R-LM(error)				10.530				22.380				20.569
				0.000				*0.000*				*0.000*
LM(lag)				27.702				23.737				24.162
				0.000				*0.000*				*0.000*
R-LM(lag)				9.722				0.323				0.113
				0.000				*0.569*				*0.737*
LR(lag)				37.625				37.900				28.566
				0.000				*0.000*				*0.000*
LR(error)				29.038				19.789				13.123
				0.000				*0.000*				*0.000*
LIK				470.7				426.3				422.4

Notes: N = 88 observations. *p* values in italics; *LIK:* value of the maximum likelihood function; *LM(error)and R-LM(error)*: Lagrange Multiplier test for residual spatial autocorrelation and its robust form. *LM(lag)and R-LM(lag):* Lagrange Multiplier test for spatially lagged dependent variable and its robust form. . LR(lag) and LR(error) test respectively the spatial lag and the spatial error model versus the spatial Durbin.

Table 5: Continued

	1971-2001 (C)				1951-1961				1961-71	1971-1981			
	OLS	Spatial Durbin			OLS	Spatial Durbin			OLS	OLS	Spatial Durbin		
	Coef.	Direct	Indirect	Total	Coef.	Direct	Indirect	Total		Coef.	Direct	Indirect	Total
	4	*4a*	*4b*	*4c*	*5*	*5°*	*5b*	*5c*	*6*	*7*	*7a*	*7b*	*7c*
Constant	0.304				0.282				0.233	0.575			
	0.000				*0.000*				*0.000*	*0.000*			
Initial per capita VA	-0.026	-0.030	-0.006	-0.035	-0.037	-0.040	-0.037	-0.003	-0.019	-0.047	-0.065	0.023	-0.040
	0.000	*0.000*	*0.911*	*0.485*	*0.000*	*0.000*	*0.781*	*0.980*	*0.000*	*0.000*	*0.000*	*0.857*	*0.763*
Illiteracy rate	-0.003	-0.003	-0.005	-0.008	-0.004	-0.003	0.049	0.046	0.000	-0.004	0.000	-0.032	-0.032
	0.000	*0.001*	*0.656*	*0.442*	*0.032*	*0.249*	*0.625*	*0.650*	*0.616*	*0.032*	*0.877*	*0.360*	*0.370*
Density of population	-0.000	0.001	-0.018	-0.017	-0.006	-0.000	-0.034	-0.034	-0.006	-0.005	-0.005	-0.035	-0.039
	0.830	*0.334*	*0.525*	*0.544*	*0.009*	*0.962*	*0.668*	*0.670*	*0.000*	*0.005*	*0.016*	*0.432*	*0.381*
Activity rate	0.017	0.018	-0.012	0.006	-0.003	0.007	-0.048	-0.041	-0.009	0.071	0.063	0.021	0.084
	0.002	*0.001*	*0.906*	*0.949*	*0.830*	*0.617*	*0.837*	*0.862*	*0.158*	*0.000*	*0.000*	*0.911*	*0.659*
Share manuf. employees	0.000	0.000	0.012	0.012	-0.005	-0.005	-0.041	-0.046	0.001	0.002	0.004	0.030	0.034
	0.894	*0.532*	*0.489*	*0.482*	*0.193*	*0.187*	*0.752*	*0.728*	*0.770*	*0.316*	*0.091*	*0.638*	*0.605*
Share employees large firms	0.002	0.002	-0.014	-0.012	0.001	0.001	0.011	0.012	0.001	0.001	0.000	-0.002	-0.002
	0.232	*0.218*	*0.519*	*0.585*	*0.144*	*0.179*	*0.732*	*0.708*	*0.200*	*0.413*	*0.780*	*0.914*	*0.930*
Per capita bank branches	-0.001	-0.002	-0.015	-0.016	0.001	0.003	0.065	0.068	0.000	0.002	0.006	0.052	0.057
	0.275	*0.186*	*0.680*	*0.655*	*0.538*	*0.303*	*0.614*	*0.606*	*0.843*	*0.409*	*0.111*	*0.620*	*0.599*
Per capita telephone lines	0.000	0.000	0.008	0.008	0.003	0.000	0.051	0.051	-0.001	-0.011	-0.014	-0.076	-0.090
	0.780	*0.533*	*0.641*	*0.634*	*0.267*	*0.930*	*0.599*	*0.607*	*0.621*	*0.014*	*0.003*	*0.617*	*0.560*
Road infrastructural index ($I^{truck70}$)	0.000	0.000	0.001	0.001						0.001	0.001	0.001	0.001
	0.003	*0.019*	*0.495*	*0.442*						*0.001*	*0.000*	*0.825*	*0.687*
Km of roads (Roads)					0.016	0.006	0.071	0.077	0.004				
					0.000	*0.037*	*0.466*	*0.434*	*0.103*				
Tollgates					0.000	0.001	0.010	0.010	0.000				
					0.863	*0.288*	*0.695*	*0.680*	*0.271*				
Share of highways Km on total KM (Qhigh)													
R-squared	0.583			0.746	*0.748*			0.841	0.600	0.656			0.710
Rho				*0.52*				0.686					0.503
				0.000				*0.000*					*0.003*
Moran's I test (errors)				0.278				0.231	0.013				0.205
				0.000				*0.000*	*0.234*				*0.000*
LM(error)				38.087				26.384	0.083				20.712
				0.000				*0.000*	*0.773*				*0.000*
R-LM(error)				13.608				6.679	0.402				6.775
				0.000				*0.010*	*0.526*				*0.009*
LM(lag)				24.680				24.472	0.015				14.678
				0.000				*0.000*	*0.902*				*0.000*
R-LM(lag)				0.201				4.767	0.334				0.742
				0.654				*0.029*	*0.563*				*0.389*
LR(lag)				27.325					36.121				23.615
				0.000					*0.000*				*0.000*
LR(error)				15.970					22.107				16.400
				0.000					*0.000*				*0.000*
LIK				423.9				360.1	360.4				*333.0*

