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Regional growth in Portugal: assessing the contribution of earnings and education inequality

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Abstract

Regional economic growth in Portugal has mainly been studied from the perspective of convergence with data ending by the early 2000's. The country as a whole has stopped converging to the output levels of the richest European countries by this period and has also become one of the most unequal EU member-states in terms of income distribution in the meantime. It is thus important to analyze the growth performance at the regional level in a more recent period, 1995-2007, emphasizing regional disparities in inequality as explanatory factors. This study examines the relationship between inequality and regional growth in Portugal at NUTS III level exploring the explanatory power of earnings and education inequality measures computed with data from the *Quadros de Pessoal* database. The results point to a positive relationship between initial inequality and regional growth, stronger for education than for earnings inequality, but with earnings inequality measures revealing a higher explanatory power. Moreover, there is evidence that it is inequality at the top of the distribution that is the relevant to explain regional growth, a result that reinforces the higher propensities to save of the richer and the incentives mechanisms of transmission from inequality to growth. Additionally, the evidence does not support the existence of convergence among Portuguese NUTS III regions during the period under analysis. These findings are robust to the introduction of most additional control variables and the consideration of alternative measures of earnings and education inequality.

Keywords: regional growth, Portugal, earnings inequality, education inequality

JEL Classification: O18; O52

1. INTRODUCTION

Portugal joined the European Union in 1986 expecting, among other things, to get closer to the income levels of its partner countries, i.e., longing for real convergence. These expectations were fulfilled until around the year 2000 but since then the Portuguese economy has become almost stagnant, with an average annual growth rate of real GDP per capita between the years 2000 and 2007 of 0.53%, less than a third of the EU-27 average growth rate and around a third of the EU-15 average growth rate¹. Relative to the EU-27, real GDP per capita in Portugal is still only around 60% of the average and in the year 2007 it was even slightly less than the figure registered in 1995 (see Figure 1 in the appendix). At the regional level the picture is not much different: between the years 2000 and 2007, twenty eight of the thirty Portuguese NUTS² III regions registered a sharp decline in the respective average annual real GDP per capita growth rate³, relative to the preceding 5 years period (1995-2000). For the seven Portuguese NUTS II regions, with the exception of the performance of Madeira that went from around 70% of the EU-27 real GDP per capita regional average in 1996 to approximately 100% in 2007, almost all the other regions remained in more or less the same position in the year 2007 relative to 1996 (see Figure 2 in the appendix)⁴.

Portugal has also become one of the most unequal EU member states in terms of income distribution in the meantime. According to recent European Commission reports on the social situation in the EU (see EC (2008, 2009, 2010)), in the year 2004 Portugal was the most unequal EU-25 member-state, presenting a Gini coefficient for the income distribution of 38% and an income quintile share ratio (S80/S20) of 6.9⁵. In 2006, Portugal registered the same value for the Gini coefficient and a S80/S20 ratio of 6.8⁶ and in 2007 the numbers were, respectively, 37% and 6.5⁷. Thus, despite the slight improvement in its relative position, Portugal is still one of the worst performers in terms of inequality in the income distribution within the EU. Several studies focusing on the analyses of either income or earnings distributions in the Portuguese economy

¹ Authors' computations based on GDP at 2000 prices and population data from Eurostat.

² Nomenclature of Territorial Units for Statistics (NUTS) established by Eurostat.

³ Authors' computations based on information from the Regional Accounts published by INE (www.ine.pt).

⁴ Açores also improved its position relative to the EU-27 regional average from 1996 to 2007 but this improvement was less impressive than that of Madeira: it moved from around 60% to more or less 70% of the EU-27 regional average.

⁵ See EC (2008), p. 125. The S80/S20 income quintile share ratio corresponds to the ratio between the total income of the member state received by the top (highest income) 20% of the population and that received by the bottom (lowest income) 20% of the population.

⁶ See EC (2009), p. 119. The most unequal country in this year was Latvia with a Gini coefficient of 39% (the EU-27 average was 30%) and S80/S20 ratio of 7.9 (the EU-27 average was 4.8).

⁷ See EC (2010), p. 276. The most unequal country in this year was Romania with a Gini coefficient of 39% (the EU-27 average was 31%) and S80/S20 ratio of 7.8 (the EU-27 average was 5.0).

also present evidence that there was an increase in inequality during the 1990's and the first years of the new millennium (see Cardoso (1998), Rodrigues (2007), Budria (2007), and Alves (2009)), although this increase was not evenly distributed throughout the period.

