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CLUB PERFORMANCE DYNAMICS AT ITALIAN REGIONAL LEVEL

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Club performance dynamics at Italian regional level

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Abstract

This paper analyze the dynamic economic performance of the Italian regions during the period 1970-2004. The measure of economic performance is given by the level and the growth rates of per capita GDP. Using the concept of economic regime, we introduce a notion of distance between the dynamical paths of the Italian regions. Afterwards, a Minimal Spanning Tree and a Hierarchical Tree are constructed from time series in order to assess the existence of groups of regions sharing similar economic performance. Two main clusters are identified, representing high performance and low performance regions, alongside other two small clusters displaying regions with similar dynamic behaviour. The high performance cluster comprises mainly regions from the north, showing the presence of agglomeration externalities. Turning to the evolution of clusters, we see a similar path until 1975, after which the two groups start to slightly diverge. Studying the evolution of each cluster's diameter we find substantial convergence within the two groups. Splitting the sample into two periods (1975-1993 and 1994-2005) the hypothesis of two performance clubs is confirmed. The club shift of some regions hints a strong effect on regional economic dynamics of the Italian 1994 crisis. The final analysis of the distance between the two clusters show that in the first period (1975-1993) the distance between the two group was constant, while in the second one (1994-2005) it has increased

Keywords: economic convergence, economic dualism, hierarchical clustering
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1. Introduction

According to neo-classical growth theory (Solow, 1956), less rich countries bearing a capital labour ratio below their long run steady state should have a rate of return in fixed investment higher than more developed countries. Here comes the convergence hypothesis, according to which developing countries should grow faster that developed ones so as to eventually attain the same level of per capita income.

Thereby income differences among economies would be due to the lack of production factors or to their inefficient combination, so that the only way to reach efficiency would be to allow market forces to operate as freely as possible, ensuring convergence of income and growth. At the outmost economic policy might be focused on labor supply and education level, as well as on the adoption of more up to date techniques of production.

However the empirical evidence does not support convergence, as productivity and income levels of developed and poor countries still diverge. This is also the case for the Italian regions, as we will see in a more detailed fashion.

In order to reconcile theory with empirics the scholar community rediscovered two alternative approaches. The first one is based on the work by Schumpeter (1934), which highlighted the function of innovative entrepreneurship and institutions in sustaining growth. The other one is the Post-Keynesian approach (Kaldor, 1957), where cumulative causation and increasing returns to scale could either keep countries in a development trap or foster development.

At the beginning of the 90s, a new approach challenging the traditional Solovian view has appeared. This is the Romer-type Endogenous Growth Theory which, although being closed to the canonical approach than the Schumpeterian or the Post-Keynesian analysis, nonetheless is very critical on market forces ability to promote optimal resources allocation and sustained growth.

Romer-type Endogenous Growth Theory, further developing the post-Keynesian view that investment might raise income due to increasing returns, argues that investments in human capital and the intertemporal knowledge spillovers are a source of long run growth. Thereby a process of convergence and catching up is possible only through technology transfers. In this view the absorptive capabilities of an economy, which is influenced

by institutional and political factors (Abramovitz 1986; Romer 1993), is pivotal.

Beside the absolute convergence or β convergence, Barro and Sala-i-Martin (1992a) introduced the definition of σ convergence, which is the tendency for the dispersion (defined in terms of standard deviation) of per capita income to decrease over time. So σ convergence does not only depend on the growth rates but also on the initial gap size.

Although widely accepted, some of these definitions have encountered bitter criticism. For instance Quah (1993) and Friedman (1992), in the context of the so-called Galton's "regression to the mean" (Stigler, 1997), pointed out that the concept of β convergence is irrelevant because what is pivotal in the analysis is to discern if the dispersion in the world's income distribution has decreased over time. In fact Quah (1993) showed that a negative coefficient in a cross-sectional regression does not necessarily involve convergence.

Moreover Mankiw (1995)[1] has argued that economic growth might be affected by a wider range of factors, other than mere traditional inputs, leading to the concept of conditional β convergence, according to which incomes of countries with identical underlying characteristics (preferences, technologies, population growth, institutions) converge in the long run independently of their initial conditions. So the difference in growth rates of income would be due to the distance of the economies from their own respective steady states.

In order to justify the conditional convergence hypothesis, many empirical studies have tried to introduce other aspects in the analysis. Among them, Mankiw, Romer and Weil (1992) introduced some additional variables as proxies for the steady state, while Barro and Sala-i-Martin (1995) limit their study to set of countries believed to have converged to the same steady state.

[1] Dalgaard and Hansen (2005) and Azariadis and Drazen (1990) by explicitly considering human capital with increasing social returns to scale after a given threshold level, have shown the possibility of multiple steady states even in the original Solow model. Durlauf and Johnson (1995) also found that countries with different initial conditions might show a different development path towards either one or multiple steady states.

Other important studies are the simulation equation models (Cracolini *et al.* 2010); the cross-sectional models and spatial panel models (*inter alias*, Carrion-i-Silvestre and German-Soto 2009, Checherita 2009); the Panel Convergence testing (Phillips and Sul 2009; Apergis *et al.* 2010), and finally the auto correlation function approach (Cagiano and Leone 2009).
Quah in 1996 and 1997 introduced a technique (which was not based on a theoretical model) for assessing the dynamics of countries' cross sectional distribution regarding the world growth pattern over the period post World War II.
According to him the per capita income at world level evolved into a twin peaks[2] distribution so that there was no convergence among countries. By contrast Quah argues that only countries which are identical in their structural characteristics converge in the long run into subsets (the so called convergence clubs) provided their initial conditions are similar. Thereby each economy moves toward its club's specific steady state equilibrium, which depends on its own initial position. In particular Quah (1997) stresses the role of human capital and growth rate in an endogenous growth framework. So according to his study economies with different human capital level would experience diverging growth rates and henceforth would not converge[3].

The standard empirical results firmly reject the hypothesis of absolute convergence, while conditional convergence and club convergence (*à la* Quah) are confirmed. Indeed, as pointed out in the survey by Durlauf (1996) and Durlauf and Quah (1999), differences in growth rate and per capita income across nations are persistent.
One might wonder if empirical evidence supports absolute convergence within a country instead of at country level, as the structural characteristics among regions are very similar. This might have been the case for some

[2] Quah (1996) has been the developer of the twin peaks hypothesis, according to which while the gap between poor and rich countries widened in the time span he considered, the intermediate income class became poorer.

[3] Other reasons leading up to the formation of clubs are path dependency and hysteresis (Quah 1996, Durlauf and Quah 1999).

developed countries, such as Italy across the period 1950-1973, for which the development process decreased the internal economic inequalities.
The revival of research in growth theory, taking place at the end of the 80s, was led by the lack of satisfaction towards the neoclassical model, according to which differences in income or productivity were due to different parameter values of the underlying model, so that countries missing such differences would have converged to a conditionally unique development path. The idea that rich and poor economies would have converged towards a conditionally unique long run growth path has been adopted to explain the differences observed in regional development (Barro and Sala-i-Martin 1992b for US and Japan; Sala-i-Martin 1996 for Europe and Japan). Given higher factor mobility, knowledge spillovers in technology and enhanced market competition regions were expected to converge to the same income growth path even easier than countries, so the that policy makers would not have to worry about supporting certain lagging regions or groups of regions. But as shown in the literature the regional convergence hypothesis has not found empirical support, peculiarly for the Italian case, thereby comes the necessity to investigate further the issue.
The notions of convergence/divergence at regional level made explicit the idea that a region's dynamics can be better characterized resorting on the notion of *regime* (Brida 2008). Owen et al. (2009) elaborate a method assuming a class or regime structure in which the regimes are discrete and not hierarchically ordered. However, the methodology here adopted advances over the existing literature by imposing an order on the regimes and by using a more adequate technique called symbolization.

The paper is organized as follows. In section 2 we give an overview of the Italian regions. Section 3 presents the empirical results of economic convergence studies at regional level in Italy**.** Section 4 highlights the phenomenon of Economic Dualism in Italy. In section 5 we introduce the Methodology and the empirical results. Section 6 includes the cluster dynamics and finally, section 7 concludes.

