Dipartimento di Scienze Economiche, Matematiche e Statistiche

Università degli Studi di Foggia

Climatic differences and Economic Growth across Italian Provinces: First Empirical Evidence

Edgardo Sica

Quaderno n. **20/2005**

Quaderno riprodotto al
Dipartimento di Scienze Economiche, Matematiche e Statistiche
nel mese di ottobre 2005 e
depositato ai sensi di legge

Dipartimento di Scienze Economiche, Matematiche e Statistiche, Largo Papa Giovanni Paolo II, 1, 71100 Foggia (Italy), Phone +39 0881-75.37.30, Fax +39 0881-77.56.16

Climatic Differences and Economic Growth across Italian Provinces: First Empirical Evidence

Edgardo SICA*

Faculty of Economics, University of Foggia

Largo Papa Giovanni Paolo II n°1

71100 Foggia, Italy

Abstract

The purpose of this study consists in verifying if climatic differences can help to explain the different economic growth's path across Italian provinces. Focusing on literature on economic convergence on one hand, and that on economics of climate on the other, the work depicts how climatic variables can enter into the traditional Solow's neoclassical growth model developing two alternative models. Afterwards, it tests whether climatic characteristics actually exert an influence on economic convergence using an original climate dataset composed by average yearly min and max temperatures (C°), humidity grade (%), number of frost-days and annual precipitations (mm) for 58 Italian Provinces uniformly distributed over the Peninsula. The results, obtained through the Arellano-Bond GMM estimator, show how some of climatic variables employed in this study actually affect the level of Provincial income.

Keywords: Climate; Economic growth; Convergence, Italian Provinces

* Corresponding author. Tel.: +39 0881 726408.
E-mail address: e.sica@unifg.it

1. Introduction

Italy presents a widely diversified climate: even if classified as a "temperate country", its climate ranges from frigid in the northern borders of the Peninsula to semitropical in the coastal areas of South. At the same time, Italy is an economic reality characterized by a deep income inequality between the industrialized Centre-North and the agricultural-based South. Specifically, one can observe that almost all less-developed Italian Provinces tend to be located in the subtropical and dry-Mediterranean climates of the Peninsula whereas the majority of high-industrialized Provinces typically stand in the cooler temperate ones. For these reasons, the question is: "how much do climate characteristics matter for economic growth of the Italian provinces?" The present work tries to answer this question: focusing on the link between the literature on economic convergence on one hand, and that on economic of climate on the other, it aims to identify the possible relationship between climate and economic growth in Italy. Verifying the existence of such link is particularly useful, since could help policymakers to adopt the best strategies to overcome the effects of climate, mainly in the disadvantaged zones of the peninsula. In fact, the argument made in this study is that exogenous climatic variables account for a significant part of the high income inequality across Italian provinces. In this sense, the present work represents the very first application of such topic to the Italian case: to the best of knowledge, in fact, there is a general lack of published studies on the impact of climatic variables on economic growth at a local level, including Italy. Moreover, compared to the earlier studies on the economic of climate, this study introduces three important innovations. First, it adopts a very wide range of climate variables; second, it employees data at a very high geographic resolution; third, it takes into account also the temperature variability as a possible determinant of economic performance.

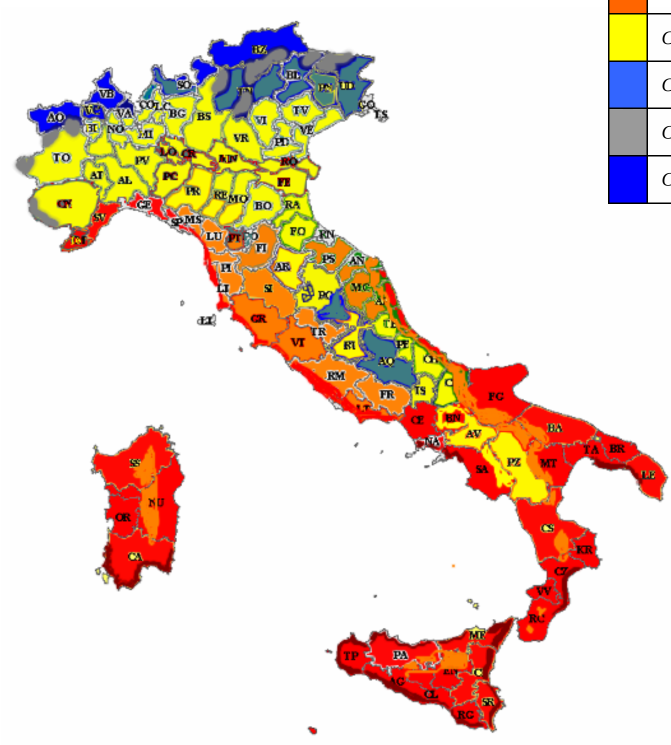
The work is articulated in the following way: section 2 depicts both the climatic and economic characteristics of Italian Provinces; section 3 reports a literature review about economics of climate; section 4 describes the theoretical model adopted in this study; section 5 explores the econometric methodology used and section 6 ends with same concluding remarks about the possible policy implications.

2. Climatic conditions and economic characteristics of Italian Provinces: is there some link?

Italy extends over 10 degrees of latitude and presents a wide variety of geo-morphological characteristics. The almost 77% of the territory is covered by mountains and hills, the 1,6% by rivers and lakes and only the remaining part by plain lands. The coastline amounts to 7,600km and represents the 80% of the total national boundaries (Rilasciati, [30]). These idro-orographical factors together with the considerable length of the peninsula affect the Italian climate which is deeply diversified from the North, attached to the European Continent, to the South, surrounded by the Mediterranean Sea. Climate, in fact, ranges from frigid in the higher elevations of Alps and Apennines (where it is similar to that of Switzerland and Austria, with short, cool summers and long, cold winters), to semitropical in the Southern peninsula as well as along the Gulf of Genoa and in the two main Italian islands - Sardinia and Sicily (where it is similar to that of North Africa, with mild winters and intense, long summers during which the maximum daytime temperature can easily exceed 40°C). Between these two extremes, Italy is characterized by intermediate climatic conditions, remarkably influenced by the configuration of the Apennines and by the tempering winds from the surrounding seas. Along the coastlines, the climate is Mediterranean with hot, dry summers and marked differences in winter climate between the East and West coasts. Along the coast of Emilia-Romagna, Marche and Abruzzi (East coast), temperatures in winter are quite low because of the winds from North-East and because of the presence of the Adriatic sea, not much deep, and, therefore, not capable of mitigating the atmosphere. In the same latitudes on the West of the peninsula (along the coast of Tuscany and Lazio) winters tend to be mild and sunny, mainly thanks to the presence of the Apennines which represent a barrier against Easterly and Northerly winds. Moreover, in these regions, climate is mitigated by the Tyrrhenian Sea, much more deep compared to the Adriatic one. In the end, the climate of the plan of Lombardy is continental, with severe winters characterized by a persistent fog typical of the Po Valley. For these reasons, the average annual temperature in Italy varies widely from province to province, ranging in last years from about 10.4°C and 20.18°C. In addition, climate in Italy is characterized by relatively abundant rain. However, the average annual rainfall is highly diversified, being not equally distributed among seasons and regions and portioning Italy into a wet centre-northern part and a semi-arid southern region. In recent years, the average annual rainfall observed has varied from less 180mm/year occurring in the Sardinian province of Cagliari, to more 1675mm/year occurring in the province of Viterbo, in the Centre. Rainfall differences distinguish also the Adriatic and the Tyrrhenian coasts, being the latter generally characterized by higher rainfall patterns. Such diversification in the average annual rainfall is largely responsible for the physical decline of some zones, particularly in the South, where the concurring of dry and warm seasons leads to negative effects on agriculture. Figure 1.1 shows the different climate graduations observed moving from the North to the South and from the coastal to the inner regions of the peninsula.