Regional economic growth in Portugal has mainly been studied from the perspective of convergence with data ending by the early 2000's⁸, but the country as a whole has stopped converging to the output levels of the richest European countries by this period and performs quite badly in terms of income distribution, as pointed out in the previous paragraphs. It is thus important and relevant in terms of redistributive regional policy to investigate what has happened in terms of growth at the regional level in Portugal in a more recent period, 1995-2007, emphasizing regional disparities in inequality as explanatory factors. This work main goal is therefore to examine the relationship between inequality and regional growth in Portugal at NUTS III level, exploring the explanatory power of earnings and education inequality measures computed with data from the *Quadros de Pessoal* database, filling in this way a gap in the literature on (regional) growth in Portugal. The paper also contributes more generally to the empirical literature on the relationship between inequality and growth since this mostly utilizes country level data and does not analyze the sensitivity of the results to the use of income vs. education inequality measures.

The remainder paper is organized as follows. In section 2 we describe the importance of assessing the impact of inequality on regional economic growth in Portugal by providing a brief review of the main theoretical and empirical findings on the subject. In section 3, we give a brief description of the data on income and earnings and education inequality and analyze its evolution. Section 4 is devoted to the presentation of the empirical model we estimate and the analysis of the results. Finally, in section 5 we conclude.

⁸ See Braga (2004), Dias and Silva (2004), Soukiazis and Antunes (2006), Barradas and Lopes (2007), Soukiazis and Proença (2008), Martins and Barradas (2009a,b). Martins and Barradas (2009a,b) are the only studies that analyze a more recent period, 1995-2006, but the methodology and aim are quite different from the ones adopted in our study.

2. INEQUALITY AND GROWTH: A BRIEF REVIEW OF THE THEORETICAL AND EMPIRICAL LITERATURE

Is inequality an impediment or a stimulus to economic growth? This is a recurrent debate in economic research. There is by now an extensive and rich literature on the relationship between inequality and economic growth that has been carefully and thoroughly surveyed by Bénabou (1996), Perotti (1996), Aghion et al. (1999), Barro (2000), García-Peñalosa (2007), Bertola et al. (2006) and Ehrhart (2009), among others⁹. In the 1990's, a renewed interest on the subject took place that led mostly to the development of theoretical models. Due to the scarcity of reliable and comparable data on inequality and due to the existence of poor measures of inequality, empirical literature on the subject lagged behind. The expected sign for the relationship between inequality and growth is a complex matter with early growth models on the subject predicting a positive sign, later ones arriving at a negative relationship and more recent growth models combining both effects. The evidence from empirical studies on the relationship between inequality and growth is also mixed. The cross-country studies usually find that higher inequality slows future growth, but the evidence from the studies that explore panel data is not compelling, pointing to an ambiguous effect of inequality on growth.

According to some theories¹⁰, also designated as classical theories on the impact of inequality upon economic growth, inequality promotes economic growth because: (i) growth depends positively on the accumulation of physical and human capital and richer individuals save more and thus invest more than poorer individuals and, in addition, there are indivisibilities and large sunk costs in physical capital investments implying a higher concentration of wealth in order to put into practice new investment projects; and (ii) it provides an incentive to the appearance of entrepreneurs/inventors expecting to belong to the wealthier part of the society, thus enhancing growth when innovation is the driving force of long run performance, as well as promoting higher effort by workers and thus efficiency.

The negative effect of inequality on growth is justified on the basis of three main arguments or mechanisms of transmission. The social-political instability channel argues that in more unequal societies individuals are more likely to be involved in

⁹ Duarte and Simões (2009) provide a survey of the theoretical and empirical literature on two specific mechanisms of transmission from inequality to growth considered by the authors as the most likely to explain the relationship in the Portuguese economy.

¹⁰ See e.g. Aghion, Caroli and García-Peñalosa (1999) and Barro (2000).

activities that act as a disincentive to private investment, such as violent protests against the regime, coups or criminal activities, which in turn hinders physical capital accumulation and thus growth (see e.g. Alesina and Perotti (1996) and Perotti (1996)). This channel is potentially more relevant to explain the inequality-growth nexus in less developed countries but less likely to occur in a country like Portugal¹¹.