2. Overview of the Italian regions

The Italian Republic encompasses 5 administrative levels: municipalities, metropolitan cities, provinces, regions and the central state. The twenty Italian Regions constitutes its first NUTS (Nomenclature of Units for Territorial Units) administrative level: Veneto, Friuli-Venezia Giulia, Trentino-Alto Adige/Südtirol, Emilia Romagna (North-East); Aosta Valley, Liguria, Piedmont, Lombardy (North-West); Tuscany, Umbria, Marche, Lazio (Center); Molise, Abruzzo, Campania, Calabria, Basilicata, Apulia (South); Sicily and Sardinia (islands).

The regional entities, disciplined by the constitutional assembly in 1947 (article 22) and instituted in 1970, are entitled with own statutes, powers and functions along the principles fixed by the article 114 of the Constitution. Each region possesses a Regional Council[4] (which is an elected parliament) and a government chaired by the President of the region, which is elected directly by the citizens. Exceptions are Trentino-Alto Adige/Südtirol and Aosta Valley, where the president is chosen by the Regional Council.

There are five regions bearing ethnic, cultural and linguistic differences with respect to the rest of Italy, and thereby enjoying a special autonomy status: Aosta Valley, Friuli-Venezia Giulia, Sardinia, Sicily, Trentino-Alto Adige/Südtirol. Those regions are autonomous as they possess legislative and administrative powers in sectors such as infrastructures, health and education which are mostly self funded. In fact the autonomous regions are entitled to retain from 60% (Friuli-Venezia Giulia) up to 100% (Sicily) of all the levied taxes.

A great level of autonomy, similar to the regional status, it is also provided to some provinces who are entitled with wide legislative and executive power. Those are the autonomous provinces of Trento and Bolzano, constituting the region Trentino-Alto Adige. The historical roots of this special status are due to the presence of a German-speaking (Südtirolerisch) minority (32.73% in the whole region).

[4] Except for Sicily, where it is called Regional Assembly.

As widely shown in the literature, Italian regions differ deeply in terms of economic performance and degree of development. As reported by EUROSTAT[5], 26 % of Italian population lives in a province with a level of income per capita equal to 125% of the EU average. On the other hand 29% of population resides in province with per capita income lower that 75% of EU average. This makes Italy the unique EU country having at the same time a per capita income in line with the continental average, but with a high share of population living well below the European standards.
In France, where per capita income is higher with respect to Italy, only 8.5% of population resides in departments with a per capita GDP higher than 125% of EU average. By contrast in Spain, where per capita GDP is comparable to Italy, only 6% of population belongs to areas where per capita income is lower than 75% of European average. Finally in United Kingdom and in Germany, where per capita income is higher than in Italy, the share of citizens living in rich areas is respectively 25% and 27%, thereby similar to the Italian case.
As we will discuss later, the main problem for Italy is the economic backwardness of the South. In fact the GDP per capita in Southern Italy is only 60.3% of the national average, the rate of fixed gross investment per capita is 61.7%, while the rate of employment and the rate of unemployment are respectively 71.6% and 293% with respect to national average.

3. Economic convergence at regional level in Italy

Barro and Sala-i-Martin (1995) have pioneered the study of regional convergence. They examined the GDP convergence hypothesis for 90 EU regions: 3 in Belgium, 3 in Denmark, 4 in the Netherlands, 11 in Germany, 11 in United Kingdom, 17 in Spain, 20 in Italy and 21 in France. Their analysis, carried out for the period 1950-1990, shows an absolute convergence at 2% of speed every year within and among countries. Also Armstrong (1995) finds a process of absolute convergence in gross per capita value added during the period 1950-1970 for 82 EU regions. All these findings would suggest that also lagging Italian regions would converge to the rest of the country. Unfortunately other empirical studies do not confirm this view. In fact in the 70s and in the 80s there has been a process of

[5] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/

convergence between countries, but the differentials among regions seemed unaltered or even increased. As an example the decrease in the Italian regional GDP per capita dispersion, which was marked in the 60s, faded after 1975. This increase in convergence before 1975 has been favored by national policies directed at increasing the southern development by accelerating the administrative decentralization (which enhanced the amount of resources devoted to the public sector), as well as aimed at diminishing the wage differential among Italian regions. These policies, as reported by Di Liberto *et al.* (2003), led to a decrease in migration from South to North during the 70s. Moreover the share of industrial investment in the south shifted from 15% during the period 1951-1959 to 44% in 1973 (Graziani 1978), thanks to national policies aimed at fostering the investment in Southern chemical and steel industry.

As reported by Aiello and Scoppa (1999) many empirical studies found that after 1975 the differential in development between southern and northern Italy widened again (Mauro and Podrecca 1994; Cosci and Mattesini 1995, 1997; Paci and Pigliaru 1995; Cellini and Scorcu 1997a, 1997b; Di Liberto 1994; Paci and Saba 1998; Bianchi and Menegatti 1997; Fabiani and Pellegrini 1997).

Among those works, Mauro and Podrecca (1994) and Paci and Saba (1998) explicitly target the robustness of the results shown in Barro and Sala-i-Martin (1995). More precisely Mauro and Podrecca (1994) argue that the data used in Barro and Sala-i-Martin (1995) were extracted from different sources (Unioncamere 1963-70; ISTAT old time series 1970-1980; ISTAT new time series 1980-1989), hence they were not timely homogeneous. In order to solve this issue, they split the sample into the three sub-periods consisting of homogeneous data. By doing that, they found evidence of a process of convergence in the 60s and 70s, but not in the 80s.

Another assessment of the convergence hypothesis for Italy in the period 1951-1993 was carried out by Paci and Saba (1998). Making use of the dataset elaborate by Mauro and Podrecca (1994), they found evidence of a catching up process taking place from 1960 to the middle of the 70s, while in 1975 per capita income and labor productivity changed pattern.

By the same token Di Liberto *et al.* (2003) computed the standard deviation of the log of GDP for Italian regions in the period 1963-1994: they found

that the dispersion of the standard deviation has increased in the middle of the 70s, but in the 80s and beginning of the 90s it has remained stable.
By observing the deviation from the average Italian income, Lombardy and Aosta Valley were the richest regions in the 60s (respectively 32% and 42% wealthier than Italian average). On the contrary the income of the poorest regions, Basilicata and Calabria, was 38% lower than the average. This disparity has decreased along the 70s and 80s, but neither persistently nor uniformly. Indeed Di Liberto *et al.* (2003) found that the Northeast of Italy (Emilia Romagna, Friuli-Venezia Giulia, Trentino-Alto Adige, Veneto) increased the distance from the rest of country. By contrast the Northwest (Aosta Valley, Liguria, Lombardy and Piedmont) decreased its relative advantage.
Similar results are found by Aiello and Scoppa (2000), who computed the standard deviation of regional per capita incomes over the period 1960-93 using the CRENoS database.
Moreover Aiello and Scoppa (2000) argued that Italian regions converged towards different output per worker steady states (conditional convergence). This hypothesis is confirmed by several empirical works (Di Liberto 1994; Cosci and Mattesini 1995, 1997; Fabiani and Pellegrini 1997; Ferri and Mattesini 1997; Bianchi and Menegatti 1997; Cellini and Scorcu 1997b; Di Liberto and Symons 1998). By contrast Cellini and Scorcu (1997a) found evidence of conditional convergence only up to the end of 1980s, while Mauro and Podrecca (1994) and Paci and Pigliaru (1995) find no evidence of it. So as we have seen there is only evidence of conditional convergence taking place for the Italian economy, while the absolute one is completely ruled out. Looking to other countries, the process of convergence has been found to be non homogeneous. In fact Sala-i-Martin (1996) found that many OECD countries displayed a stop in regional convergence in the 70s[6], while De la Fuente (1997) showed that the convergence process in Spain followed a pattern similar to the Italian one.

[6] It is arguable that the stop in the convergence process might have been determined by an increase in oil price in 1973-1974, which pinned down investments and technology transfers.

4. Economic Dualism in Italy

Dualism is the coexistence, within the same economic system, of two entities (e.g. northern and southern Italy) following different development paths, in terms of per capita income growth as well as in terms of social and economic transformations. As Vita and Realfonzo (2006) point out, the economic dualism can be characterized in three different ways: territorial dualism (differences in spatial development); industrial dualism (dichotomy among firms, sectors or productive systems); job market dualism (presence of regular and irregular employed). In the Italian case the three dimensions are interconnected.