Fig 1.1. Different climate graduations in Italy

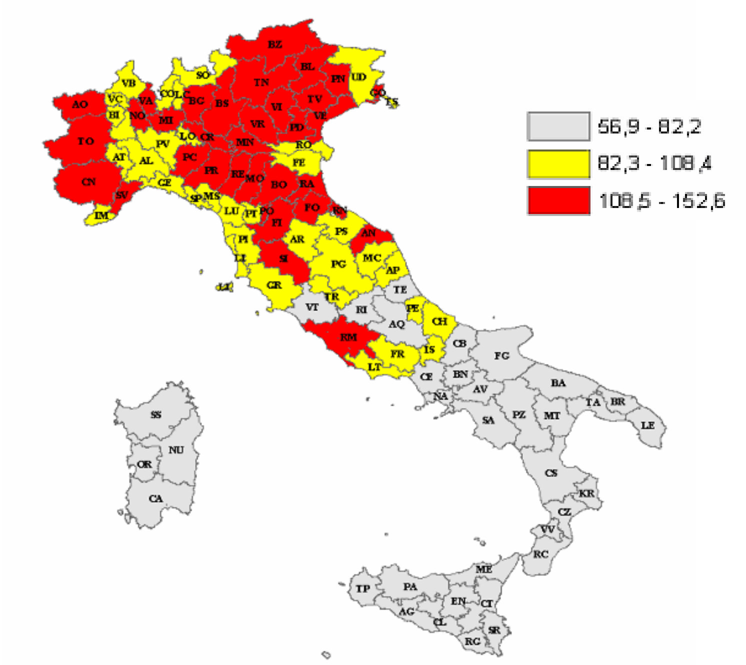
	Subtropical climate
	Dry Mediterranean climate
	Sublitoral climate
	Continental climate
	Cool Temperate climate
	Cold climate
	Cold Polar



Source: own elaboration based on "Italian Aerobiology Association" climatic classification [36]

From an economic point of view, Italy is a territorial reality historically characterized by provincial income inequality, given the coexistence of rich, developed geographical areas together with other less advanced (Dunford, [07]). Income gaps are mainly marked among the industrialized Northern Provinces and the agricultural-based southern ones. In fact, a crucial problem for Italian economy is represented by the slow growth of industrialization in the South of the peninsula: while the North is characterized by a diversified industrial base, southern provinces lag behind the North in several aspects of economic development. The sharp North-South contrast appears as evident if we look at the following data produced by the "*Istituto Guglielmo Tagliacarne*" [13]. In 2002, Italy's leading province was Milan with a per capita GDP equal to 152,6% of the Italian average, followed by Bolzano (150,6%), Bologna (136,5%) and Modena (135,4%), all located in the North Italy. At the bottom of the list were the southern provinces of Caltanisetta (58,8%), Enna (57,7%), Foggia (57,5%) and Crotone (56,9%). Moreover, only the provinces of Latina, Frosinone, Pescara, Chieti and Isernia exceeded 82% of the Italian average. Compared to 1995 data, the northern province of Siena rose from 47th place to 29th, while Ravenna and Genova (both in the North) rose, respectively, 15 and 13 places. On the opposite, the major declines were recorded by the northern industrialised provinces of Lecco (-25 places) and Como (-21 places). Generally, in 2002 the wide gap in development between Italy's provinces was approximately the same of those recorded in 1995, without any sign of decrease. Figure 2.1 below, plots 2002 provincial GDP expressed as a percentage of the Italian average, showing the large divergence across Italian provinces.

Figure 2.1. 2002 provincial GDP expressed as a percentage of the Italian average



Source: "Istituto Guglielmo Tagliacarne" [13]

The divergence of Italian economy, characterized by a prosperous North coexisting with less advanced southern provinces is not a new phenomenon. It dates back to the nineteenth century, when the country became a unitary state by bringing together various regions with different development levels (Terrasi [35]; Daniele [05]). Subsequently, the problem of the dualistic nature of the Italian economy (the so called "*southern question*") has taken on great importance in national political agenda, particularly after the 1950s, when Italy faced an impressive process of growth, defined as the "*Italian economic miracle*". As a consequence, the development of South Italy and the concern of provincial income disparity became an important case-study (Mauro [22]), extensively analyzed from both a microeconomic and a macroeconomic perspective. A broad range of reasons have been adopted in order to explain the wide economic disequilibrium between the provinces of the North and those of the South, but no mention to possible climate causation can be found in the literature.

However, compared to figure 1, figure 2 shows an unmistakable correlation between economic development and climatic features: almost all high-income Italian Provinces, in fact, are located in the continental-climate areas while the provinces in the semi-tropical climate zones tend to be poorer. Of course, climate correlation presents some important exceptions. In this sense, the case of the Liguria provinces appears particularly evident: even if characterized by a semi-tropical climate similar to that of the southern Italian provinces, they show a higher level of GDP per capita compared to those. Nevertheless, economic development seems to be favoured in the continental-climate provinces: after a brief literature review on economics of climate, the next sections will try to verify this hypothesis.

3. The impact of climate on economic performance: a literature review

Literature on economics of climate can be generally decomposed in two main branches:

- the first analyses the impact of climate changes on environmental sustainability, stressing the implications of climate variability on economy (Goria and Gambarelli [10]; Cao [03]; Moonen et al. [24]; Salinger et. al. [31]). In this branch can be included those studies exploring the importance of the climate amenity value through a microeconomic approach based on the hedonic technique (Maddison and Bigano [18]);
- the second focuses on the relationship between climatic conditions and long-run economic development (Demurger et al. [06]; Masters and Sachs [21]; Olsson

and Hibbs [27]; Olsson [26]; Easterly and Levine [08]; Gallup et al. [09]; Mellinguer et al. [23]; Ram [28], [29]; Kamark [15]; Acemoglu et al. [01]).

Following the first approach, literature shows how climatic change can determine both direct and indirect consequences on economy. On one hand, climatic variations directly affect several economic sectors, such as tourism, agriculture and energy; on the other hand, they can significantly influence the human health, the basic needs and the psychological wellness, determining an indirect impact on human productivity and, therefore, on economy. With respect to the direct impact, climatic variations tend to heavily affect the demand for seasonal tourism. Goria and Gambarelli, 2004 [10] show how in Italy extremely hot summers increase tourism flows toward the cooler areas, such as the coastal ones. On the opposite, higher winter temperatures and lower rainfall patterns determine a negative effect on winter tourism in Alpine regions, mainly due to their effects on winter sports. High temperatures, abundant precipitations, and frosts are some of the most important limiting factors for agricultural production: frost risk or excessively hot temperatures during the growing periods as well as irregular rainfall during the cultivating ones can seriously damage agricultural products (Moonen et al. [24]). Moreover, extremes temperatures both in winter and summer raise the demand for energy for domestic use, given the increased use of heating systems in winter and air conditioners in summer. About the indirect impact, high temperatures not only tend to increase cardiovascular and respiratory diseases and, generally, mortality, but are responsible for the transmission of pathogens and dangerous microbes. In addition, climatic conditions represent an important input to many household activities: they affect clothing and nutritional needs as well as recreational and leisure activities, determining psychological wellness (Maddison and Bigano [18]). For all these reasons, climatic characteristics have a pervasive effect on human productivity and, therefore, on economy.