Notes: N = 88 observations. *p* values in italics; *LIK:* value of the maximum likelihood function; *LM(error)and R-LM(error)*: Lagrange Multiplier test for residual spatial autocorrelation and its robust form. *LM(lag)and R-LM(lag):* Lagrange Multiplier test for spatially lagged dependent variable and its robust form. . LR(lag) and LR(error) test respectively the spatial lag and the spatial error model versus the spatial Durbin.

In order to rule out the possibility that the results could be affected by the problem of reverse causality between infrastructural investments and growth, we look at the correlation between the variable $I^{truck70}$ and provincial per capita income distribution. The correlation coefficient between $I^{truck70}$ and provincial per capita income in 1961 is 0.64. It remains practically unchanged (0.63) if calculated between $I^{truck70}$ and provincial per capita income in 1971 (0.63) while it grows significantly if calculated between $I^{truck70}$ and provincial per capita income in 1981 (0.75). Results therefore suggest that reverse causality should not be an issue in this case.

The picture arising from the results reported in Table 5 seems to present a growing Italy with peculiar features prevailing in each decade taken into consideration. In particular:

- during the ‘50s growth rates are spatially dependent and provincial road endowment significantly affects growth rates;
- during the ‘60s growth rates are no longer spatially dependent[30] and road endowment is no more significant;
- finally, during the ‘70s growth rates are again spatially dependent and the index $I^{truck70}$ affects growth significantly.

During the ‘70s Italy returned towards a situation that appears to resemble the one in the ‘50s (high convergence and high spatial dependence). The kernel analysis reported in Section 3 shows an evident club convergence process starting during the ‘70s. It is therefore interesting to look at the results of the regime switching regressions for the two sub-periods 1951-2001 and 1971-2001.

Table 6 reports the outcomes of the OLS switching regression; they indicate that also in this case the most suitable spatial model (when applicable) is the SDM model. Results from spatial Chow Wald test in all regressions show evidence of the presence in Italy of two spatial regimes (Centre-North and South) in the convergence process in the period under examination.

Table 6: Conditional convergence with regime switching in Italian provinces :1951-2001