The Italian catching up process with the rest of the developed world, which started at the end of the 19th century, had seen its most favorable moment from the 50s to the 70s. According to many sources, such as the Penn World Tables, growth slowed down at the end of the 70s and in the 90s the gap with the rest of the developed world widened again. The regional imbalances followed roughly the same process: the cleavage among regions diminished when Italy was in the catching up process, and increased afterwards. In fact nowadays Italy remains in a situation of economic dualism: on one hand there is an economically and socially advanced centre North, and on the other hand there is the virtually pre-industrial South, lacking social and economic infrastructures, entrepreneurial spirit, bearing low productivity and wages, and huge propensity to emigrate.

With the beginning of Italian industrialization (early 20th century) the cleavage between northern and southern Italy, which before was quite limited, started to deepen, due to historical and structural causes[7], as well as to wrong policies.

Only after the Second World War the South started to develop alongside the rest of Italy, also thanks to public intervention aimed at attracting investments toward Southern industry. In fact in this period 50% of

[7] From 1861 to 1950 many "special laws" tried to alleviate the backwardness of the South, without much success. During Fascism (1922-1940) the authorities even denied the very existence of the economic dualism, as their objective was to divert the excessive Southern agricultural labor force towards the Libyan and Abyssinian colonies.

investments in the South belonged to state owned companies. As evident this process was not sustainable, thereby after the crisis in the 70s and especially in the 90s the convergence process between North and South stopped.
Many economic models have been elaborated during the 50s and the 60 in order to explain the determinants of the dualism and the possible ways of coping with it. Lutz (1962), Lewis (1958) and Kindlerberger (1964) emphasized unbalances and distortions in the job market; Eckaus (1961) and Liebenstein (1962) stressed the relevance of the technological development process; by contrast Marzano (1961) and Graziani (1965) argued that the market mechanism would not bring the system to its equilibrium, so that the distortions in the Italian economy would increase thus reinforcing the dualistic process.

Lutz (1962) blames the absence of free market as a determinant for the Italian economic dualism, as in regime of perfect competition the system would work in full employment and each factor's remuneration would be equal among sectors. Thereby there would be the maximum level of employment according to technology and endowments. By contrast the Italian system used to bear many distortions, such as the presence of unions, wages controls, the presence of monopolistic positions in the final goods market, all leading to an excessive factors' remuneration. Moreover Lutz blamed an excess of supply in industrial goods (due to insufficient propensity to consumption) which, together with a lack of demand for agricultural products, would cause insufficient revenues for industry hence halting the accumulation and development processes.
Thereby to restore the equilibrium it is recommended to decrease the pressure on the agricultural sector fostering migration in order to augment productivity and income (demand side), as well as to increase the agricultural production in order to substitute imports (supply side).
Ackley (1963) and Spaventa (1962) criticized this thesis especially for what concern the necessity for a strong emigration from South to North in order to sustain industrialization. They show that, in case of an unbalance between the demand for industrial products and the supply of agricultural goods, a quick industrialization in the North together with a massive emigration in the

South would be harmful for the entire country, because the market for Southern firms would shrink.

Lewis' idea (1958) is pretty much the opposite of Lutz's. In fact Lewis argues that the development process requires imbalances. He assumes 2 sectors (capitalist and subsistence), closed economy, unlimited work supply and no work specialization. The capitalistic sector is profit maximizing so that price and marginal product equalize. By contrast the subsistence sector's firms are not profit maximizing, so that marginal and average productivities are low and workforce is superabundant.

The labor force surplus in the subsistence sector moves to the capitalistic sector seeking for higher wages, increasing income, while the subsistence sector wages remain constant. The increase in income boosts expenditure, profits, investments and development. During this process, the marginal productivity of workers in the capitalistic sector will be driven up by capital formation and driven down by additional workers entrance.

The system continues to grow until the following conditions are satisfied: workforce surplus in the subsistence sector; the ability of the subsistence sector to satisfy the demand increase, order to prevent inflation, thanks to the income growth given by the shift of labor to the capitalistic sector; the absence of Unions demanding wage rage in the capitalist sector; a lower wage in the subsistence sector.

Kindlerberger (1964) argued that Lewis' model (1958) was suitable to describe the Italian economic development until 1963. This because in his view there was a work surplus in southern agricultural and traditional tertiary activities given by subsistence wages. Thereby a labor shift to the north, characterized by industrial activity, a modern tertiary sector, capitalist agriculture and higher wages and productivity, would not affect wages at the beginning, but instead would boost profits and investments, thus reinforcing the process. This virtuous process of development would continue until the labor shift from the South stops, leading to an increase in wages and a contextual decrease in profits and investments.

Among the scholars who criticized Kindleberger's thesis, it is worth mentioning Vaciago (1969), who claimed that in 1963 the system did not reach full employment because a process of differentiated technical progress nested on economic dualism determined a productivity heterogeneity which favored a continuous reallocation of resources.

Some other scholars, e.g. Eckaus (1961) and Liebenstein (1962), highlight the role of technological progress in development. According to Eckaus (1961) the technical improvements create the a cleavage among sectors: some will adopt modern and capital intensive production techniques, while others will remain traditional and job intensive. On this ground unemployment in backward economies, where production technique is mostly traditional, is due to the presence of market imperfections, limited factors' mobility, and poor factors' substitutability. Innovation and technological progress are carried out only by industrialized economies, while lagging countries can only imitate and import techniques which are soon outdated.

According to Liebenstein (1962) despite the higher potential of improvement in production techniques there is no incentive to invest in the underdeveloped sector in order to equalize the rate of development among sectors and regions through the diffusion of technical progress. By contrast there are limits to invest in the backward sector because in order to permanently shift the production techniques, it would be necessary to substantially increase the capital/labor ratio. Thereby market expansion, increasing returns to scale and lower wages would determine an incentive for firms to move to the backward sector erasing the unbalances.

All the aforementioned models rely on the classic paradigm according to which market mechanisms foster development by removing unbalances. However, there is a class of models which is in contrast with the standard paradigm. For instance Marzano (1961) claims that structural and historical differences determine sectoral and territorial development concentration leading to economics dualism.

In his models there are two categories of agents: capitalists, who divert a considerable part of their income to savings; and workers, who consume all of their wage. There are also three sectors: a leading industrial sector, a led non agricultural sector and a led agricultural sector, which are different with respect to their contribution to development in terms of capital accumulation rate. Finally there is a territorial distinction: Italy has an unbalanced development due to the concentration of investments and innovation in the North. Thus investment decisions in the leading sector drive the process of development (bearing effects on the led sectors), so that some regions would enjoy an advantage while some others would suffer a disadvantage. Differences increase along time due to the cumulativeness of

the process. Finally, according to the export-led development models, economic openness fosters the divergence process among advanced and backward regions or sectors.
In particular according to Graziani (1965) export-led development determines and reinforces economic dualism because it favours exporting firms while local market productions are penalized. This because exporting firms would adopt capital and innovation intensive production techniques, enjoying higher returns to scale and competitiveness in the local market too. By contrast firms producing for the local market have a smaller incentive to increase productivity as they do not face foreign competition.
Moreover foreign demand determines a shift in production from traditional to new commodities, thereby only innovative productions would specialize and enjoy returns to scale. Thus the economy is divided in two sectors: one export oriented, innovative and specialized, and the other one stagnant and producing for the internal market. The workforce, given that the advanced export sector has a limited absorption capability, would converge towards the back ward sector pinning down wages hence fostering the incentive to adopt further labor intensive production techniques.

Then the indexes relative to the year of reference (for instance 2000) are obtained by chaining the previous year price estimations, and finally the series in monetary terms are obtained by multiplying those indexes for the current 2000 values. Thereby, the weighing system is updated every year, so that the dynamics of national account aggregates are measured consistently with the real dynamics of the economic phenomena. Before 2005, there was a fixed weighing method based on a year of reference.