Following the second approach, literature stresses the role of climatic conditions in the long-run economic development. Actually, the importance of climate in empirical studies of comparative growth has been sometimes neglected: according to conventional economic growth theory, in fact, climate is irrelevant for explaining income inequality across countries (Olsonn and Hibbs [27]). Human and physical capital accumulation is considered as independent of natural characteristics, including climatic variables. However, traditional growth theories are not able to explain why such factors tend to accumulate faster in some locations than in others: in this sense, climate could play both an historical and a current role on resource productivity (Masters and Sachs [21]). On a world wide scale, differences in ecological conditions may represent a possible determinant of income inequality between the temperate and the tropical zones. From an empirical point of view, the correlation between ecological zones and income level is supported by the evidence that over 90% of the world's poor is concentrated between the tropic of Cancer and the tropic of Capricorn (Demurger et al. [06]). Economies in the geographic tropics display lower income levels that the rest of world. This could depend upon the intrinsic effects of tropical ecology on human health and agriculture. Mellinguer et al. [23] argue that the effects of tropical infectious diseases on human health determine shortfalls in economic performance much larger compared to that on health. In a seminal work on climate and development, Kamark [15] underlines how erratic patterns of rainfall in tropical climates lead to a drastic reduction of mineral resources and organic materials in the land with dramatic consequences for agriculture. Moreover, compared to temperate environments, the absence of frosts in tropical countries encourages the development of a wide variety of microbes, insects ad fungi, leading to poor crops yields. Following Kamark, Theil and Finke [34] before and Ram [28] later, adopt the distance from equator as a proxy variable for climate. In this sense, latitude becomes an indicator for the differences in several types of natural endowments across countries. Their findings seem to confirm the intuition that exogenous climatic variables account for a significant part of the unequal income distribution across countries. Recently, Masters and McMillan [20] have noted that what the tropics have in common is the absence of winter frost. Frost kills dangerous organism and permits to control for pathogens and parasites in plants and animals other than for the transmission of diseases. Therefore, despite the previous works, they employ the incidence of frost in winter as a proxy for climatic conditions. Their results show that frost frequency has a remarkable significance for economic behaviour since people tend to live where there is some frost but not too much; moreover, temperate countries converge towards a common high level of income, while tropical countries tend to converge towards income level depending on their economic scale. Compared to all these studies, Crosby [04] and Ram [29] focus on a most confined geographical context. Crosby considers the climate of Europe as a crucial determinant for Europe's success in economic development, stressing again the advantages of the temperate zones in terms of agricultural productivity and disease ecology. Ram makes a longitudinal study of the U.S., testing whether tropical proximity determines or not an income-disadvantage. His findings show that states located closer to the equator actually are disadvantaged even if the adverse effects of tropicality were mitigated significantly over time mainly thanks to public policies and improvements in technology. In the end, several studies (Olsson [26]; Easterly and Levine [08]; Acemoglu et al. [01]) argue that the impact of climate on long-run economic development goes through the quality of a country's economic institutions which is in turn strongly influenced by its geography. Summarizing, the state of art can be depicted as follows: formal modellers of economic growth have often uncared for the climatic conditions as a possible determinant of economic growth, although part of literature recognizes the crucial role of climatic variables in the process of economic development. Moreover, even though many countries face substantial domestic income inequality, almost all studies have focused on a global scale, ignoring the possibility that climate affect the local growth and help to explain intra-country income disparities.

4. Theoretical model

This section describes how climatic variables can enter into a textbook neoclassical growth model through some modifications to the production function. Since climatic conditions can affect economic growth through their influence on labour productivity and production technologies (in other words, climate affects the inputs into the production function and, therefore, the production function itself) two theoretical models are developed here, both representing a variant of the standard Solow's [33] model, as added up of human capital by Mankiw et al. [19]. In the first model, the efficiency term is augmented in order to capture the impact of climatic variables. In the second one, the human capital term is modelled to take into account the possible impact determined by the climate on human health.

First model

In the first model the production function is the following:

$$Y = K^{\alpha} H^{\beta} (AL)^{1-\alpha-\beta} \quad [3.1]$$

where Y is output, K and H are, respectively, the stock of physical and human capital, L is the workforce and A is the level of technology. L and A are assumed to grow exogenously, respectively at rates n and g :

$$L_t = L_0 e^{nt} \quad [3.2]$$

$$A_t = A_0 e^{gt} \quad [3.3]$$

As already noted by Mankiw et al., the A_0 term "*reflects not just technology but resource endowments, climate, institutions*" (Mankiw et al. [19], p.410-411). Therefore, following Knight et al. [17] first, and Gundlach and Matus-Velasco [11] later, the efficiency term can be augmented in order to take into account the possible effects on output of climatic and socio-cultural variables:

$$A_t = A_0 e^{gt} e^{\omega CLIM + \sigma SOCCUL} \qquad [3.4]$$

Assuming that s_k and s_h are constant fractions of output invested, respectively, in physical and human capital, Mankiw et al. derive the evolution of the economy in the following way:

$$\begin{aligned} \dot{k} &= s_k y - (n + g + \delta)k \\ \dot{h} &= s_h y - (n + g + \delta)h \end{aligned} \qquad [3.5]$$

where $y = Y / AL$, $k = K / AL$, $h = H / AL$ are expressed in terms of effective unit of labour and δ is the rate of depreciation of physical and human capital. From equations [3.5], k and h converge to their respective steady-state levels defined as:

$$\begin{aligned} k^* &= \left(\frac{s_k^{1-\beta} s_h^{\beta}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)} \\ h^* &= \left(\frac{s_k^{\alpha} s_h^{1-\alpha}}{n + g + \delta} \right)^{1/(1-\alpha-\beta)} \end{aligned} \qquad [3.6]$$

Substituting equations [3.6] into the production function [3.1] and taking logs, the output per worker is equal to:

$$\ln(Y/L) = \ln A_0 + gt + \varpi CLIM + \sigma SOCCUL + \\ - (\alpha + \beta)/(1 - \alpha - \beta)\ln(n + g + \delta) + \\ + \alpha/(1 - \alpha - \beta)\ln s_k + \beta/(1 - \alpha - \beta)\ln s_h \qquad [3.7]$$

Equation [3.7] shows how output per worker depends on population growth, accumulation of physical and human capital, as well as on climatic characteristics and socio-cultural conditions.

Second model

In the second model, climate enters into the model as a factor affecting human capital accumulation. Moreover, following several authors (Gundlach and Matus-Velasco [11]; Klenow and Rodriguez-Clare [16]; Jones [14]), human capital is here considered not as an independent factor of production but as directly linked to labour. Therefore, the Cobb-Douglas production function is now the following:

$$Y = K^{\alpha}\left(ALe^{\omega sSCHOOL}e^{\sigma CLIM}\right)^{1-\alpha} \qquad [3.8]$$

where $SCHOOL$ is a variable which measures the level of schooling. This specification implies that human capital is given by:

$$H = Le^{\omega sSCHOOL}e^{\sigma CLIM} \qquad [3.9]$$

In other words, human capital is directly linked to the workforce and results as being dependent on the level of schooling as well as on the climatic characteristics.