	1951-2001				1971-2001 (A)			
	OLS	Spatial Durbin			OLS	Spatial Durbin		
	Coef.	Direct	Indirect	Total	Coef.	Direct	Indirect	Total
	1	*1a*	*1b*	*1c*	*2*	*2a*	*2b*	*2c*
Constant - CN	0.202				0.394			
	(0.000)				(0.000)			
Constant - S	*0.223*				*0.372*			
	(0.000)				(0.000)			
Initial per capita VA-CN	-0.020	-0.019	-0.012	-0.031	-0.036	-0.030	-0.015	-0.045
	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)	(0.000)	(0.421)	(0.013)
Initial per capita VA -S	*-0.019*	*-0.019*	*0.000*	*-0.019*	*-0.035*	*-0.035*	*0.020*	*-0.016*
	(0.000)	(0.000)	(0.971)	(0.010)	(0.000)	(0.000)	(0.427)	(0.556)
Illiteracy rate-CN	-0.001	-0.002	0.005	0.003	-0.002	-0.003	0.001	-0.002
	(0.142)	(0.001)	(0.003)	(0.038)	(0.004)	(0.001)	(0.584)	(0.319)
Illiteracy rate-S	*-0.004*	*-0.002*	*-0.002*	*-0.004*	*-0.004*	*-0.007*	*0.015*	*0.008*
	(0.111)	(0.201)	(0.760)	(0.514)	(0.501)	(0.190)	(0.583)	(0.789)
Density of population -CN	0.000	-0.001	-0.003	-0.032	0.002	0.000	0.002	0.002
	(0.965)	(0.317)	(0.415)	(0.254)	(0.035)	(0.818)	(0.644)	(0.616)
Density of population- S	*-0.003*	*-0.002*	*-0.011*	-0.028	*-0.003*	*-0.001*	*-0.025*	*-0.026*
	(0.010	(0.022)	(0.006)	(0.047)	(0.033)	(0.459)	(0.026)	(0.025)
Activity rate-CN	0.002	0.012	-0.040	*-0.009*	0.027	0.030	-0.017	0.013
	(0.706)	(0.005)	(0.009)	(0.401)	(0.000)	(0.000)	(0.461)	(0.527)
Activity rate-S	*0.002*	*-0.008*	*-0.001*		*0.000*	*0.012*	*-0.019*	*-0.006*
	(0.680)	(0.305)	(0.926)		(0.970)	(0.184)	(0.770)	(0.918)
Share manufact. employees -CN	-0.002	-0.001	0.003	0.001	0.000	-0.001	-0.003	-0.004
	(0.130)	(0.075)	(0.367)	(0.605)	(0.729)	(0.155)	(0.433)	(0.349)
Share manufact. employees -S	*0.001*	*0.003*	*-0.008*	*-0.005*	*-0.002*	*0.001*	*0.001*	*0.002*
	(0.822)	(0.391)	(0.539)	(0.730)	(0.239)	(0.706)	(0.891)	(0.853)
Share employees large firms -CN	0.001	0.001	0.002	0.003	0.004	0.004	-0.002	0.002
	(0.028)	(0.000)	(0.053)	(0.009)	(0.095)	(0.016)	(0.845)	(0.817)
Share employees large firms -S	*0.000*	*0.001*	*-0.001*	*-0.001*	*0.003*	*-0.001*	*-0.020*	*-0.021*
	(0.130)	(0.948)	(0.427)	(0.486)	(0.451)	(0.766)	(0.390)	(0.398)
Per capita bank branches -CN	0.000	0.000	0.010	0.010	-0.001	-0.001	-0.010	-0.012
	(0.707)	(0.737)	(0.000)	(0.000)	(0.464)	(0.179)	(0.100)	(0.120)
Per capita bank branches -S	*0.001*	*0.002*	*-0.002*	*-0.001*	*-0.002*	*-0.003*	*0.003*	*-0.001*
	(0.501)	(0.026)	(0.572)	(0.850)	(0.121)	(0.029)	(0.822)	(0.952)
Per capita telephone lines-CN	0.002	0.002	-0.001	0.000	0.000	0.000	-0.001	-0.002
	(0.004)	(0.000)	(0.530)	(0.857)	(0.916)	(0.435)	(0.554)	(0.514)
Per capita telephone lines-S	*0.001*	*0.001*	*-0.004*	*-0.003*	*0.000*	*0.000*	*0.009*	*0.009*
	(0.322)	(0.506)	(0.529)	(0.675)	(0.911)	(0.617)	(0.051)	(0.073)
Road infrastructural index ($I^{truck70}$) -CN								
Road infrastructural index ($I^{truck70}$) -S								
Km of roads (Roads) - CN	0.002	0.001	0.012	0.013	-0.002	0.000	0.013	0.013
	(0.024)	(0.150)	(0.001)	(0.000)	(0.294)	(0.782)	(0.160)	(0.200)
Km of roads (Roads) - S	*0.007*	*0.003*	*0.010*	*0.013*	*0.006*	*0.003*	*-0.006*	*-0.003*
	(0.003)	(0.037)	(0.060)	(0.013)	(0.009)	(0.239)	(0.770)	(0.897)
Tollgates-CN	0.000	0.000	0.000	0.001	0.000	0.000	-0.002	-0.002
	(0.310)	(0.000)	(0.598)	(0.265)	(0.788)	(0.350)	(0.013)	(0.027)
Tollgates-S	*0.000*	*0.000*	*0.004*	*0.003*	*0.000*	*0.000*	*0.000*	*0.000*
	(0.460)	(0.286)	(0.100)	(0.195)	(0.123)	(0.897)	(0.967)	(0.958)
Share highways Km on total KM (Qhigh)-CN								
Share highways Km on total KM (Qhigh)-S								
R-squared	0.907			0.966	0.693			0.855
Rho				*-0.128*				*6.360*
				(0.563)				(0.012)
Moran's I test (errors)				0.133				0.113
				(0.000)				(0.000)
LM(error)				8.856				7.424
				(0.003)				(0.006)
R-LM(error)				2.567				0.863
				(0.109)				(0.353)
LM(lag)				13.159				1.676
				(0.000)				(0.195)
R-LM(lag)				6.869				7.173
				(0.009)				(0.007)
LR(lag)				77.953				58.649
				(0.000)				(0.000)
LR(error)				74.640				54.974
				(0.000)				(0.000)
LIK				501.646				447.758
Chow-Wald structural instability test	3.291			61.774	3.510			*43.202*
	(0.001)			(0.000)	(0.001)			*(0.001)*

Notes: $N = 88$ observations. *p* values in parentheses; *LIK:* value of the maximum likelihood function; *LM(error)and R-LM(error)*: Lagrange Multiplier test for residual spatial autocorrelation and its robust form. *LM(lag)and R-LM(lag):* Lagrange Multiplier test for spatially lagged dependent variable and its robust form. . LR(lag) and LR(error) test respectively the spatial lag and the spatial error model versus the spatial Durbin.