5. Methodology

5.1 The Database

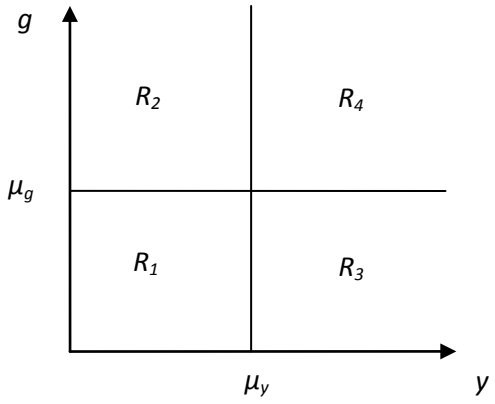
The performance of the Italian regions during the period 1970-2004 will be analyzed using the database from the "Regio-It 1970-2004: Data-base on the Italian regions" developed by CRENoS. The financial crisis period (2007-2009) is not included in the sample, however the time series is longer than the one released by the Italian institute of statistics (ISTAT), spanning from 1995 to 2009. Due to consistency issues, it is not possible to integrate the two series as they have been obtained by using two different methodologies.

In fact the European Community guidelines has defined new standards starting from 2005 according to which national account variables would have to be estimated by using the chain index method in order to measure the real dynamics of economic aggregates. In particular the chain index method makes use of volume measures which are obtained for each year of the estimation on the basis of previous year prices (for instance the estimations of 2001 are based on 2000 prices, the estimations of 2000 are based on 1999 prices, and so on).

5.2 Regime Dynamics

The evolution of per capita GDP in levels and growth rates allows us to assess the dynamics of economic growth.

Figure 1: Performance regimes



We use the notion of regime in order to describe the qualitative behaviour of a regional economy. More precisely we describe the economic dynamics as a sequence of regimes. The state-space in figure 1 displays the level of per capita regional GDP (y) in the horizontal axis and the growth rates of per capita GDP (g_y) in the vertical axis.

The subdivision of the state space into four regions is determined by the exogenous threshold values μ_y and μ_g, which are the average values of levels and growth rate of per capita GDP within a given period. We can assume a transition across time from left to right in the graph: at the beginning a country finds itself in the region where GDP is low and growth is weak; then in the second portion of the Cartesian plane growth rates are high but levels are low; in the third portion both levels and growth rates are high; in the fourth and final stage GDP levels are high but growth rates are low.

As pointed out in our previous work on the topic (Brida et al. 2011), future research will include the replication of the exercise for different partitions using other convenient thresholds. However it is clear that the statistical significance of the outcomes might be affected by the increase of the state space partition, given the fact that we have a finite sample.

Any change of regime signals some form of structural change. The sequential ordering of visited regimes and other parameters of the time dimension give relevant information for understanding which structural change it underwent. To be more precise, we define the four regimes as the following portion of the Cartesian plane [8]:

$$R_1 = \{(y, g_y):\ y \leq \mu_y,\ g_y \leq \mu_g\}$$

$$R_2 = \{(y, g_y):\ y \leq \mu_y,\ g_y \geq \mu_g\}$$

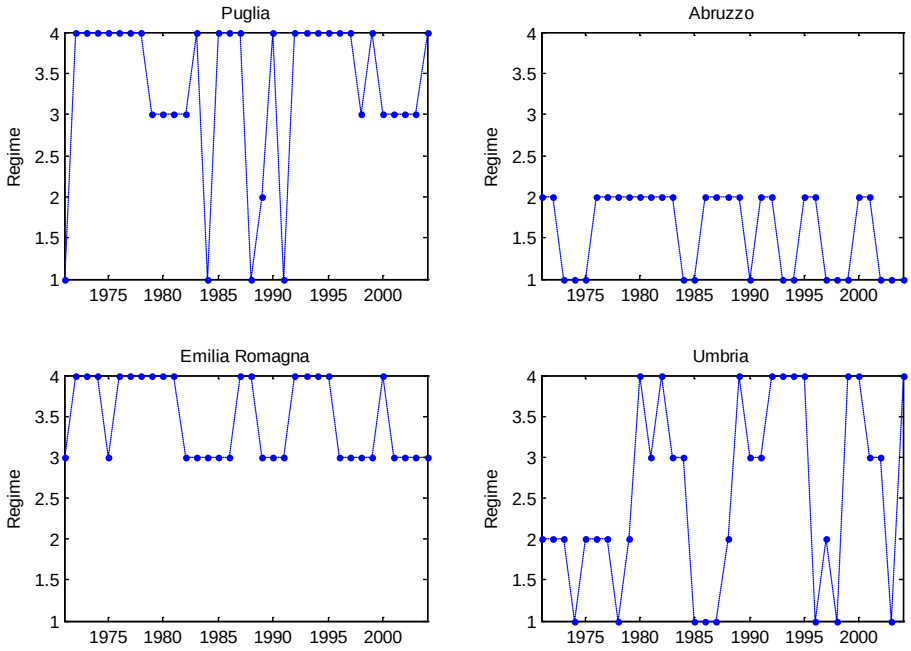
$$R_3 = \{(y, g_y):\ y \geq \mu_y,\ g_y \geq \mu_g\}$$

[8] Given that the probability of being in two regimes at the same time is 0, the boundaries of the regimes themselves are defined by $\geq$ rather than $<$

$$R_4 = \{(y, g_y):\ y \geq \mu_y,\ g_y \leq \mu_g\}$$

So the regional economic history can be seen as a trajectory across the regimes. In figure 2 there are plotted the different trajectories of four regions during the studied period.

Figure 2: Representation of regimes dynamics



Note: The graphs show the evolution of the regional economies and their regime switches. On the horizontal axis we represent time and on vertical axis the four regimes. The graph shows the performance of Apulia, Abruzzo, Emilia Romagna and Umbria as representing some typical behaviours.

As we can see Emilia Romagna always orbited around regimes 3 and 4 in the period 1970-2005, indicating that this economy started already with high levels of per capita GDP. On the other hand, the economy of Abruzzo did not emerge from the low per capita GDP regimes (1 and 2). Things are more complex for Apulia and Umbria. Apulia started with a low per capita GDP regime (1), but afterwards has remained around regimes 3 or 4, besides from three years at the end of the 70s, the middle of the 80s and at the beginning of the 90s. Umbria instead is an example of back and forth behaviour: at the end of the 70s it jumped from regime 2 to regime 4 and then kept switching.

As we have seen some regions have remained in similar regimes, while others have often changed from one to another. This qualitative dynamics that we dubbed as regime dynamics (i.e., dynamics across regimes) can be represented as follows. Labeling each regime R_i by the symbol *i*, we can substitute the original bi-dimensional time series $\{(y_1, g_{y1}),(y_2, g_{y2}),...,(y_T, g_{yT})\}$ by a sequence of symbols $\{s_1, s_2,..., s_T\}$ such that $s_t = j$ if and only if (y_t, g_{yt}) belongs to R_j. The regime dynamics of a regional economy is summarized by this symbolic sequence (Brida et al., 2003a and 2003b). To compare and classify the economic performances of the 20 regional economies we divide them into different clusters obtained through a nonparametric methodology based on a Minimal Spanning Tree (MST) and a Hierarchical Tree (HT), to be defined thoroughly in the next paragraph.

In order to obtain these representations we define a metric of the economic performance of different regions. We measure a "distance" between the economic performances of two regions by assessing how correlated their respective regime dynamics are.

In formal terms we introduce a distance between symbolic sequences, where each sequence represents the regimes a region goes through in time. There are several distances which can be postulated (inter alias Tang et al., 1994, 1995 and 1997; Tang and Tracy, 1997; Molgedey and Ebeling, 2000; Piccardi, 2004).