The borrowing constraints in human capital investments channel explains the relationship between inequality and growth based on the analysis of investments in human capital, that foster growth, when there are imperfections in credit markets. Only those individuals that have a high enough initial level of wealth are able to invest in human capital because borrowing is costly and difficult. Thus, an economy with a less unequal wealth distribution will be growth enhancing because it invests more in human capital. For instance, Galor and Zeira (1993) show that in initially highly unequal societies, because of borrowing constraints, fewer individuals are able to invest in human capital, which in turn is detrimental to growth. Galor and Tsiddon (1994), on the other hand, develop a model in which the relationship between inequality and growth depends on the stage of development of an economy. At earlier stages of capitalism, the engine of growth is the accumulation of physical capital and a more unequal wealth distribution is beneficial to growth because the owners of capital have a higher propensity to save. At later stages of capitalism the engine of growth is human capital accumulation. If there are borrowing constraints on individual's human capital investment due to the existence of capital market imperfections to the borrowers, at later stages of capitalism a less unequal wealth distribution enhances economic growth because individuals decide to invest more in human capital.

The fiscal approach literature is based on the interplay of two mechanisms, the political mechanism and the economic mechanism (see e.g. Bertola (1993); Alesina and Rodrik (1994), and Persson and Tabellini (1994)). The political mechanism states that in more unequal societies the median voter will vote for higher levels of taxation and government expenditure. These introduce distortions which will in turn discourage private investment, hindering in this way economic growth – the economic mechanism.

At the empirical level, a set of studies (see e.g. Persson and Tabellini (1994), Alesina and Rodrik (1994), Alesina and Perotti (1996), Clarke (1995), Perotti (1996), Deininger

¹¹ Duarte and Simões (2009) review in more depth the fiscal policy and the borrowing constraints on human capital investments channels based on the argument that they are the relevant ones to explain the relationship between inequality and growth in an economy like Portugal.

and Squire (1998), Chen (2003), Balisacan and Fuwa (2003), Bleaney and Nishiyama (2004)) tried to assess the contribution of inequality to cross-country variation in growth rates, after controlling for a number of variables that have been found relevant in the explanation of cross-country growth performance in a large number of empirical growth studies. The estimates of the impact of inequality on economic performance of most of the cross-country studies reveal a negative long-run relationship between the two variables, a result that is usually robust to different sensitivity analyses such as controlling for different inequality measures, different samples and time periods, the presence of outliers, model uncertainty, measurement error, reverse causation, and heteroscedasticity.

However, following the release of the Deininger and Squire inequality dataset¹² that assembled more reliable data with time series information for a large enough group of countries, a number of studies estimated the inequality and growth relationship using panel data techniques (see e.g. Persson and Tabellini (1994), Forbes (2000), Barro (2000), Banerjee et al. (2004), Voitchovsky (2005)), trying to uncover in this way a short to medium-term relationship. Contrary to the common message conveyed by most cross-country studies, the panel data evidence is quite diverse, finding either a positive, negative or non-existent correlation between inequality and growth.

The empirical assessment of the importance of inequality for economic growth implies the use of inequality measures suitable on theoretical grounds. The most widely used measures of inequality relate to the income distribution but most theoretical studies explain the relationship between inequality and growth based on the distribution of wealth. However, few empirical studies use wealth inequality as an explanatory variable due to data constraints. Despite the fact that the shape of wealth and income distributions usually vary together in cross-sections of countries, Alesina and Perotti (1994), Alesina and Rodrik (1994) and Deininger and Squire (1998) use the Gini coefficient of land distribution as a proxy for wealth inequality in their empirical studies and present better results with this measure than with the income distribution measure. Human capital inequality measures have also been shown to provide more robust results than income inequality measures in the estimation of standard growth and investment equations (see e.g., Birdsall and Londono (1997), Barrio-Castro et al. (2002), Castelló-Climent and Doménech (2002)), a result attributed to the importance of human capital

¹² See Deininger and Squire (1996).

in the explanation of the distribution of wealth present in many theoretical models¹³. The estimated coefficient for the human capital inequality measure in all three studies is negative.