Table 6: Continued

	1971-2001 (B)				1971-2001 (C)			
	OLS	Spatial Durbin			OLS	Spatial Durbin		
	Coef.	Direct	Indirect	Total	Coef.	Direct	Indirect	Total
	3	3a	3b	3c	4	4a	4b	4c
Constant - CN	0.399				0.361			
	(0.000)				(0.000)			
Constant - S	0.376				0.357			
	(0.000)				(0.000)			
Initial per capita VA-CN	-0.037	-0.033	0.004	-0.029	-0.036	-0.029	-0.030	-0.059
	(0.000)	(0.000)	(0.890)	(0.334)	(0.000)	(0.000)	(0.024)	(0.000)
Initial per capita VA -S	-0.035	-0.036	0.018	-0.018	-0.035	-0.036	-0.009	-0.045
	(0.000)	(0.000)	(0.645)	(0.671)	(0.000)	(0.000)	(0.564)	(0.013)
Illiteracy rate-CN	-0.002	-0.003	0.005	0.001	-0.092	-0.004	0.000	-0.004
	(0.003)	(0.002)	(0.344)	(0.773)	(0.003)	(0.001)	(0.848)	(0.011)
Illiteracy rate-S	-0.007	-0.008	0.024	0.016	-0.011	-0.007	0.000	-0.008
	(0.080)	(0.052)	(0.682)	(0.787)	(0.006)	(0.043)	(0.923)	(0.383)
Density of population -CN	0.002	0.000	0.007	0.007	0.001	0.001	0.001	0.001
	(0.048)	(0.494)	(0.256)	(0.221)	(0.198)	(0.272)	(0.831)	(0.632)
Density of population- S	-0.003	-0.002	-0.035	-0.037	-0.002	0.002	-0.031	-0.029
	(0.022)	(0.268)	(0.238)	(0.227)	(0.183)	(0.167)	(0.004)	(0.004)
Activity rate-CN	0.027	0.030	-0.033	-0.003	0.019	0.027	-0.017	0.010
	(0.000)	(0.000)	(0.419)	(0.945)	(0.010)	(0.000)	(0.395)	(0.536)
Activity rate-S	0.003	0.012	-0.059	-0.047	-0.003	0.018	-0.056	-0.038
	(0.782)	(0.214)	(0.583)	(0.666)	(0.735).	(0.106)	(0.200)	(0.327)
Share manuf. employees -CN	0.000	-0.001	0.000	0.001	0.000	0.000	0.005	0.005
	(0.680)	(0.071)	(0.988)	(0.605)	(0.728)	(0.541)	(0.126)	(0.119)
Share manuf. employees -S	-0.001	0.000	-0.005	-0.005	-0.003	0.003	0.004	0.006
	(0.332)	(0.950)	(0.741)	(0.756)	(0.056)	(0.145)	(0.594)	(0.353)
Share employees large firms -CN	0.004	0.004	-0.005	0.000	0.003	0.003	-0.009	-0.006
	(0.082)	(0.019)	(0.746)	(0.995)	(0.083)	(0.095)	(0.113)	(0.302)
Share employees large firms -S	0.003	-0.002	-0.040	-0.042	-0.003	-0.002	-0.013	-0.016
	(0.478)	(0.679)	(0.357)	(0.366)	(0.373)	(0.368)	(0.352)	(0.261)
Per capita bank branches -CN	-0.001	-0.002	-0.025	-0.027	0.000	0.000	0.001	0.001
	(0.487)	(0.080)	(0.253)	(0.229)	(0.780)	(0.769)	(0.803)	(0.862)
Per capita bank branches -S	-0.002	-0.004	-0.001	-0.005	0.003	0.002	-0.001	0.002
	(0.220)	(0.050)	(0.943)	(0.784)	(0.065)	(0.046)	(0.925)	(0.846)
Per capita telephone lines-CN	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
	(0.935)	(0.906)	(0.742)	(0.757)	(0.763)	(0.557)	(0.877)	(0.795)
Per capita telephone lines-S	0.000	0.000	0.011	0.012	0.000	0.001	0.006	0.007
	(0.723)	(0.654)	(0.243)	(0.250)	(0.555)	(0.370)	(0.031)	(0.031)
Road infrastructural index ($I^{truck70}$) -CN					0.000	0.000	0.000	0.001
					(0.053)	(0.049)	(0.020)	(0.002)
Road infrastructural index ($I^{truck70}$) -S					0.000	0.000	0.001	0.001
					(0.039)	(0.501)	(0.111)	(0.108)
Km of roads (Roads)- CN	-0.002	0.000	0.004	0.004				
	(0.309)	(0.744)	(0.800)	(0.785)				
Km of roads (Roads)- S	0.007	0.003	-0.010	-0.006				
	(0.002)	(0.226)	(0.777)	(0.864)				
Tollgates-CN								
Tollgates-S								
Share highways Km on total KM (Qhigh) -CN	0.024	0.056	-0.786	-0.730				
	(0.641)	(0.196)	(0.187)	(0.238)				
Share highways Km on total KM (Qhigh) -S	0.100	-0.043	0.437	-0.480				
	(0.153)	(0.573)	(0.720)	(0.703)				
R-squared	0.692			0.856	0.841			0.841
Rho				0.294				-0.225
				(0.133)				(0.343)
Moran's I test (errors)				0.118				0.123
				(0.000)				(0.000)
LM(error)				6.906				7.424
				(0.008)				(0.006)
R-LM(error)				1.264				0.002
				(0.260)				(0.967)
LM(lag)				6.756				14.596
				(0.009)				(0.000)
R-LM(lag)				1.114				7.173
				(0.291)				(0.007)
LR(lag)				61.412				58.499
				(0.000)				(0.000)
LR(error)				54.331				56.546
				(0.000)				(0.000)
LIK				447.311				445.854
Chow-Wald structural instability test	3.321			49.989	2.047			43.839
	(0.001)			(0.001)	(0.041)			(0.001)