The correlation coefficient between the symbolic sequence of two regions is defined as

$$\rho_{ij}(\Delta t) = \frac{\langle Y_i, Y_j \rangle - \langle Y_i \rangle \langle Y_j \rangle}{\sqrt{\left(\langle Y_i^2 \rangle - \langle Y_i \rangle^2\right)\left(\langle Y_j^2 \rangle - \langle Y_j \rangle^2\right)}}$$

$$\rho_{ij}(\Delta t) = \frac{\langle Y_i, Y_j \rangle - \langle Y_i \rangle \langle Y_j \rangle}{\sqrt{\left(\langle Y_i^2 \rangle - \langle Y_i \rangle^2\right)\left(\langle Y_j^2 \rangle - \langle Y_j \rangle^2\right)}}$$

where Y_i and Y_j are two time series and Δt is the time horizon. The empirical statistical average, indicated in this paper with the symbol $\langle \ldots \rangle$, is here a temporal average always performed over the investigated time period. By definition, $\rho_{ij}(\Delta t)$ can vary from −1 (completely anti-correlated pair of series) to 1 (completely correlated pair of series). When $\rho_{ij}(\Delta t) = 0$ the two stocks are uncorrelated. Then, following (Gower, 1966) a metric distance between a pair of time series can be rigorously determined by defining

$$d^{\rho}\left(Y_i, Y_j\right) = \sqrt{2\left(1 - \rho_{ij}(\Delta t)\right)}$$

$$d^{\rho}\left(Y_i, Y_j\right) = \sqrt{2\left(1 - \rho_{ij}(\Delta t)\right)}$$

The correlation distance d^{ρ} between two economies i and j quantify the degree of similarity between the synchronous time evolution of i and j. The distance varies in the range [0,2] with 0 meaning that the two economies are totally correlated (meaning that they move in lockstep with the other, either up or down) and 2 means that the two economies completely anti-correlated. Note that d_{ij}^{ρ} fulfils the three axioms of a metric: (i) $d_{ij}^{\rho} = 0$ if and only if $i = j$; (ii) $d_{i,j}^{\rho} = d_{j,i}^{\rho}$ and (iii) $d_{i,j}^{\rho} \leq d_{i,k}^{\rho} + d_{k,j}^{\rho}$. We call d_{ij}^{ρ} the correlation distance, or just the distance, between two time series.

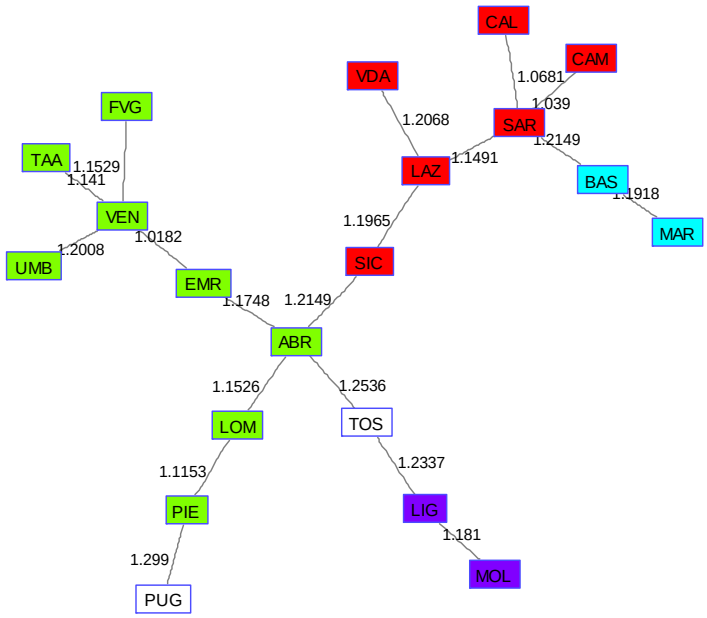
5.3 Minimum Spanning Tree (MST) and the Hierarchical Tree (HT)

Now we are ready to use this distance in order to group the regions of the sample into different clusters according to their performance by the mean of

a minimum spanning tree (MST) and a hierarchical tree (HT), using the nearest neighbour single linkage cluster analysis. We construct the MST by linking all the regions in a graph distinguished by a minimal distance between time series, starting with the shortest distance.

The method is based upon Kruskal's (1956) algorithm of single linkage and in our case the tree is a graph with 20 vertices corresponding to each region and 19 links selecting the most relevant connections of each element of the set. In the first step we connect a pair of time series with the shortest distance. In the second step we link a pair with the 2nd shortest distance with a line proportional to the previous bond. In the third step of the process we connect the nearest pair that is not linked by the same tree, repeating the exercise until all regions are connected in a unique tree. By the mean of the MST we obtain in a unique and direct way the ultrametric distance and the hierarchical organization of the elements (regions in our case) of the investigated data set (see Brida and Risso, 2008b). In figure 3 we show the MST obtained for our set of regions.

Figure 3: Minimum Spanning Tree



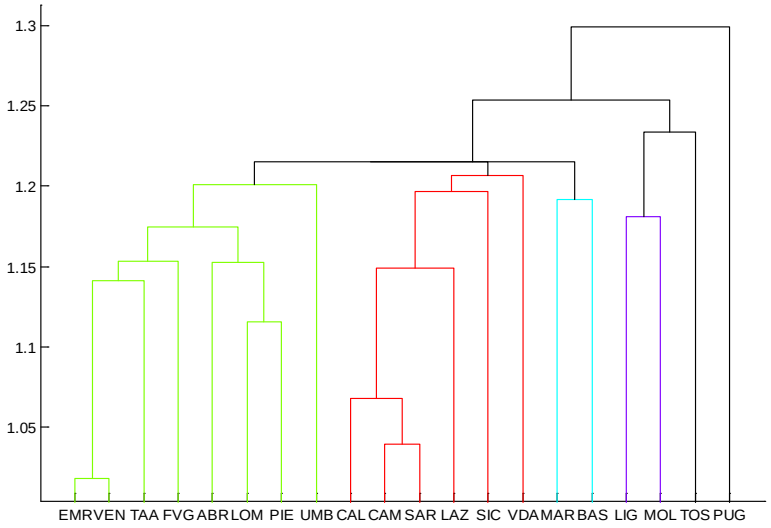
Note 1: UMB: Umbria. TAA: Trentino Alto-Adige. VEN: Veneto. FVG: Friuli Venezia-Giulia. EMR: Emilia Romagna. ABR: Abruzzo. LOM: Lombardy. TOS: Tuscany. LIG: Liguria. MOL: Molise. SIC: Sicily. LAZ: Lazio. SAR: Sardinia. BAS: Basilicata. MAR: Marche. CAM: Campania. CAL: Calabria. VDA: Aosta Valley. PIE: Piedmont. PUG: Apulia.
Note 2: Green: high performance regions, red: low performance regions

By using the MST approach we can obtain the (subdominant) ultrametric distance $d^<$ between *i* and *j*, $d^<(i, j)$ (Mantegna, 1999; Mantegna and Stanley, 2000), which is the maximum value of any distance $d_k(l;m)$ in the shortest path connecting *i* and *j* in the Maximum Spanning Tree. Then we can use the ultrametric distance $d^<$ in order to construct a Hierarchical Tree

(HT). Ramal et al. (1986) describe a method to obtain it directly through the MST. From the MST, the ultrametric distance $d^{<}(i, j)$ between two countries *i* and *j* is given by:

$$d^{<}(i, j) = Max\{d_k(w_i; w_{i+1}); 1 \le i \le n-1\}$$

Figure 4: Dendrogram



Note: UMB: Umbria. TAA: Trentino Alto-Adige. VEN: Veneto. FVG: Friuli Venezia-Giulia. EMR: Emilia Romagna. ABR: Abruzzo. LOM: Lombardy. TOS: Tuscany. LIG: Liguria. MOL: Molise. SIC: Sicily. LAZ: Lazio. SAR: Sardinia. BAS: Basilicata. MAR: Marche. CAM: Campania. CAL: Calabria. VDA: Aosta Valley. PIE: Piedmont. PUG: Apulia.

where $\{(w_1; w_2); (w_2; w_3); \ldots; (w_{n-1}, w_n)\}$ denotes the unique path in the MST *i* and *j,* where $w_1 = i$ and $w_n = j$. In figure 4 we show the HT obtained for our set of regions.