In face of the mixed evidence on the inequality-growth relationship provided by empirical studies, Dominicus et al. (2006) use the statistical methodology known as meta-analysis, that combines the results of several empirical studies on inequality and growth to give a quantitative summary of the main findings, to survey the empirical literature. The analysis is based on 22 studies that give a total of 254 estimates for the coefficient of the inequality measure¹⁴, restricted to be the Gini coefficient of income distribution¹⁵. The results show that the variation in the estimates of the income inequality-growth relation are systematically associated with differences in estimation methods, sample coverage and data quality – fixed effects and GMM estimates are usually higher, the negative impact is stronger in poorer countries and when the growth period analyzed is longer, and poorer data quality leads to lower coefficient estimates. Of particular interest to our study is the result concerning the introduction of human capital inequality measures: the evidence shows that the inclusion of these does not affect the direction and magnitude of the estimated coefficient on income inequality. A final quite relevant suggestion by the authors is that, “The analysis of the growth-inequality linkage on a regional basis may, however, be much more informative than the analysis based on worldwide cross-country datasets, as we have seen that some of the variation observed in cross-section of countries studies vanishes after allowing for regional effects. (...) Limiting the scope of the study to regions within the same country (...) would definitely help to shed new light on the relationship between inequality and growth.” Dominicus, Groot and Florax (2006), p. 22.

The regional dimension of the relationship between inequality and growth has been the focus of some studies. Partridge (1997), Partridge (2005), Panizza (2002) and Frank (2009) analyze evidence for the U.S. states¹⁶. Partridge (1997) and Panizza (2002) explore the panel structure of the data to uncover the sign of the relationship between

¹³ In our paper human capital inequality is measured as inequality in the distribution of years of formal education/schooling, similar to what is done in Birdsall and Londoño (1997), Barrio-Castro, López-Bazo and Serrano-Domingo (2002), Castelló-Climent and Doménech (2002), that build human capital inequality measures based on data on average years of schooling from Barro and Lee (1993, 1996, 2001) and Nehru et al. (1995).

¹⁴ See the citations in the previous paragraphs for examples of many studies included in this meta-analysis.

¹⁵ The authors point out “(...) the large heterogeneity in the sample, with around 40% of the values showing a negative value, and an equal amount of estimates that exhibits a value close to zero. Only the remaining 20% of the estimates are positive.” Dominicus, Groot and Florax (2006), p. 10.

¹⁶ Fallah and Partridge (2007) also analyze the inequality-growth relationship for the U.S. but using county data (not state data) for the 1990's. The authors find a positive correlation in urban areas but a negative one in nonmetropolitan areas.

inequality and growth. The first study considers ten-years growth episodes during the period 1960-90, finding a positive correlation between the Gini coefficient of income and growth, indicating a positive relationship between inequality and growth, but also a positive correlation between the income share of the middle quintile and growth, indicating a positive relationship between equality, not inequality, and growth. The second study uses state data from different sources covering a wider period (1940-80), Gini coefficients of income and the income share of the middle quintile, analyzes ten and twenty-years growth episodes, and uses different panel data techniques (pooled OLS, fixed effects, GMM), reaching the conclusion that the sign and significance of the estimated relationship changes when different measures of inequality are used and that controlling for outliers, serial correlation and structural breaks substantially changes the results. Partridge (2005) resumes the same issue for the period 1960-2000, estimating a short-term model with data averaged for 10 years periods and a long-run model in which 1960-2000 growth is regressed on the initial values of the explanatory variables, namely the initial Gini coefficient of income and the initial middle-quintile share. The results show a positive correlation between the middle-class share and overall inequality and long-run growth but the short-term results (associated with fixed effects estimations) are ambiguous with no definite conclusion possible. Frank (2009) uses state-level annual data over the period 1929-2000 to determine whether the income share of the top decile Granger causes income growth and to determine the sign of the relationship. The results confirm that inequality causes growth and give evidence that an increase in the income share of the top decile reduces future income growth but with regional differences – the relation is stronger for the more densely populated states.