Notes: N = 88 observations. *p* values in parentheses; *LIK:* value of the maximum likelihood function; *LM(error)and R-LM(error)*: Lagrange Multiplier test for residual spatial autocorrelation and its robust form. *LM(lag)and R-LM(lag):* Lagrange Multiplier test for spatially lagged dependent variable and its robust form. . LR(lag) and LR(error) test respectively the spatial lag and the spatial error model versus the spatial Durbin.

Regressions include the same explicative variables reported in Table 5 for the whole of Italy. Looking at the direct effect, the Spatial Durbin model shows that for the period 1951-2001 the growth rate is significantly affected in the South by relative road endowment and not by the presence of tollgates (column 1a). In the Centre-North, however, provincial growth is affected only by tollgates, a proxy of road quality, and not by road length. Neither road length nor tollgates (nor the variable Qhigh in 1971) affect later provincial growth in the Centre-North or in the South (column 2a). During 1971-2001 a polarization with high values of the beta parameters can be noted both in the Centre-North and in the South. The Centre-North and the South converge strongly toward different steady states but, surprisingly, only in the North the provinces with a higher $I^{truck70}$ are characterised by a relatively higher growth. Results reported in column 4a show that the variable $I^{truck70}$ significantly and positively affects provincial growth only in the Centre-North both directly and indirectly (column 4b). This result needs further investigation: Southern provinces characterized by a higher road infrastructural endowment in 1951 grew more than the others in the following fifty years but this is no longer true when we consider their relative road infrastructural endowment in 1971 (proxied by road length or by $I^{truck70}$). The change in transportation cost caused by the opening of the *Autostrada del Sole* may have significantly modified the balance between agglomeration and dispersion forces, generating a core-periphery pattern in which Southern province's relative accessibility seems to loose importance.

5.Conclusions

Italian post-war Governments supporting the ambitious project of the *Autostrada del Sole* assumed that, after its opening, the relevant reduction of time distance between the North and the South would have contributed to a reduction in the North-South development gap. However, during the 70s the gap widened.

The unequal endowment of infrastructures in a very delicate phase of Italian economic development may have fostered this polarisation process: in Italy the opening of the *Autostrada del Sole* in 1964 significantly widened the gap between the quality of the road endowment in the lagging provinces of the South and the rest of Italy. The continuation of the highway from Naples toward Reggio Calabria, the most Southern province in continental Italy, was planned only in 1964 and did not give Southern provinces an efficient road network. We are not arguing that the huge highway investment in the 50s and early 60s caused the emergence of the two convergence clubs observed as starting from the 70s. Presumably several factors concurred to increase the North-South gap in Italy during the 70s, but our results suggest that the uneven highway endowment may have been one of these factors. We must emphasise, however, that during the early ‘70s two very important shocks concurred to foster convergence: the oil shock that mainly affected the Northern, more developed part of the country and huge national subsidies that flowed to the Southern, less developed part of the country. Our results show that when the *Autostrada del Sole* was opened during the years of the so-called “Italian economic miracle”, a significant convergence process was occurring in the country as a whole and spatial dependence among local growth rates was weakening. During the ‘70s relative road infrastructural endowment, proxied by the index $I^{truck70}$, significantly affects provincial growth rates but this happens only in the Centre-North (characterized by a much higher road infrastructural endowment with respect to the South).

Regional policies based on infrastructures often risk neglecting the role of geography in influencing growth performance: the change in transportation cost caused by the opening of the *Autostrada del Sole* may have significantly modified the balance between agglomeration and dispersion forces, generating a core-periphery pattern that later transport infrastructure policies were not able to alter. The results presented in this study raise the doubt that if the 1956 project of the *Autostrada del Sole* had linked Milan to Reggio Calabria instead of Naples, maybe Italy would have achieved a less polarised growth process. Further research in this field would help planners and policy makers to evaluate the effects of transport programmes.