In figure 3 and 4 two main clusters can be clearly detected as well as other two small groups whose dynamical behaviour is different from the average of the two main clusters. One of the two main clusters, for 1970-2005 period, is constituted by: Emilia Romagna, Lombardy, Veneto, Friuli Venezia-Giulia, Trentino Alto-Adige, Piedmont, Umbria. Since those regions are most of the time in regimes 3 and 4, we call this the *high performance* cluster. The second main cluster is composed by Calabria, Campania, Sardinia, Lazio, Sicily, Aosta Valley. In this case, the countries live most of the time at regimes 1 and 2 and so we call this the *low performance* clu*ster*. There are 6 regions that do not belong to the two main clusters: Marche, Basilicata, Liguria, Molise, and finally Tuscany and Apulia which do not belong to any cluster. Those regions show an evolution that can be clearly differentiated from the average of the dynamics of both main clusters.
What are the reasons for this economic cleavage? As we have seen in northern Italy there is a huge concentration[9] of economic activities in the manufactural and service sectors. Considering the structure of production we have that in northern Italy there are 70-80 firms per 1000 inhabitants, against an Italian average of just 66. By contrast in the south the figure is significantly lower than the average. Furthermore almost 2/3 of the Italian population lives in the north, producing more than 70% of Italian GDP and enjoying twice as much of southern per capita income (23,389 against 13,688).
From the historical point of view, we have already seen that Northern regions performed historically better than Southern ones since the Italian unification, despite the process of convergence in the 50s and in the 60, which nevertheless has halted in the middle of the 70s and was even reversed in the 80s and 90s. In order to make sense of these stylized facts we can have

[9] All the data in this paragraph belong to ISTAT.

a look at the theories on spatial distribution of economic activities. According to the New Economic Geography (inter alias, Baldwin et. al, 2001) growth is a spatially cumulative process having the tendency to increase inequalities, so that regions within the same geographic cluster are likely to develop similar economic dynamics. Indeed a core-periphery pattern occurring at regional level is representative of spatial heterogeneity and may imply the presence of convergence clubs.

The crucial subject of NEG research are the location and agglomeration externalities, which are due to knowledge spillovers and input-output linkages among firms at several spatial levels (e.g. regions, cities, district of cities, etc.). The interplay between agglomeration externalities and dispersion forces determine the economic landscape of a region. In particular an increase in economic integration (i.e. a decrease in transaction costs) triggers a circular cumulative causality mechanism which favours the clusterization of economic activities, so that two territories with slight underlying difference end up diverging dramatically. This might be one of the causes of Italian dualism. At the time of unification the economic difference between northern and southern Italy were not that impressive. However after the economic integration given by the construction of highways, taking place since the beginning of the last century, agglomeration forces shaped the Italian economic landscape into a core-periphery structure where the core is a club whose elements (regions) enjoy positive growth spillovers. It is safe to say, from a continental perspective, that the North is a part of the bigger economic cluster going from reaching Scandinavia and Southern England, passing through France, Belgium, Germany and the Netherlands. By contrast Southern regions belong to the periphery.

Looking at Liguria, we see that despite being geographically located in the north, this region share the same economic dynamics with the low performing regions. This is probably due to structural differences. For instance in Piedmont, Emilia Romagna, Friuli-Venezia Giulia and Veneto there is a high concentration of industrial firms, while in Lombardy and Trentino-Alto Adige services to small and big enterprises are common. By contrast in Liguria we see the prevalence of services to micro firms. This is probably due to the process of de-industrialization affecting Liguria after the 70%, which transformed an old economy based on big iron and steel, chemical and mechanical industries (partly owned by the state) into a new

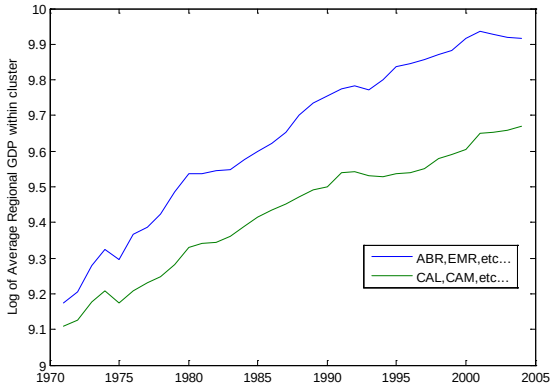
one where the share of services in value added is 82.4%, much higher than the average of the rest of the North west (64%).

6 Clusters Dynamics

The previous analysis shows that some regions have similar performance, which in turn can be differentiated from others. According to their overall performance it is possible to identify four clusters and two outsiders regions during the period running from 1970 to 2005. However, in a dynamic analysis these differences may vary. Do the clusters tend to be more or less compact, and how does evolve the distance between them?

To investigate if the distance between clusters has increased or not along the period of time considered, plotted the evolution of log GDP of the two main clusters' average regions.

Figure 5: Evolution of regimes and GDP of regions within clusters

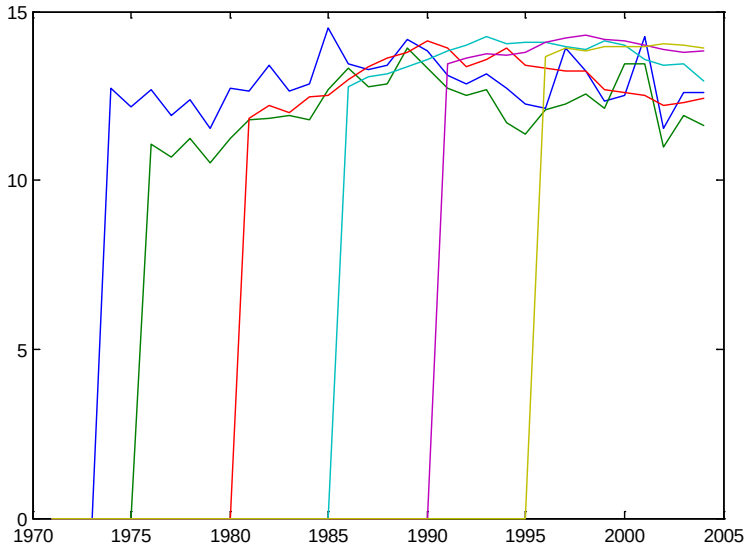


Note: this figure displays the log GDP of the two main cluster's average region

In figure 5 we see the effects of the economic crisis in the middle of the 70s and at the beginning of the 90s. Moreover the two clusters follow a similar path until 1975, before starting to slightly diverge. The difference in levels between the two lines shows the presence of a "rich" and a "poor" cluster.

To analyze how the distance between the clusters has change a time window of length v <T is considered and the distance between the clusters for all sub-periods of length v within the time span are computed. For each sub-period the trees are constructed and their respective groups are identified. This allows the exploration of the evolution of clusters. The trees are obtained for windows of v=3, 5, 10, 15, 20 and 25 years in length. To study whether the regions of a cluster get closer or not over time, a global distance measure is needed. Following the methodology proposed by Onnela (2002), this measure is obtained by summing up all distances from the minimum spanning tree. This represents the diameter of the group. Figure 6 shows the evolution of the diameter of the two major groups of regions through windows of 3, 5, 10, 15, 20 and 25 years.

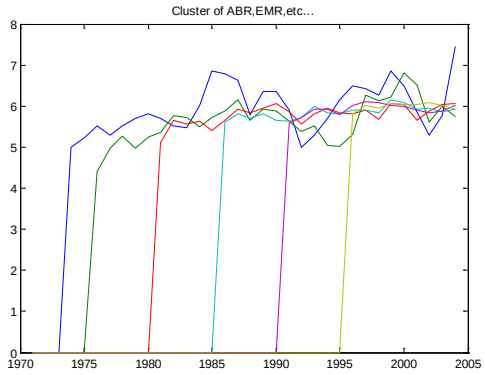
Figure 6: Minimum distance between the regions



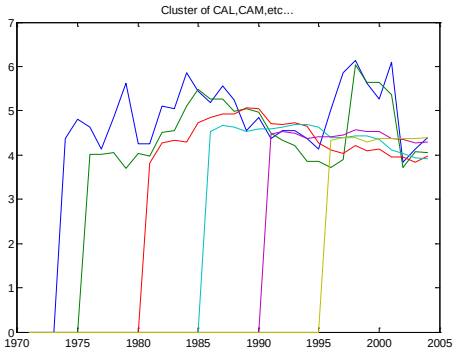
Note: Diameter of all the regions through mobile windows of 3, 5, 10, 15, 20 and 25 years.

At the beginning the distance is moderately increasing showing that the trajectories of the regions tend to diverge, meaning that the economics performance departs. However in the second period the divergence stops, so that the economic performances tend to be more similar. Anyway the final magnitude of the diameter is quite similar to the initial one.

Figure 7: Minimum distance between the regions



Note: Diameter of the regions in the cluster with Abruzzo, Emilia Romagna, Lombardy, Piedmont, Veneto, etc…, through mobile windows of 3, 5, 10, 15, 20 and 25 years



Note: Diameter of the regions in the cluster with Sicily, Lazio, Calabria, etc…, through mobile windows of 3, 5, 10, 15, 20 and 25 years

Now we can study the evolution of each cluster's diameter (figure 7), noticing that there is stability even within the clusters. Indeed we can see that the high performance regions diameter is roughly constant through mobile windows of 3, 5, 10, 15, 20 y 25 years, after a short initial period where it grows. By the same token, the evolution of the distance for the low performing regions tends to be constant, apart for what concerns the windows of 3 and 5 years. Thereby there is a substantial convergence within the two groups.