Assuming that a constant fraction of output, s, is invested, the evolution of economy is now given by:

$$\dot{k} = sy - (n + g + \delta)k \qquad [3.10]$$

and the steady-state value k^* is:

$$k^* = e^{\varpi SCHOOL} e^{\sigma CLIM} \left(\frac{s}{n + g + \delta} \right)^{1/(1-\alpha)} \qquad [3.11]$$

Substituting equations [3.11] into the production function [3.8] and taking logs, the output per worker is now equal to:

$$\begin{aligned} \ln(Y_t / L_t) = \quad & \ln A_0 + gt - \alpha/(1-\alpha)\ln(n + g + \delta) + \\ & + \alpha/(1-\alpha)\ln s + \omega SCHOOL + \sigma CLIM \end{aligned} \qquad [3.12]$$

Again, output per worker depends on population growth, accumulation of physical and human capital, as well as on climatic characteristics.

5. Empirical application

From an empirical point of view, equations [3.7] and [3.12] describe an economy in steady-state and are useful to specify two different “levels” regressions. They may be employed to test if dissimilar levels of income across Italian Provinces depend on physical and human capital accumulation, population growth as well as on climatic and socio-cultural characteristics, on condition that Provinces are actually on their steady state balanced growth path. Since this assumption is unlikely to hold, two “growth” regressions are here derived explicitly.

Following Hauk and Wacziarg [12], models proposed in the previous section can be approximated around the steady-state level y^*:

$$\frac{d\ln y_t}{dt} = \lambda\left[\ln\left(y^*\right) - \log\left(y_t\right)\right] \qquad [3.13]$$

where $\lambda = \left(g + n + \delta\right)\left(1 - \alpha - \beta\right)$ is the rate of convergence, representing the percentage of gap between a Province's steady–state and its current level of income that will be closed in one period, *ceteris paribus*. Using [3.13], equation [3.7] can be turned into the following dynamic panel growth regression (details are reported in appendix):

$$\begin{aligned} \ln\left(Y/L\right)_{it} &= \phi\ln\left(Y/L\right)_{it-1} + \gamma' x_{it} + \eta_t + \varepsilon_{it} \\ \varepsilon_{it} &= \mu_i + v_{it} \end{aligned} \qquad [3.14]$$

where i and t are, respectively, a province and a year index, ϕ is a scalar and $\gamma' = \left[\gamma_0, \gamma_1, \gamma_2, \gamma_3, \gamma_4, \gamma_5\right]$,
$x'_{it} = \left[1, \ln s_{k,it-1}, \ln s_{h,it-1}, \ln\left(n + g + \delta\right)_{it-1}, CLIM_{it-1}, SOCCUL_{it-1}\right]$, η_t is a time-specific effect, μ_i is an individual effect and ε_{it} is the error-term $v_i \sim iidN(0, \sigma_v^2)$.
Similarly, equation [3.12] becomes:

$$\begin{aligned} \ln\left(Y/L\right)_{it} &= \theta\ln\left(Y/L\right)_{it-1} + \xi' x_{it} + \eta_t + \varepsilon_{it} \\ \varepsilon_{it} &= \mu_i + v_{it} \end{aligned} \qquad [3.15]$$

where $x'_{it} = \left[1, \ln s_{it-1}, \ln\left(n + g + \delta\right)_{it-1}, SCHOOL_{it-1}, CLIM_{it-1}\right]$ and $\xi' = \left[\xi_0, \xi_1, \xi_2, \xi_3, \xi_4\right]$.

Models [3.14] and [3.15] look very similar. Thanks to the presence of the lagged dependent variable among the regressors, both the models permit to take into account the *dynamic* of adjustments of per capita income rate of growth as a consequence of several factors including climate. The only two differences between the models are that equation [3.14] explicitly permits to control for socio-cultural differences across Italian provinces and that in equation [3.15] the human capital variable does not enter in a logarithmic form.

Variables used and data sources

In order to estimate models [3.14] and [3.15], variables were measured in the following way:

- Y : added value generated in each Italian Province analyzed (source: *Italian National Statistical Institute, ISTAT* for short). It was employed as a proxy for GDP, since no data about provincial income is available. Added value was deflated using the GDP deflator (source: *World Bank, World Development Indicators – WDI*);
- L : working-age population, defined as 15 to 64 (source: *ISTAT*);
- n : average rate of growth of the working-age population (source: own elaboration on *ISTAT* data);
- $g + \delta$: following Mankiw et al. [19] it was assumed to be constant and equal to 0.05. Changes in this hypothesis minimally affect the estimates;
- s_h in [3.14] and *SCHOOL* in [3.15]: number of last-year higher school students (source: *ISTAT* and *Italian Ministry of Education*). In [3.14] this variable was used as a proxy for the rate of human capital accumulation. Under the basic assumption that the number of last-year higher school students is proportional to s_h , this variable can be used to estimate equation [3.14] independently of the proportionality factor, which affects only the constant term (see Mankiw et al. [19]). In [3.15] this variable is used as a proxy for the level of schooling. No alternative data (e.g. public spending on education) was available on a provincial scale;

- s_k in [3.14] and s in [3.15]: share of amount of private investment in the manufacturing sector in real added value (source: own elaboration on *AIDA* data, sectors 15-36, *ATECO 2002* classification). Despite this narrow approach, measurement of provincial investment presented great difficulties, since no macroeconomic data is available. For this reason, the amount of investment was calculated adopting microeconomic data on Italian firms: more precisely, it was derived as the difference between the amount of total material fixed assets for all manufacturing enterprises operating in each Italian Province at year t with respect to the previous year. Such variable was deflated using the GDP deflator (source: *WDI*). Obviously, this approach presents some limitations since takes into account only a part of Italian firms (the manufacturing ones, although they are particularly dynamic in terms of investments) and completely excludes public investments. Anyway, even if imperfect, this variable is representative for trends in Provincial investments;
- $SOCCUL$: number of crimes denounced divided by resident population (source: *ISTAT*);
- $CLIM$: since Italian Provinces differ in many dimensions of climate, a wide variety of climatic variables are employed as proxies for $CLIM$, including: mean yearly values (based on monthly, decadal and daily means) of the min and the max temperatures (C°) (respectively, MIN and MAX) and of the humidity grade (%) ($HUMID$); max and min temperatures variability ($VARMIN$ and $VARMAX$); total number of frost-days per year (FRO); total annual precipitations (mm) ($RAIN$) (source: *Ufficio Centrale di Economia Agraria, UCEA* for short). All data are recorded from several meteorological stations positioned in various locations over the Italian territory. In comparison to temperature and frost days (already adopted in previous studies as proxies for climate), for the first time in this study other climatic indicators as humidity grade and precipitations are employed with the aim of controlling for the effects of climate on economic growth;

- i : 58 Italian Provinces uniformly distributed over the Peninsula, covering the almost 54% of the total number of Italian provinces. No climatic data were available for the remaining 45 Italian Provinces;
- t : 1997-2002 (no data were available for the previous years).

Appendix reports the complete list of the provinces analyzed, the names and latitudes of the related meteorological stations, and the descriptive statistics of climatic variables.