Arbia et al. (2005), Ezcurra (2007) and Rodríguez-Pose and Tselios (2010) investigate the link between inequality and regional growth from the perspective of the EU. The first two studies apply spatial econometrics techniques. Arbia, Dominicus and Piras (2005) use regional data at NUTS II level for the period 1977-2002 dividing the sample into non-transition and transition European countries. For the sample without transition countries regions, the effect of income inequality on growth is positive and significant, but being located close to regions with a high level of income inequality is detrimental to a region's growth performance. The same conclusions apply when data for the transition countries regions are introduced indicating that while inequality within a country is growth enhancing, unequal realities in the neighbours have a detrimental impact. Ezcurra (2007) examining 63 NUTS I and II EU regions over the 1993-2002

period and using information from the European Community Household Panel (ECHP) to build income inequality measures, on the other hand, arrives at a negative relationship between a region's income dispersion and growth. Rodríguez-Pose and Tselios (2010) assess the contribution to regional growth of both income and education inequalities, again using data from the ECHP between 1994 and 2001 to compute dispersion measures for both distributions. The results indicate that both income and educational inequality matter for regional growth and have a positive impact upon it, although relatively small.

3. INEQUALITY AND GROWTH IN THE PORTUGUESE REGIONS: DATA OVERVIEW

The aim of this paper is to assess the contribution of income and education inequality to regional growth in 30 Portuguese NUTS III regions over the period 1995-2007. We start by describing the data and respective sources and analyze the growth and inequality performance of the regions during the period under analysis to get an initial grasp of the relationship.

Regional growth corresponds to the average annual growth rate of per capita GDP in year 2000 euros computed using data from the Portuguese National Institute of Statistics (INE) Regional Accounts and Departamento de Prospectiva e Planeamento (DPP) of the Ministry of Environment¹⁷. Table 1 summarizes the real per capita GDP data.

In 1995, Grande Lisboa was the richest region and Serra da Estrela the poorest one, and the same positions are maintained in 2007. The same applies to the other two poorest regions in 1995, Tâmega and Pinhal Interior Norte, that remain in the same position in 2007. In the top three positions, the most significant changes are those of Madeira, that moves up from the 8th to the 3rd position in the ranking, and Grande Porto that moves down from the 2nd to the 7th position. Middle positions also suffer some changes but not as impressive. From 1995 to the year 2007 all the regions registered a positive average annual growth rate and only in Grande Porto was growth less than 1% a year. Madeira was the region that grew at the highest rate, 4.52% a year. However, growth for all regions was uneven during the period with a sharp decline of the average

¹⁷ We thank Natalino Martins from DPP for providing us data on Gross Value Added in year 2000 euros that allowed us to compute regional price indexes. See also Martins and Barradas (2009a).

annual growth rate in the last seven years under analysis relative to the preceding five-year period. The exceptions are Pinhal Interior Sul and Baixo Alentejo that grew faster over the period 2000-2007. The coefficient of variation of per capita real GDP, a measure used to assess the existence of σ -convergence¹⁸, despite the slight decline in 2007 relative to the year 2000, has increased for the whole period, a result that corresponds to a higher dispersion of real GDP per capita among the 30 NUTS III regions or divergence.

Table 1: Growth performance in the 30 Portuguese NUTS III regions, 1995-2007

NUTS III	Per capita GDP year 2000 euros			Average annual growth (%)		
	1995	2000	2007	1995-2000	2000-2007	1995-2007
Minho-Lima	6420	7355	7991	2,721	1,185	1,825
Cávado	7744	8962	9844	2,922	1,341	2,000
Ave	8218	9483	9396	2,863	-0,133	1,116
Grande Porto	11592	12658	12667	1,760	0,011	0,739
Tâmega	5582	6500	7295	3,045	1,647	2,229
Entre Douro e Vouga	8600	10088	10730	3,193	0,881	1,844
Douro	6047	7205	8706	3,504	2,703	3,037
Alto Trás-os-Montes	6256	7345	8694	3,208	2,410	2,742
Baixo Vouga	9744	11209	11974	2,802	0,943	1,717
Baixo Mondego	10454	11929	13060	2,640	1,295	1,855
Pinhal Litoral	10257	12311	13337	3,649	1,144	2,188
Pinhal Interior Norte	5670	6755	7610	3,504	1,701	2,453
Dão-Lafões	6405	8190	8967	4,916	1,295	2,804
Pinhal Interior Sul	6406	6974	9500	1,698	4,417	3,284
Serra da Estrela	5159	6318	7268	4,055	2,001	2,857
Beira Interior Norte	6364	7907	8543	4,342	1,107	2,455
Beira Interior Sul	9158	10148	11316	2,055	1,556	1,764
Cova da Beira	7034	7823	8331	2,127	0,899	1,410
Oeste	8648	10147	11631	3,197	1,950	2,470
Médio Tejo	8741	10568	11035	3,798	0,618	1,943
Grande Lisboa	15833	19566	21127	4,234	1,096	2,404
Península de Setúbal	8289	9740	9810	3,225	0,103	1,404
Alentejo Litoral	11577	14738	17977	4,829	2,837	3,667
Alto Alentejo	8391	9758	10924	3,017	1,613	2,198
Alentejo Central	8094	10505	10911	5,214	0,542	2,489
Baixo Alentejo	8886	8854	10128	-0,073	1,921	1,090
Lezíria do Tejo	9223	10942	11448	3,418	0,647	1,801
Algarve	11116	12362	12966	2,125	0,682	1,283
Açores	8218	9590	11493	3,086	2,587	2,795
Madeira	9420	13503	16199	7,201	2,601	4,518
Mean	8451	9981	11029	3,28	1,45	2,21
Coef. of variation	0.2687	0.2844	0.28222			
Min	5159	6318	7268	-0,07	-0,13	0,74
Max	15833	19566	21127	7,20	4,42	4,52