6.1 Regimes Evolution

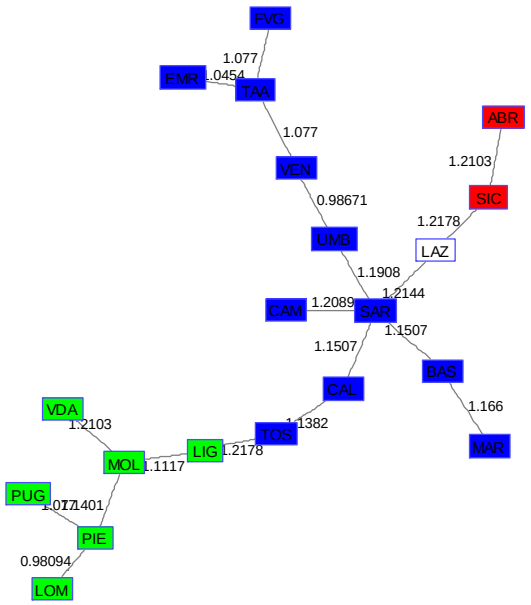
It would be interesting to know: there have always been four clusters? Do the regions have changed from one cluster to another? To answer these

questions the minimum spanning trees (MST) and the hierarchical trees (HT) for the two periods 1975-1993 and 1994-2005 are constructed. The choice of time spans is not arbitrary, as in 1993-1994 Italy was hit by an economic turmoil following the exit from the European Monetary System in 1992. It would have been interesting to analyse the effects of the oil crisis in 1973, but the shortness of the time span (1970-1974) would have affected the consistency of the results.

In order to assess the performance level of the clusters, we will also compute the mean of the cluster regimes in the two period 1994-2005 (3 and 2.6)

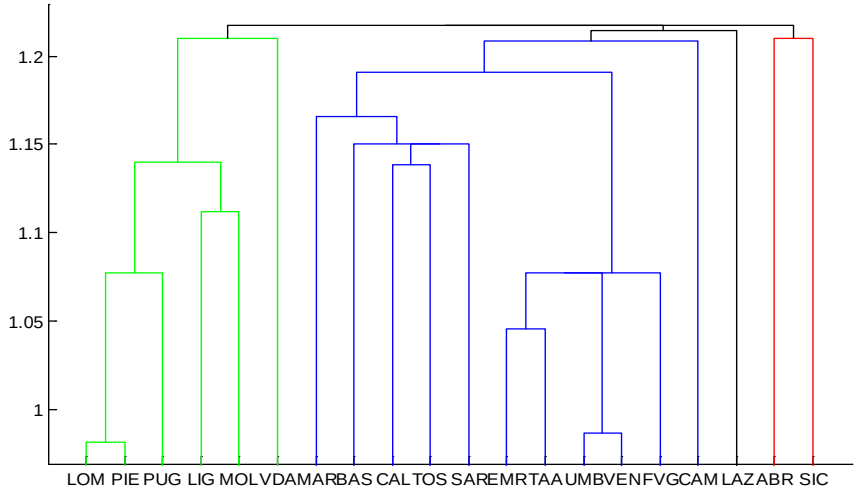
As we can see from figures 8 and 9 in the period 1975-1993 there are basically two main clusters. The high performance cluster (with a mean of the regimes equal to 2.77) is composed by Aosta Valley, Liguria, Lombardy, Piedmont, Molise, Apulia. On the other hand the low performance one (mean of the regimes 2.66) is made up of Sardinia, Trentino-Alto Adige, Marche, Basilicata, Campania, Emilia Romagna, Friuli Venezia-Giulia, Tuscany, Umbria, Veneto. Moreover we have Sicily and Abruzzo constituting a small cluster by themselves and finally Lazio which does not belong to any cluster.

Figure 8: Minimum Spanning Tree 1975-1993



Note: Green: high performance cluster, blue: low performance cluster

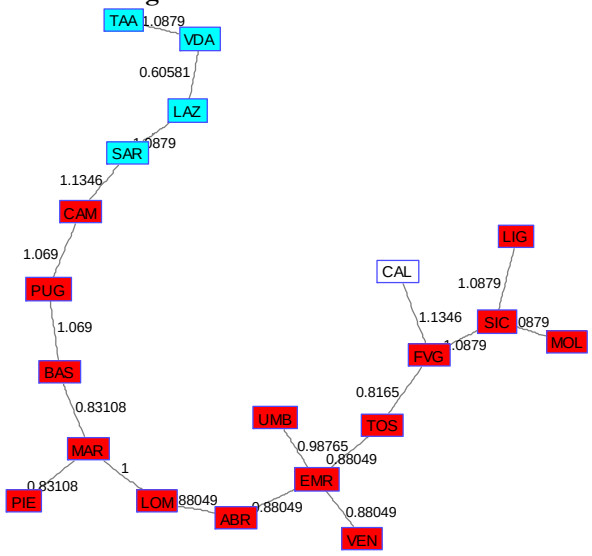
Figure 9: Dendrogram with clusters 1975-1993



Note: Green: high performance cluster, blue: low performance cluster

Turning to the period 1994-2005 (figures 10 and 11) we see the formation of two main clusters. One is composed by Lazio, Aosta Valley, Sardinia, Trentino Alto-Adige with the best average performance (mean of the regimes 3), while the other one (mean of the regimes 2.6) comprises Liguria, Lombardy, Molise, Piedmont, Apulia, Marche, Basilicata, Campania, Emilia Romagna, Friuli Venezia-Giulia, Tuscany, Umbria, Veneto, Abruzzo, Sicilia. Furthermore we have that Calabria does not belong to any cluster.

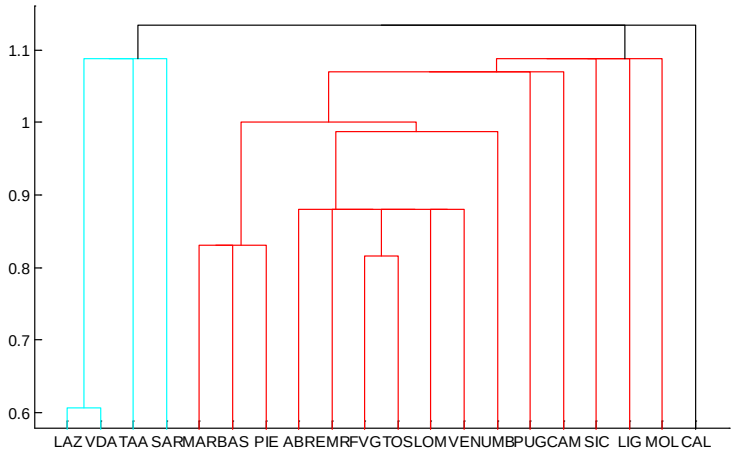
Figure 10: MST for 1994 to 2005



Note: Light blue is the high performance cluster, and in red are is low performance cluster

As we can see from the analysis Aosta Valley remained in the best performing cluster. By contrast Marche, Basilicata, Campania, Emilia Romagna, Friuli Venezia-Giulia, Tuscany, Umbria and Veneto remained in the relatively low performance cluster. Moreover Liguria, Lombardy, Molise, Piedmont and Apulia shifted to the relatively low performance cluster, so we might argue that their performance has worsened. Finally Sardinia and Trentino-Alto Adige moved from the relatively low performance to high performance cluster.

Figure 11: Dendrogram and Clusters for 1994 to 2005



Note: Light blue is the high performance cluster, and in red are is low performance cluster

6.2 Analysis of the dynamic of the distance between clusters

In this section we use bootstrapping to test whether the distance between two clusters of regions have statistically changed during the period (the test is described in the appendix). Using a window of size[10] v=10, we carry out the analysis for the two biggest clusters selected in the periods 1975-1993 and 1994-2005.