Methodology

Equations [3.14] and [3.15] were estimated using the Arellano-Bond (1991) [02] GMM estimator. Alternative approaches as pooled OLS, FE within estimator or RE GLS estimator could not be employed since biased and inconsistent given the presence of the lagged dependent variable among the regressors. In fact, the pooled OLS estimator is unbiased and consistent (but not efficient) when all explanatory variables are exogenous and uncorrelated with the individual specific effects. This is not the case of models [3.14] and [3.15] where $\ln(Y/L)_{it}$ is a function of μ_i and $\ln(Y/L)_{it-1}$ is also a function of μ_i. Since a right-hand variable results correlated with the error term, the OLS estimator is biased and inconsistent even if v_{it} is not serially correlated. Wiping out the individual effects μ_i through the within transformation does not solve the problem. In this case $Cov\left[\ln(Y/L)_{it-t} - \ln\left(\overline{Y/L}\right)_{i-t}, v_{it} - \bar{v}_i\right] \neq 0$ even if $\bar{v}_{it}$ is not serially correlated. For T fixed, this correlation does not go to zero as N tends to infinity with the consequence that also the FE within estimator results biased and inconsistent (Nickell, 1981) [25]. This is valid also for RE GLS estimator. On the opposite, the Arellano-Bond GMM approach generates consistent estimates since it instruments the variables correlated with the error term. The efficient instrument matrix differs according to whether the vector of regressors x_{it} in [3.14] and [3.15] is correlated with μ_i or not, and whether it is predetermined (i.e. $E[x_{it}, v_{is}] \neq 0$ for $s < t$ and 0 otherwise) or strictly exogenous (i.e. $E[x_{it}, v_{is}, v_{is-1}] = 0$ for all t, s). With regard to this, the Solow's model is silent but there is a strong presumption that x_{it} in both [3.14] and [3.15] is highly correlated with the initial level of technology across Italian Provinces (captured by the term $\gamma_0 + \mu_i$) and that many elements of the vector are predetermined. In this study, although some regressors can be thought as strictly exogenous (for example, this is the case of the climatic variables: the error term at time s should not have some feedback in the future realizations of this regressor) and others as predetermined (for example, the future realizations of s_k in [3.14] and s in [3.15] can depend on past values of $\ln(Y/L)_{it}$), given the very short period of time analyzed all independent variables are considered as strictly exogenous. In fact, even if an adverse economic situation can affect some regressors, this generally occurs through a delayed effect in the years.

Regression results

Analysis was performed using "STATA 9.0" econometric software package. Table [4.1] reports the results obtained.

Table 4.1. Arellano-Bond dynamic estimation

Model [3.14]		**Model [3.15]**	
Regressors	**Coefficient**	**Regressors**	**Coefficient**
$\ln(Y/L)_{it-1}$	.5163935** (.2144971)	$\ln(Y/L)_{it-1}$	.5241319** (.2122853)
$\ln s_{k,it-1}$	.5941407* (.1548857)	$\ln s_{it-1}$	.6024871* (.1528842
$\ln s_{h,it-1}$	-.1261573 (3.634074)	$SCHOOL_{it-1}$	.0061452 (.0343304)
$\ln(n+g+\delta)_{it-1}$	-7.508878 (6.765115)	$\ln(n+g+\delta)_{it-1}$	-7.832806 (6.747703)
FRO_{it-1}	.0510938** (.0209844)	FRO_{it-1}	.0504587** (.0207789)
MAX_{it-1}	-.6210465** (.2796528)	MAX_{it-1}	-.6221963** (.2792019)
$VARMAX_{it-1}$	.052153 (.0333856)	$VARMAX_{it-1}$	.0529431 (.0325387)
MIN_{it-1}	.2038126 (.3003313)	MIN_{it-1}	.2073248 (.297673)
$VARMIN_{it-1}$	-.1292989* (.048591)	$VARMIN_{it-1}$	-.1293842* (.0472765)
$RAIN_{it-1}$	.000205 (.0009874)	$RAIN_{it-1}$	.0002256 (.0009825)
$HUMID_{it-1}$	.0523695 (.0393075)	$HUMID_{it-1}$	.0528827 (.0393037)
$SOCCUL_{it-1}$	-1.928511 (12.38887)		
Year	.3783552** (.1816564)	*Year*	.3871904** (.1801427)
Test	**Value §**	**Test**	**Value §**
Wald	23.35* (0.0000)	Wald	16.86* (0.0000)
Sargan	5.88 (0.6610)	Sargan	5.50 (0.7032)
Autocorrelation (2)	-0.87 (0.3855)	Autocorrelation (2)	-0.86 (0.3887)

- Dependent variable is $\ln(Y/L)_{it}$;
- Standard errors in parenthesis;
- * = significant at 1%; ** = significant at 5% (small-sample statistics adopted);
- TESTS: Wald test for jointly significance of coefficients (null hypothesis: all coefficients are not jointly significant); Sargan's [32] test of over-identifying restrictions (null hypothesis: the model is correctly specified); Arellano-Bond test that average autocovariance in residuals of order 2 is 0 (null hypothesis: no autocorrelation);
- § = in parenthesis the p-values.

The results from regressions [3.14] and [3.15] are much closed and this is obvious given the similarity between the two models estimated. The test of second-order serial correlation in residuals confirms the validity of the Arellano-Bond GMM estimator which is, therefore, consistent. Moreover, Sargan's [50] test of the instruments supports the assumption that the two models are correctly specified and that all independent variables employed in this study can be considered as strictly exogenous. According to the Wald test, regressors are jointly significant at a 1% level but, taken individually, some variables do not result statistically different from zero. With regard to the significant coefficients, all signs are as expected. In particular way, the positive (and less than one) sign of the coefficient associated to $\ln(Y/L)_{it-1}$ guarantees the existence of economic convergence across Italian provinces in the period considered[1] and confirms the weak reduction of economic disparity between the Centre-North and the South already observed in most recent years in Italy (Istituto Guglielmo Tagliacarne [13]). The coefficients performed by the climatic variables suggest that high mean yearly values of the max temperatures as well as an excessive variability of the min ones badly affect economic growth. On the opposite, the number of frost days per year determines a positive effect on the dependent variable. On the whole, the estimates presented in table 4.1 seem to reveal that climatic characteristics actually affect the level of income across the Italian Provinces.

6. Concluding remarks

The results achieved in the present study should help to understand whether climatic features can help to explain the different economic growth's path between the Provinces of Centre-North and those of South Italy. The findings reveal three notable characteristics that can be summarized as follows: first, average max

[1] In model [3.14] the growth rate can be written (subtracting $\ln(Y/L)_{it-1}$ from both sides of equation) as:

$$\ln(Y/L)_{it} - \ln(Y/L)_{it-1} = \phi \ln(Y/L)_{it-1} - \ln(Y/L)_{it-1} + \gamma' x_{it} + \eta_t + \varepsilon_{it}$$

Therefore:

$$\ln(Y/L)_{it} - \ln(Y/L)_{it-1} = (\phi - 1)\ln(Y/L)_{it-1} + \gamma' x_{it} + \eta_t + \varepsilon_{it}$$

For convergence: $-1 < (\phi - 1) < 0 \Rightarrow 0 < \phi < 1$ (the same for model [3.15]).