Source: authors calculations based on INE, Regional Accounts and DPP.

¹⁸ See e.g. Barro and Sala-i-Martin (1991). There is σ -convergence among regions when there is a reduction in the dispersion of income levels.

In order to characterize inequality at the regional level in Portugal we use data from the *Quadros de Pessoal* database which is the result of an annual compulsory survey conducted by the *Ministério do Trabalho e da Solidariedade Social (MTSS)* where firms are required to provide information about their workers on items such as monthly compensation, highest schooling level attained, age, and monthly hours worked. The data is available for the 1985-2007 period (with the exception of the years 1990 and 2001)¹⁹.

The characterization of earnings inequality is based on the analysis of two variables: average earnings²⁰ of the employees working full time and the number of employees distributed according to the economic activity of firms and the levels of education of employees. The methodology used to assess income inequality at the regional level is the Lorenz dominance analysis (see Fields (2001) and Cowell (2000)). For each region we constructed weighted distributions of earnings from which we compute the inequality measures to be used in the estimations: the Gini coefficient, (Xu (2004)), Theil's first measure (Theil (1967)), Atkinson's index (Atkinson (1970)), and the ratios between percentiles 90% and 50% (P90/P50) and between percentiles 50% and 10% (P50/P10), that provide information on the impact of inequality in different parts of the distribution, top and bottom, respectively. Most empirical studies on the relationship between inequality and growth use the Gini coefficient as the proxy for inequality. However, the Gini coefficient is quite sensitive to changes in the middle of the distribution, so we use Theil's first measure and Atkinson's index²¹ as alternative inequality measures, since these are more sensible to changes in the bottom and the top of the distribution, respectively. Table 2 summarizes the data on earnings inequality measured as the Gini coefficient of earnings²².

From 1995 until 2007, most regions registered an increase in earnings inequality (only 5 regions present a decline) with Península de Setúbal showing the highest increase. This evolution however was uneven during the period, with sixteen regions inverting its performance in the second period, 2000-2007, relatively to the first period, 1995-2000. For instance, in Alto Trás os Montes and Beira Interior Norte inequality increases from 1995 to 2000 but then declines between 2000 and 2007, while in Baixo

¹⁹ Data provided by GEP-MTSS.

²⁰ This is a monthly average reported each year referring to the month of October. We consider average full earnings of the employees that performed complete working hours during the month of October.

²¹ With the coefficient of risk aversion to inequality equal to 0.5.

²² Theil's and Atkinson's indexes give similar results as far as the ranking of regions and the evolution of inequality are concerned an indicator that the results from the estimation of the impact of inequality on growth will not differ according to the inequality measure used.

Vouga and Lezíria do Tejo the opposite happens. This means that some regions changed a lot its position in the earnings inequality ranking between 1995 and 2007. For instance, Península de Setúbal became the most unequal region in 2007, from a middle position in 1995 and 2000, and Dão-Lafões and Oeste also became much more unequal. As for the least unequal regions, Algarve was the region with the lowest Gini coefficient in 2007. The dispersion in earnings inequality measured as the coefficient of variation of the Gini coefficient increased slightly for the whole period but from 1995 to 2000 the increase was greater.