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Appendix 1

Bank of Italy (Alampi and Messina 2012) provides an index that uses transport time as an instrument to measure infrastructural endowment at the provincial level. Without transport infrastructure linking the different regions, the only factor determining an area's capacity to have access to relevant markets is geographic distance. The potential market for an area i (i.e. the geographic accessibility index A_i) depends on the geographic distance with respect to all the other areas.

$$A_i = \sum m_j C_{ij} \qquad (1a)$$

Where

$$C_{ij} = f(d_{ij}) \quad \text{and} \quad \partial C_{ij} / \partial d_{ij} < 0 \qquad (2a)$$

Equation (1a) is the definition of accessibility used by New Geographic models; it combines m_j, a proxy of region j's importance (in terms of population or value added) with C_{ij} that is a factor that decreases with the distance d_{ij} between the two areas considered (i.e. C_{ij} falls with the cost of reaching the region j given its geographical position with respect to region i). Alampi and Messina define the following index of accessibility corrected for the transport infrastructure effect:

$$A_i^T = \sum m_j C^T_{ij} \qquad (3a)$$

where

$$C_{ij}{}^T = f(t_{ij}{}^T) \quad \text{and} \quad \partial C_i^T{}_j / \partial t_{ij}{}^T < 0 \qquad (4a)$$

$t_{ij}{}^T$ represents the run time from i to j when the transport of type T is used (car, truck, train, etc.). The idea is that transport speed affects the accessibility perimeter.

The infrastructural index is obtained comparing A_i with A_i^T. Since A_i^T and A_i are not calculated in the same unit of measure, they are indexed with respect to their average values. :

$$I_i^T = A_i^T - A_i \qquad (5a)$$

Index I_i^{car} is calculated using the provincial physical accessibility rates, according to which all possible destinations are weighted by population, and the time run by car between every couple of provinces. Index I_i^{truck} is also calculated using the provincial physical accessibility rates, but all possible destinations are weighted by value added, and the time run by truck between every couple of provinces. Value added seems preferable to population to describe the borders of the reference markets for firms' input supply and output delivery. According to Schurmann e Talaat (2000) the first of these indexes captures the potential market for firms producing services, while the second evaluates the potential markets for firms producing goods.

Appendix 2

The stochastic kernel estimates the conditional distribution of per capita income y_{t+k} at time $t+k$, given its value at time t (y_t); this can be obtained by the formula:

$$\hat{f}(y_{t+k} / y_t) = \frac{\hat{f}(y_t, y_{t+k})}{\hat{f}(y_t)} \tag{6a}$$

The marginal distribution of y_t can be calculated via a numerical integration of the joint distribution with respect to y_{t+k} whereas $\hat{f}(y_t, y_{t+k})$ can be estimated by the following bivariate kernel density estimator:

$$\hat{f}(y_t, y_{t+k}) = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{h_1}\frac{1}{h_2}K\left(\frac{y_t - y_{ti}}{h_1}\right)K\left(\frac{y_{t+k} - y_{t+ki}}{h_2}\right) \tag{7a}$$

K(·) is the kernel function that must integrate to 1, h_1 and h_2 are the smoothing parameters or bandwidths. This study adopts Gaussian kernel functions and the normal optimal smoothing parameters suggested by Silverman (1986).

The stochastic kernel is represented by means of a three-dimensional graph or by the "contour plot", i.e. a graph in which contours of the "mountain" are drawn as level curves in an orographic map. In other words, the three-dimensional curve has been cut at different heights (probability values) to allow for an easier interpretation of the graph, especially with reference to the aim of capturing multimodality. The presence of disjoint borders is a clear sign of more than one mode in the distribution.

Appendix 3

To get the matrix *W*, a weight is assigned to the spatial effects between regions based on the geographical distance due to its unambiguous exogeneity (see Anselin and Bera 1998, Anselin et al 1996). However, given that, in case of islands, the weight matrix *W* would present rows and columns with only zeros, simple contiguity matrices are not applied. Instead, the distance is calculated through the Great circle distance formula between couples of centroids of the 88 provinces. Geometrically the centroid is the centre of an area or of a polygon. Provincial areas are usually irregularly shaped polygons; thus, the centroid is derived mathematically and is weighted to approximate a sort of "centre of gravity". In the Geographical Information System (GIS) these discrete locations expressed in geographical coordinates are often used to index or reference the polygon (hence the provinces) within which they are located. Centroids are assumed to be provinces' "centres of gravity" from an economic point of view. To exploit the information on distances a $n \times n$ symmetric spatial weight matrix *W* is used, where element w_{ij} specifies the intensity of the effects between provinces *i* and *j*; i.e. how province *i* is spatially connected to province *j* (Anselin and Bera 1998). Furthermore, the spatial weight matrix is usually row standardized so that each row's elements sum up to one in order to normalize the effects of all regions on their neighbours. Each element of the row standardized weight matrix therefore measures the regional share of the global spatial effects on a particular observational unit (Niebuhr 2001). The spatial weighting matrix is based on an "inverse distance" function that downweights observations that are geographically more distant (Badinger et al. 2004). The inverse of the distance is considered in this case to reflect a "gravity model" function. The elements of the matrix *W* are therefore the following:

$$\begin{cases} w_{ij} = 0 & if \quad i = j \\ w_{ij} = 1/d_{ij} & if \quad d_{ij} \le Me \;\; and \;\; w_{ij} = w_{ij} \Big/ \sum_j w_{ij} \\ w_{ij} = 0 & if \quad d_{ij} > Me \end{cases} \qquad (2)$$

where *Me* is the median of the great circle distance distribution and d_{ij} is the distance between regions i and j. Similar results have been obtained using other weighting matrices calculated substituting the median (the critical cut-off parameter) respectively with the first and the third quartile of the geographical distance distribution.