temperatures appear to have a substantial adverse effect on income; second, an excessive variability of the min temperatures negatively affects economic growth; third, frost determines a positive impact on Provincial income. These results seem to depict a typical continental climate, generally characterized by severe winters (with very low temperatures and frequent frosts) and warm summers, and, therefore, by great temperature variability. The continental climate characterizes most of the North Italy Provinces, particularly those located in the Po Valley, which represent also the most industrialized and developed in Italy. For this reason, the findings provided by the presents study seem to indicate that climate matters importantly for economic development of Italy. Last evidence opens the discussion to a further consideration: climate represents a deterministic element which calls to be added to the debate about the possible determinants of economic growth. But this deterministic perspective not necessarily implies a pessimistic view about the possible decline and, eventually, solution, of the dualistic nature of the Italian economy. In fact, national policies can help to overcome the deterministic effect of climate, adopting opportune growth mechanism for the climatically-disadvantaged Italian provinces. As noted by Masters and Sachs [21] climatic conditions could play only a historical role in economic development of some areas. In such cases the diffusion of policies and institutions from economically-successful provinces to less developed ones may represent the best way for a faster growth. But if climate affects current productivity levels of Italian provinces (as the results presented here seem to confirm), then “location-specific innovations” may be needed. If economic growth at provincial level is constrained by climatic characteristics affecting agriculture or disease, then public investment in R&D for new technologies in agriculture and health could overcome the effects of climate in the climatically-disadvantaged areas. In other words, identifying the role of climate conditions for economic development can help policymakers to circumvent their effects through innovation and R&D targeted to climatically-disadvantaged provinces rather than innovation or the diffusion of existing policies and institutions. The evidence for this statement surely calls for further investigations since could represent a way to reduce the persistent inequality in income levels between the northern and the southern Italian provinces.

References

[01]Acemoglu, D., S. Johnson and J.A. Robinson (2002) "*Reversal of Fortune: Geography and Institutions in the Making of the Modern World Income Distribution*", Quarterly Journal of Economics 117(4): 1231-1294.

[02]Arellano, M. and S. Bond (1991) "*Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations*", Review of Economic Studies, Vol. 58, pp. 277-297.

[03]Cao, X. (2003) "*Climate change and energy development: implications for developing countries*" Resources Policy 29, 61–67.

[04]Crosby, A. W. (1986) "*Ecological Imperialism: The Biological Expansion of Europe, 900-1900*" Cambridge University Press, Cambridge, UK.

[05]Daniele, V. (2002) "*Diari di sviluppo di convergenza regionale in Italia*" Università degli Studi Magna Grecia di Catanzaro, DOPES WP No 09.

[06]Demurger, S., J.D. Sachs, W.T. Woo, S. Bao, G. Chang and A.Mellinger (2002) "*Geography, Economic Policy and Regional Development in China*" Harvard Institute of Economic Research Paper No. 1950. http://ssrn.com/abstract=286672

[07]Dunford, M. (2002) "*Italian Regional Evolutions*" Environment and Planning A, (2002) 34: 657-94

[08]Easterly, W. and R. Levine (2003) "*Tropics, germs, and crops: how endowments influence economic development*", Journal of Monetary Economics 50, 3-39

[09]Gallup, J.L., J.D. Sachs and A. Mellinger (1999) "*Geography and Economic Development*" CID Working Papers No. 1, Center for International Development at Harvard University.

[10]Goria, A, and G. Gambarelli (2004) "*Economic Evaluation of Climate Change Impacts and Adaptation in Italy*", Fondazione Eni Enrico Mattei, Working Paper No 103.

[11]Gundlach and Matus-Velasco (2000) "*Climatic Conditions, Cultural Diversity and Labor Productivity"* Working Paper No. 1015, Kiel Institute of World Economics.

[12]Hauk, W. R. and R. Wacziarg (2004) "*A Monte Carlo Study of Growth Regressions*" NBER Technical Working Paper #T0296

[13]Istituto Guglielmo Tagliacarne (2003) "*Le traiettorie dello sviluppo delle province italiane attraverso l'analisi del prodotto interno lordo. Una prima analisi 1995-2002",* Rome, Istituto Guglielmo Tagliacarte

[14]Jones, Charles I. (1996) "*Human Capital, Ideas, and Economic Growth*" Stanford University (mimeo) prepared for VIII Villa Mondragone International Economic Seminar - Rome June 25-27.

[15]Kamarck, A.M. (1976) "*The Tropics and Economic Development*" John Hopkins University Press, Baltimore, MD

[16]Klenow, Peter J., Andrés Rodriguez-Clare (1997) "*The Neoclassical Revival in Growth Economics: Has it Gone Too Far?*" NBER Macroeconomics Annual 12: 73-114.

[17]Knight, M., N. Loayza and D. Villanueva (1993) "*Testing the Neoclassical Theory of Economic Growth: A Panel Data Approach*" IMF Staff Papers 40, 512-541.

[18]Maddison D., and A. Bigano (2003) "*The Amenity Value of the Italian Climate*" Journal of Environmental Economics and Management, vol. 45, issue 2, pages 319-332.

[19]Mankiw, N.G., D. Romer, and D.N. Weil (1992) "*A Contribution to the Empirics of Economic Growth*" Quarterly Journal of Economics, Vol. 107, pp. 407-437.

[20]Masters, W. and M.S. McMillan (2001) "*Climate and Scale in Economic Growth*" Journal of Economic growth, 6(3), September, 167-186.

[21]Masters, W.A. and J.D. Sachs (2001) "*Climate and Development*" Paper presented at the annual meetings of the AEA, New Orleans LA, 7 January 2001

[22]Mauro, L. (2004) "*The macroeconomics of Italy: a regional perspective*" Journal of Policy Modeling 26 927-944

[23]Mellinguer, A.D., J.D. Sachs and J.L. Gallup (1999) "*Climate, Water Navigability, and Economic Development*" CID Working Paper no. 24, Center for International Development at Harvard University

[24]Moonen, A.C., L. Ercoli, M.Mariotti and A. Masoni (2002) "*Climate change in Italy indicated by agrometeological indices over 122 years*" Agricultural and Forest Meteorology, vol. 111, pp. 13-27.

[25]Nickell, S.J., (1981) "*Biases in Dynamic Models with Fixed Effects*" Econometrica, 49, 1417-1426.

[26]Olsson, O. (2003) "*Geography and Institutions: A Review of Plausible and Implausible Linkages*" Working Papers in Economics No 106, Department of Economics, Göteborg University.

[27]Olsson, O. and D.A. Jr. Hibbs, (2000) "*Biogeography and long-run economic development*" Göteborg University Working Papers in Economics No 26.

[28]Ram, R. (1997) "Tropics and Economic Development: An Empirical Investigation" World Development, Vol. 25, No 9, pp. 1443-1452.

[29]Ram, R. (1999) "*Tropics and Income: A Longitudinal Study Of The U.S. States*" Review of Income and Wealth, Series 45, Number 3.

[30]Rilasciati, L (2002) "*Italy Country Base Line Study. Climate, Water, and Wetlands*" Paper presented at the Mediterranean Regional Roundtable Athens, Greece, December 10-11.

[31]Salinger, M.J, C.J. Stigter, and H.P. Das (2000) "*Agrometeorological adaptation strategies to increasing climate variability and climate change*" Agricultural and Forest Meteorology 103(1/2): 167-184.

[32]Sargan, J. D. (1958) "*The estimation of economic relationships using instrumental variables*", Econometrica, vol.26, 393-415.