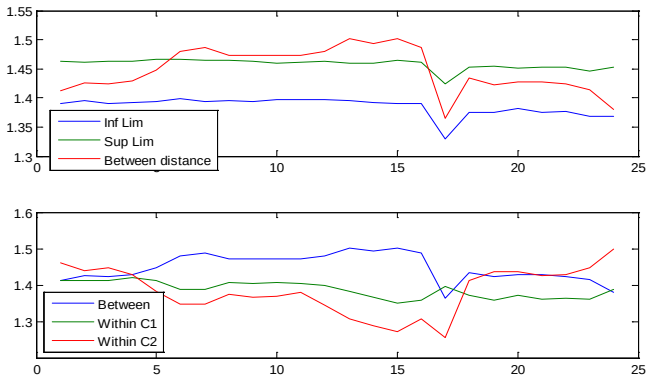
The clusters are composed by these regions,

C1	SAR, TAA, MAR, BAS, CAM, EMR, FVG, TOS, UMB, VEN, CAL
C2	VDA, LIG, LOM, MOL, PIE, PUG

[10] The test was also executed for windows of size v=5, v=15 and v=25, without observing considerable differences with the windows of size v=10.

The graph in the first row in Figure 12 represents the statistic test with 90% of confidence under the null that the distance between the two clusters is a random distance. There is a period, of about 10 years where it can be said that it is rejected the null that the distance was random, and that the distance between the two clusters was slightly increasing. The graph in the second row, represents distance between and within the two clusters. Whereas the distance between the clusters has been relatively constant, the distance within the cluster C2 was grew considerably at the end of the period.

Figure 12: Period 1975-1993



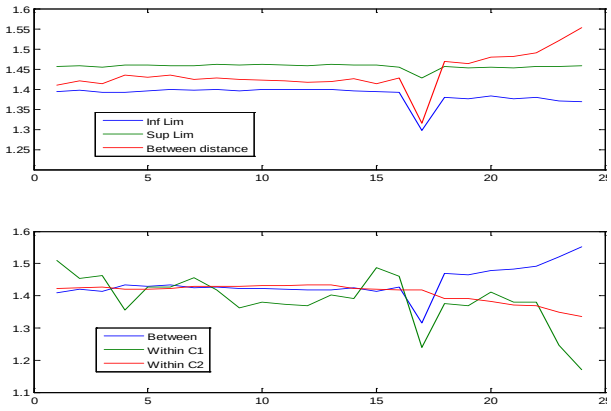
Note: In the first graph the red line is the test's value and the green and blue lines are the confidence interval of 90%. The second graph put together the between distance and the within distance of the clusters

The same analysis is made for the period 1994-2005 in Figure 13. In this case the regions in each cluster are:

C1	LAZ, VDA, SAR, TAA
C2	LIG, LOM, MOL, PIE, PUG, MAR, BAS, CAM, EMR, FVG, TOS, UMB, VEN, ABR, SIC

Notice that the null that the distance is random at the end of the period is rejected. Moreover in the second plot, it is important to notice that whereas the between distance grew, the within distance in the two clusters went down.

Figure 13: Period 1994-2005



Note: In the first graph the red line is the test's value and the green and blue lines are the confidence interval of 90%. The second graph put together the between distance and the within distance of the clusters

Whereas during the period 1975-1993 the distance between the two clusters was relatively stable some of the regions within the clusters were falling apart. The trend is reinforced with the results obtained during the period 1994-2005 where the distances within the clusters were reduced, and the distance between the clusters grew.

7 Conclusions

In our study we analyzed the dynamics of convergence from the perspective of economic performance, in order to identify performance clubs. We

measure the economic performance by the mean of concept of regime, which is given by the combination between the level and the growth rate of per-capita GDP. To this end we studied the behavior of per capita income for the Italian regions along the period 1970-2004 using a non-traditional (non-parametric) statistical model: the Minimum Spanning Tree and the Hierarchical Tree.

The current paper represents an extension of our previous one (Brida *et al.*, 2011a) in that it encompasses the analysis of the performance regimes of the clusters and the study of the dynamical properties of the clusters' structure evolution as well by the mean of time windows.

Our analysis shows the appearance of two main clusters. The high performance one is constituted by Emilia Romagna, Lombardy, Veneto, Friuli Venezia-Giulia, Trentino Alto-Adige, Piedmont and Umbria, which remain most of the time in regimes 3 and 4. The second main cluster comprises Calabria, Campania, Sardinia, Lazio, Sicily and Aosta Valley, which float around regimes 1 and 2 and thereby form the low performance cluster. There are also 6 regions that do not belong to the two main clusters: Marche, Basilicata, Liguria, Molise, and finally Tuscany and Apulia which do not belong to any cluster. The high performance cluster consists mainly of northern regions, showing the presence of agglomeration externalities.

Looking at particular cases we see that Liguria, even though geographically located in the North, follows a dynamic which is very similar to the low performance regions. This might depend from the process of de-industrialization affecting Liguria after the 70%, which raised the share of services in value added up to a level much higher than the average of the rest of the North west.

Furthermore we detect a high correlation in the economic paths between Lombardy and Piedmont on one hand and Veneto and Emilia Romagna on the other hand, confirming the New Economic Geography and the traditional Geographic Economic point of view that regions within the same geographic cluster are likely to develop similar economic dynamics.

Taking into account the evolution of the clusters, we see that the two clubs show similar trajectories until 1975, although the difference in level shown in figure 5 remarks the different performances of the two clusters. After the mid 70s, the two trajectories start to diverge, confirming the stylized facts

stating that the convergence among Italian regions stopped in the 80s and 90s.

When we split the sample into two periods (1975-1993 and 1994-2005) we have that the presence of two main performance clubs is confirmed. The Italian economic crisis of 1992-1993, which forced the country to leave the European Monetary System, might have caused the shift of Liguria, Lombardy, Molise, Piedmont and Apulia from the high performance to the relatively low performance cluster, as well of Sardinia and Trentino-Alto Adige which moved from the relatively low performance to high performance cluster. Finally the analysis of the distance between the two clusters show that in the first period (1975-1993) the distance between the two group was constant, while in the second one (1994-2005) it has increased.

Unfortunately our research is limited by the short length of time series as well as by the use of a unique variable to represent a very complex system. Further it would be interesting to adopt other concepts of distances or some other variables representing the economic performance of the regions so as to enrich the discussion. For example a possible other measure of economic performance would be a development index which could take into account not only per capita income levels and growth, but also other variables such as institutional and public services quality, human capital or technological distance from the production possibility frontier.

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Appendix 1

Test for the dynamic of the distance between clusters

Given a distance matrix D_t, using hierarchical clustering techniques *n* clusters are identified and denoted by C_i with *i=1..n*. Each cluster *i* is composed by a number m_i of regions and they are represented by $C_i = \{c_{i1}, c_{i2}, \dots, c_{im_i}\}$.

The distance **within** a cluster, which is a measure of compactness is given by the average distance within all the regions in the cluster. Formally

$$d_w(C_i, t) = \frac{2}{m_i * (m_i - 1)} \sum_{j=1}^{m_i} \sum_{k>j}^{m_i} D_t\left(c_{ij}, c_{ik}\right)$$

Where m_i is the number of regions in the cluster *i* and $D_t\left(c_{ij}, c_{ik}\right)$ is the distance between the region c_{ij} and c_{ik} measured at time *t* in the matrix D_t.

The distance **between** two clusters is defined as the average distance of the distance between all the pair of regions of the two clusters. Thus given two clusters C_i and C_j, the distance is defined as

$$d_b\left(C_i, C_j, t\right) = \frac{1}{m_i * m_j} \sum_{k=1}^{m_i} \sum_{s=1}^{m_j} D_t\left(c_{ik}, c_{js}\right)$$

Test of distance

The statistical test is built in steps

1. The two clusters C_1 and C_2 are identified, with their numerosity m_1 and m_2 respectively.

2. The size of the temporal windows *v* is defined
3. All the distance matrixes D_t^v using v periods are computed, with *t=v..T*, where T is the number of periods available in the data. Notice that if the data availability is T, there will be T-v distance matrixes.
4. For each matrix D_t^v, two random clusters of size m_1 and m_2 are obtained and the distance $d_b\left(C_x, C_y\right)$ between these two clusters is obtained. Step 4 is repeated 5000 times, so that a distribution of distances between two random clusters using the matrix distance D_t^v es obtained. This distribution of distances $F\left(d_b\left(C_x, C_y\right)\right)$ is employed to make the test vs the original distance $d_b(C_1, C_2)$.

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