Appendix 4

List of provinces included into the sample

Number	NUTS CODE	PROVINCES	Number	NUTS CODE	PROVINCES
1	ITC11	Torino	45	ITE18	Arezzo
2	ITC12	Vercelli	46	ITE19	Siena
3	ITC15	Novara	47	ITE1A	Grosseto
4	ITC16	Cuneo	48	ITE21	Perugia
5	ITC17	Asti	49	ITE22	Terni
6	ITC18	Alessandria	50	ITE31	Pesaro e Urbino
7	ITC20	Aosta	51	ITE32	Ancona
8	ITC31	Imperia	52	ITE33	Macerata
9	ITC32	Savona	53	ITE34	Ascoli Piceno
10	ITC33	Genova	54	ITE41	Viterbo
11	ITC34	La Spezia	55	ITE42	Rieti
12	ITC41	Varese	56	ITE43	Roma
13	ITC42	Como	57	ITE44	Latina
14	ITC44	Sondrio	58	ITE45	Frosinone
15	ITC45	Milano	59	ITF11	L'Aquila
16	ITC46	Bergamo	60	ITF12	Teramo
17	ITC47	Brescia	61	ITF13	Pescara
18	ITC48	Pavia	62	ITF14	Chieti
19	ITC4A	Cremona	63	ITF2	Molise
20	ITC4B	Mantova	64	ITF31	Caserta
21	ITD1	Bolzano/Bozen	65	ITF32	Benevento
22	ITD2	Trento	66	ITF33	Napoli
23	ITD31	Verona	67	ITF34	Avellino
24	ITD32	Vicenza	68	ITF35	Salerno
25	ITD33	Belluno	69	ITF41	Foggia
26	ITD34	Treviso	70	ITF42	Bari
27	ITD35	Venezia	71	ITF43	Taranto
28	ITD36	Padova	72	ITF44	Brindisi
29	ITD37	Rovigo	73	ITF45	Lecce
30	ITD4	Friuli-V. Giulia	74	ITF51	Potenza
31	ITD51	Piacenza	75	ITF52	Matera
32	ITD52	Parma	76	ITF61	Cosenza
33	ITD53	Reggio nell'Emilia	77	ITF63	Catanzaro
34	ITD54	Modena	78	ITF65	Reggio Calabria
35	ITD55	Bologna	79	ITG11	Trapani
36	ITD56	Ferrara	80	ITG12	Palermo
37	ITD57	Ravenna	81	ITG13	Messina
38	ITD58	Forlì	82	ITG14	Agrigento
39	ITE11	Massa-Carrara	83	ITG15	Caltanissetta
40	ITE12	Lucca	84	ITG16	Enna
41	ITE13	Pistoia	85	ITG17	Catania
42	ITE14	Firenze	86	ITG18	Ragusa
43	ITE16	Livorno	87	ITG19	Siracusa
44	ITE17	Pisa	88	ITG2	Sardegna

Appendix 5

Variables description

Variable	*Description*	*Source*
Initial per capita VA	Gross value added divided by population (1951,1961,1971).	Tagliacarne Institute
Illiteracy rate	Number of illiterate over population (1951,1961,1971).	ISTAT
Density of population	Population density per square km (1951,1961,1971).	ISTAT
Activity rate	Labour force over population (1951,1961,1971).	ISTAT
Share manufacture employees	Employed in manufacture over total employed (1951,1961,1971).	ISTAT
Share employees large firms	Employed in firms having more than 500 employees over total employed (1951,1961,1971).	ISTAT
Per capita bank branches	Number of bank branches over population (per 10.000 bank branches; 1951, 1961, 1971)	Bank of Italy
Per capita telephone lines	Telephone lines over population (1951,1961,1971).	ISTAT
Road infrastructural index	Truck infrastructural index in 1970 (that uses transport time as an instrument to measure infrastructural endowment)	Bank of Italy: Alampi and Messina (2012)
Km of roads	Km of road per square km (1951,1961,1971).	ISTAT
Tollgates	Number of municipalities where a tollgate is localised (1950,1960,1970).	CERTeT-Università Commerciale Bocconi (2006)
Share of highways (Qhigh)	Weight of highways per road kilometres in 1971.	ISTAT

Note: All variables in the regressions are measured at the beginning of the sample period

[1] The European Commission's White Paper of 2011 sets out a range of policy measures which aim at removing remaining barriers to the internal market with a strong emphasis on the railway and maritime sectors.