[33]Solow, R. (1956) "*A contribution to the Theory of Economic Growth*" Quarterly Journal of Economics, Vol. 70 (1), 65-94

[34]Theil, H. and R. Finke (1983) "*The distance from the equator as an instrument variable*" Economic Letters 13, 357-360.

[35]Terrasi, M. (1999) "*Convergence and divergence across Italian regions*" The annals of regional science, No. 4, pp. 491-

Visited websites:

[36]Italian Aerobiology Association: http://www.isao.bo.cnr.it/aerobio/aia/index_e.html

APPENDIX

From equation [3.13], given two points in time $t_1 < t_2$, income per effective worker at the end of period is:

$$\ln(y)_{t_2} = \left(1 - e^{-\lambda\tau}\right)\ln(y^*) + e^{-\lambda\tau}\ln(y)_{t_1} \qquad \text{[A.1]}$$

where $\tau = (t_2 - t_1)$. Subtracting $\ln\left(y_{t_1}\right)$ from both sides and re-arranging:

$$\ln(y)_{t_2} - \ln(y)_{t_1} = \left(1 - e^{-\lambda\tau}\right)\left[\ln(y^*) - \ln(y)_{t_1}\right] \qquad \text{[A.2]}$$

First model

Taking into account that $\ln(y) = \ln(Y/AL) = \ln(Y/L) - \ln(A) = \ln(Y/L) - \ln(A_0) - gt - \omega CLIM - \sigma SOCCUL$, equation [3.7] can be substituted into $\ln(y^*)$ in equation [A.2]:

$$\left[\ln(Y/L)_2-\ln(A_0)-gt_2-\omega CLIM-\sigma SOCCUL\right]-\left[\ln(Y/L)_1-\ln(A_0)-gt_1-\omega CLIM-\sigma SOCCUL\right]=$$
$$\left(1-e^{-\lambda\tau}\right)\left[-(\alpha+\beta)/(1-\alpha-\beta)\ln(n+g+\delta)+\alpha/(1-\alpha-\beta)\ln s_k+\beta/(1-\alpha-\beta)\ln s_h-\ln(y)_{t_1}\right]+$$
$$-\left(1-e^{-\lambda\tau}\right)\left[\ln(Y/L)_1-\ln(A_0)-gt_1-\omega CLIM-\sigma SOCCUL\right] \quad \text{[A.3]}$$

Re-arranging, adding an error term and using the panel data notation:

$$\begin{aligned}\ln(Y/L)_{it} = \; & \gamma_0+\gamma_1\ln s_{k,it-\tau}+\gamma_2\ln s_{h,it-\tau}+\gamma_3\ln(n+g+\delta)_{it-\tau}+\gamma_4 CLIM_{it-\tau}+ \\ & +\gamma_5 SOCCUL_{it-\tau}+\phi\ln(Y/L)_{it-\tau}+\mu_i+\eta_t+v_{it}\end{aligned} \quad \text{[A.4]}$$

where: τ represents the duration of a time period beginning at $t-\tau$ and ending at t, $\gamma_0+\mu_i=\left(1-e^{-\lambda\tau}\right)\ln(A_0)$ corresponds to the initial level of technology which varies across Italian Provinces (specifically: γ_0 is a constant capturing the average level of initial technology, μ_i is a province-specific effect), $\gamma_1=\left(1-e^{-\lambda\tau}\right)\frac{\alpha}{(1-\alpha-\beta)}$; $\gamma_2=\left(1-e^{-\lambda\tau}\right)\frac{\beta}{(1-\alpha-\beta)}$; $\gamma_3=-\left(1-e^{-\lambda\tau}\right)\frac{(\alpha+\beta)}{(1-\alpha-\beta)}$; $\gamma_4=\left(1-e^{-\lambda\tau}\right)\omega CLIM$; $\gamma_5=\left(1-e^{-\lambda\tau}\right)\sigma SOCCUL$; $\phi=e^{-\lambda\tau}$; $\eta_t=g\left(t_2-t_1e^{-\lambda\tau}\right)$ is a time-specific effect; v_i is an error term $v_i \sim iidN(0,\sigma_v^2)$.

Equation [3.14] is given by [A.4] written in a compact form when $\tau=1$.

Second model

Taking into account that $\ln(y) = \ln(Y/AL) = \ln(Y/L) - \ln(A) = \ln(Y/L) - \ln(A_0) - gt$, equation [3.12] can be substituted into $\ln(y^*)$ in equation [A.2]:

$$\begin{aligned}&\left[\ln(Y/L)_2 - \ln(A_0) - gt_2\right] - \left[\ln(Y/L)_1 - \ln(A_0) - gt_1\right] = \\ &\left(1 - e^{-\lambda\tau}\right)\left[-\alpha/(1-\alpha)\ln(n+g+\delta) + \alpha/(1-\alpha)\ln s + \omega SCHOOL + \sigma CLIM\right] + \\ &-\left(1 - e^{-\lambda\tau}\right)\left[\ln(Y/L)_1 - \ln(A_0) - gt_1\right]\end{aligned} \qquad \text{[A.5]}$$

Re-arranging, adding an error term and using the panel data notation:

$$\begin{aligned}\ln(Y/L)_{it} = \;& \xi_0 + \xi_1 \ln s_{it-\tau} + \xi_2 \ln(n+g+\delta)_{it-\tau} + \xi_3 SCHOOL_{it-\tau} + \\ & + \xi_4 CLIM_{it-\tau} + \theta \ln(Y/L)_{it-\tau} + \mu_i + \eta_t + v_{it}\end{aligned} \qquad \text{[A.6]}$$

where: $\xi_0 + \mu_i = \left(1 - e^{-\lambda\tau}\right)\ln(A_0)$; $\xi_1 = \left(1 - e^{-\lambda\tau}\right)\dfrac{\alpha}{(1-\alpha)}$; $\xi_2 = \left(1 - e^{-\lambda\tau}\right)\dfrac{\alpha}{(1-\alpha)}$; $\xi_3 = \left(1 - e^{-\lambda\tau}\right)\omega SCHOOL$;

$\xi_4 = \left(1 - e^{-\lambda\tau}\right)\sigma CLIM$; $\theta = e^{-\lambda\tau}$; $\eta_t = g\left(t_2 - t_1 e^{-\lambda\tau}\right)$.

Equation [3.15] is given by [A.6] written in a compact form when $\tau = 1$.