[2] The ratio between road passenger traffic and railway passenger traffic passed from 2.47 in 1960 to 4.40 in 1965 and 7.35 in 1970. Later it continued to increase but at a much lower rate: it went from 8.53 in 1975, to 9.14 in 1980, 11.43 in 1985 and 13.56 in 1990 (data from *Conto nazionale delle infrastrutture e dei trasporti* published by *Ministero delle infrastrutture e dei trasporti).*

[3] After 1975 the development of the highway network slowed down drastically since an act interrupted the construction of new highways. For a detailed description of the development of Italian highway network see Table 4.

[4] Di Giacinto, Micucci and Montanaro (2009).

[5] See Paci and Pigliaru (1997), Picci (1999), La Ferrara and Marcellino (2000), Di Giacinto and Nuzzo (2006), Destefanis and Sena (2005), Bronzini and Piselli (2009), Di Giacinto, Micucci, Montanaro (2010).

[6] They argue that road construction may have been a substitute for social assistance.

[7] It is very difficult to compare results that refer to very different economic situations such as the US and Europe. In other words, the "highway effect" in an environment dominated by large firms, like that prevailing in the US, may not be comparable with the effect when small enterprises are scattered throughout the territory like in many European countries.

8 See Picci (1999, Bonaglia et al. (2000), Bronzini and Piselli (2009).

[9] The analysis excludes all the segments of the highway that are free of payment because are managed by ANAS (National Autonomous Roads Corporation).

[10] Only 51 tollgates were opened before the '50s, 12 during the '50s, and 25 after 1980.

[11] See Geurs and Wee (2004) for a review of the accessibility measures used in the literature.

[12] See Appendix 1 for details.

[13] See Quah, 1996a,b; 1997.

[14] Annual provincial data are not available for the five decades.

[15] Thus, like in Cosci and Mattesini (1995), the number of provinces considered is smaller than the actual number, generally reflecting the provinces into which Italy was divided in 1951. The regions of Friuli V. Giulia, Molise and Sardegna are not broken down into provinces. The complete list of administrative units used is reported in Appendix 4.

[16] Durlauf and Quah (1999) give a detailed definition and a description of some of the main properties of stochastic kernels in the study of distribution dynamics. See Appendix 2 for details

[17] The spatial weight matrix, as explained in the following section, is row standardized with all elements in each row sum to one.

[18] In particular if Moran's I test on OLS errors reveals the presence of residual autocorrelation (Cliff and Ord 1981) that suggest that the standard growth regression should be extended to explicitly include spatial elements, and it is typically estimated via maximum likelihood (ML) based techniques.

[19] See also, among others, Arbia et al (2010), Seya et al. (2012), Meliciani and Chapman (2016) and Meliciani (2016) for an application of the SDM specification to the spatial analysis of growth and regional convergence.

[20] Lagrange Multiplier tests and their robust versions are used to test the OLS versus the SAR and SEM Lagrange Multiplier tests and their robust versions are used to test the OLS versus the SAR and SEM; Likelihood ratio (LR) tests are used for testing the SAR and SEM versus the SDM while the test of the SLX versus the SDM is a t-test on the coefficient of the spatial lag of the dependent variable in the SDM. If the (robust) LM tests point to another model than the LR tests, then the spatial Durbin model is adopted. This is because this model generalizes both the spatial lag and the spatial error model.

[21] In addition, the robustness of results is checked using spatial weight matrices based on the *k*-nearest neighbors with *k*=10,15,20,25 neighbors (see Ertur and Koch 2006). A *k*-nearest neighbors weight matrix is computed from the distance between the regions' centroids and implies that each region is connected to the same number *k* of neighbors. Complete results on robustness analysis are available from the authors upon request.

[22] All computations in this paper have been carried out using SpaceStat 1.91 (Anselin 1999) and the spatial econometrics toolbox in Matlab (LeSage 1999) .

[23] For and application of spatial regimes analysis see, among others, Allers and Elhorst (2005) and Chapman et al (2012).

[24] Provinces of Centre-North belong to Val D'Aosta, Piemonte, Lombardia, Veneto, Trentino-Alto Adige, Liguria, Emilia Romagna, Toscana, Umbria, Marche, Lazio. The provinces of the remaining regions are included in the group named South.

[25] See Appendix 5 for a detailed description.

[26] The correlation between $I^{truck70}$ and the variable Roads in 1971 is 0.07.

[27] The highway linking Naples to Pompei was opened in 1923 and the highway linking Pompei to Salerno was opened in 1961.

[28] We included the variables usually considered as potential determinants of local growth (see among the others: Ferri and Mattesini, 1997, Aiello and Scoppa, 2000 and D'Aunto et al. 2004) available at the provincial level for the whole period. We reported in Table 4 only the ones that we found significant at least in one regression.

[29] All the checks for the presence of possible outliers have been done (in particular we performed data trimming on the variables included in our econometric analysis and no outliers were detected).

[30] A decrease in spatial dependence in Italy during the '60s is reported also in Arbia and Basile (2005).