Figure A.1. Map of Provinces analyzed

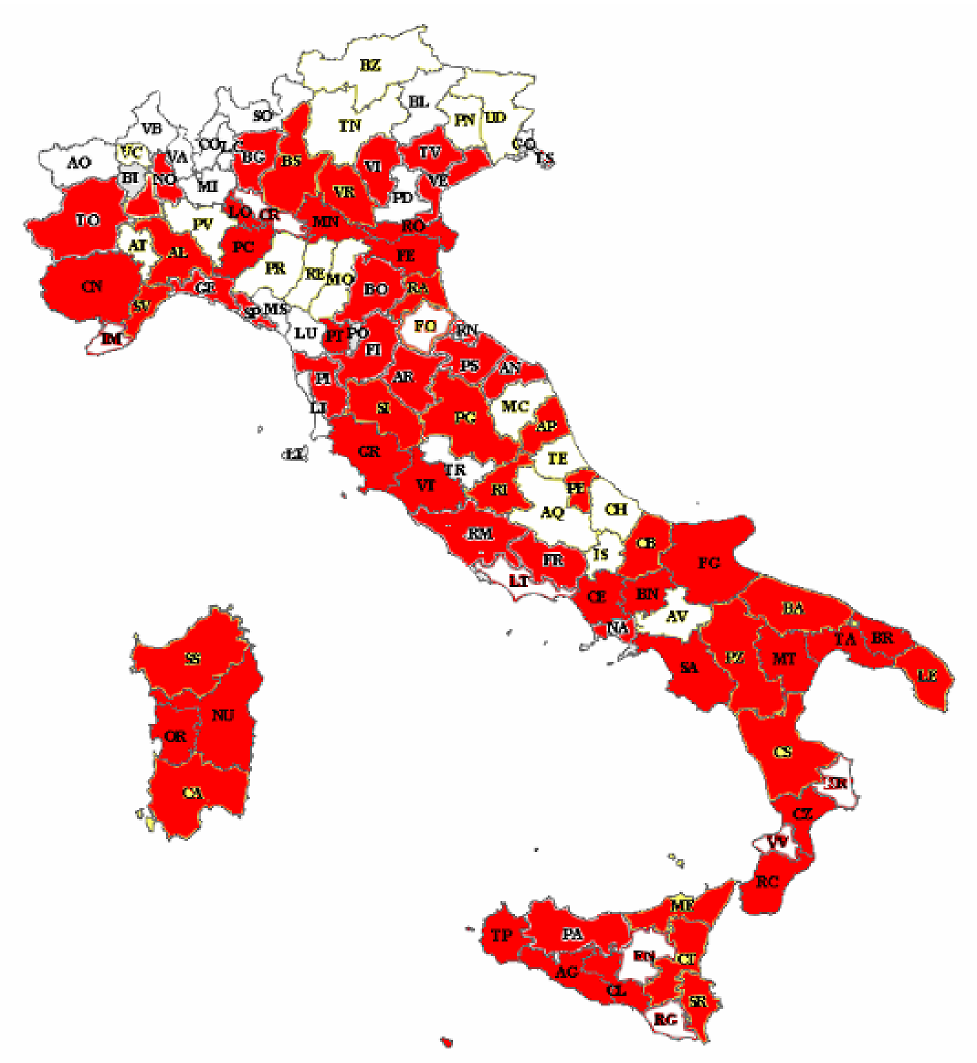


Table A.1. List of meteorological stations

PROVINCE	METEREOLOGICAL STATION	ALTITUDE	LATITUDE	LONGITUDE	PROVINCE	METEREOLOGICAL STATION	ALTITUDE	LATITUDE	LONGITUDE
TORINO	TORINO CASELLE	301	45° 11'	07° 39'	VITERBO	CAPRAROLA	650	42° 19'	12° 10
NOVARA	NOVARA CAMERI	178	45° 31'	8° 40'	ROMA	ROMA CIAMPINO	129	41° 48'	12° 35'
CUNEO	MONDOVI'	559	44° 23'	7° 49'	FROSINONE	FROSINONE	180	41° 38'	13° 18'
ALESSANDRIA	CARPENETO	230	44° 40'	8° 37'	PESCARA	PESCARA	10	42° 26'	14° 12'
BERGAMO	ORIO AL SERIO	238	45° 40'	9° 42'	TERMOLI	TERMOLI	16	42° 0'	15° 0'
BRESCIA	BRESCIA GHEDI	102	45° 25'	10° 17'	CASERTA	GRAZZANISE	9	41° 3'	14° 4'
MANTOVA	ZANZARINA	40	45° 12'	10° 31'	BENEVENTO	PIANO CAPPELLE	152	41° 6'	14° 49'
MILANO-LODI	MONTANASO LOMBARDO	83	45° 19'	9° 27'	NAPOLI	NAPOLI CAPODICHINO	88	40° 51'	14° 18'
VERONA	VERONA VILLAFRANCA	67	45° 28'	10° 55'	SALERNO	CAPO PALINURO	184	40° 1'	15° 16'
VICENZA	VICENZA	39	45° 34'	11° 31'	FOGGIA	FOGGIA AMENDOLA	57	41° 26'	15° 33'
TREVISO	TREVISO SANT'ANGELO	18	45° 39'	12° 11'	BARI	PALO DEL COLLE	191	41° 3'	16° 37'
VENEZIA	VENEZIA TESSERA	2	45° 30'	12° 20'	TARANTO	MARINA DI GINOSA	2	40° 26'	16° 53'
TRIESTE	TRIESTE	8	45° 39'	13° 47'	BRINDISI	BRINDISI	15	40° 39'	17° 57'
SAVONA	CAPO MELE	220	43° 57'	8° 10'	LECCE	LECCE	48	40° 21'	18° 10'
GENOVA	GENOVA SESTRI	2	44° 24'	8° 52'	POTENZA	POTENZA	823	40° 38'	15° 48'
LA SPEZIA	SARZANA LUNI	9	44° 5'	9° 59'	COSENZA	BONIFATI	484	39° 35'	15° 53'
PIACENZA	PIACENZA	134	45° 0'	9° 42'	CATANZARO	LAMEZIA TERME	216	38° 58'	16° 19'
BOLOGNA	SBOLOGNA B. PANIGALE	36	44° 30'	11° 19'	REGGIO CALABRIA	REGGIO CALABRIA	11	38° 4'	15° 38'
RAVENNA	MARINA DI RAVENNA	2	44° 28'	12° 17'	TRAPANI	TRAPANI BIRGI	7	37° 55'	12° 30'
RIMINI	RIMINI	12	44° 2'	12° 37'	PALERMO	PALERMO PUNTA RAISI	21	38° 10'	13° 5'
FIRENZE	SAN CASCIANO	230	43° 40'	11° 9'	MESSINA	MESSINA	59	38° 12'	15° 33'
PISA	SAN PIERO A GRADO	3	43° 40'	10° 20'	AGRIGENTO	PIETRANERA	158	37° 30'	13° 31'
AREZZO	AREZZO	248	43° 28'	11° 51'	GELA	GELA	11	37° 5'	14° 13'
SIENA	RADICOFANI	896	42° 54'	11° 46'	CATANIA	SANTO PIETRO	313	37° 7'	14° 31'
GROSSETO	GROSSETO	5	42° 45'	11° 7'	SIRACUSA	COZZO SPADARO	46	36° 41'	15° 8'
PERUGIA	SANTA FISTA	311	43° 31'	12° 7'	SASSARI	OLBIA COSTA SMERALDA	11	40° 54'	9° 31'
PESARO-URBINO	FRONTONE	570	43° 31'	12° 44'	NUORO	CAPO BELLAVISTA	138	39° 56'	9° 42'
ANCONA	FALCONARA	12	43° 37'	13° 22'	CAGLIARI	CAGLIARI ELMAS	4	39° 15'	9° 3'
ASCOLI PICENO	MONSAMPOLO	43	42° 53'	13° 47'	ORISTANO	SANTA LUCIA	14	39° 58'	8° 37'

Table A.2. Descriptive statistics of climatic variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
FRO	281	25.47331	24.7907	0	93
MAX	299	20.17753	2.007599	15.30839	24.9932
MIN	287	10.41389	2.575035	5.078148	17.07656
RAIN	327	705.567	263.5229	179.8	1675.1
HUMID	279	66.00551	5.74403	47.7074	84.60021