Table 2: Earnings inequality performance in the 30 Portuguese NUTS III regions, 1995-2007

NUTS III	Gini coefficient			Total change (%)		
	1995	2000	2007	1995-2000	2000-2007	1995-2007
Minho-Lima	0.1732	0.1762	0.1954	1.73	10.90	12.82
Cávado	0.1669	0.1601	0.1788	-4.07	11.68	7.13
Ave	0.127	0.165	0.1843	29.92	11.70	45.12
Grande Porto	0.195	0.209	0.201	7.18	-3.83	3.08
Tâmega	0.1713	0.1682	0.1975	-1.81	17.42	15.29
Entre Douro e Vouga	0.1233	0.1675	0.1837	35.85	9.67	48.99
Douro	0.2167	0.2239	0.2084	3.32	-6.92	-3.83
Alto Trás os Montes	0.3136	0.2407	0.2765	201.47	-63.69	-11.83
Baixo Vouga	0.1761	0.1857	0.1884	-23.25	14.87	6.98
Baixo Mondego	0.1745	0.1844	0.1908	5.45	1.45	9.34
Pinhal Litoral	0.1324	0.1539	0.1754	5.67	3.47	32.48
Pinhal Interior Norte	0.1763	0.2032	0.1909	16.24	13.97	8.28
Dão-Lafões	0.1708	0.2055	0.2282	15.26	-6.05	33.61
Pinhal Interior Sul	0.2952	0.3036	0.3355	20.32	11.05	13.65
Serra da Estrela	0.1504	0.2534	0.1914	2.85	10.51	27.26
Beira Interior Norte	0.191	0.1918	0.1832	68.48	-24.47	-4.08
Beira Interior Sul	0.1937	0.19	0.1981	0.42	-4.48	2.27
Cova da Beira	0.2178	0.267	0.2674	-1.91	4.26	22.77
Oeste	0.1654	0.1714	0.2038	20.36	-1.86	23.22
Médio Tejo	0.1497	0.1705	0.1976	0.30	-5.28	32.00
Grande Lisboa	0.2312	0.2376	0.2997	22.59	0.15	29.63
Península de Setúbal	0.1756	0.1946	0.4294	3.63	18.90	144.53
Alentejo Litoral	0.2576	0.2569	0.2223	13.89	15.89	-13.70
Alto Alentejo	0.2045	0.1945	0.2316	2.77	26.14	13.25
Alentejo Central	0.1762	0.1952	0.1856	10.82	120.66	5.33
Baixo Alentejo	0.2195	0.218	0.2234	-0.27	-13.47	1.78
Lezíria do Tejo	0.1842	0.2181	0.2088	-4.89	19.07	13.36
Algarve	0.1564	0.4715	0.1712	-0.68	2.48	9.46
Açores	0.2361	0.2368	0.2243	18.40	-4.26	-5.00
Madeira	0.1744	0.2099	0.206	10.78	-4.92	18.12
Mean	0.1899	0.2141	0.2193			
Coef. of variation	0.2332	0.2808	0.2499			
Min	0.1233	0.1539	0.1712			
Max	0.3136	0.4715	0.4294			

Source: authors calculations based on data from *Quadros de Pessoal* database.

Measures of human capital (education) inequality were also computed in order to be able to proxy wealth inequality more accurately, the theoretical concept of inequality used in most growth models. Human capital is proxied by the years of formal education of the workers included in *Quadros de Pessoal* database corresponding to the number of years of schooling of the highest completed schooling level. The methodology used to assess education inequality at the regional level is the same as for earnings inequality: for each region we construct weighted distributions of years of education from which we compute the analogous education inequality measures to be used in the estimations: the Gini coefficient, Theil's entropy measure, Atkinson's measure, and the ratios between percentiles 90% and 50% (P90/P50) and between percentiles 50% and 10% (P50/P10). Table 3 summarizes the data on education inequality, again using the Gini coefficient²³.

From 1995 until 2007, all regions registered a sharp decline (higher than 50%) in education inequality, with Baixo Alentejo showing the highest decrease (69.03%). This evolution was due mostly to the decrease in the 2000-2007 period when all regions registered a decline higher than 49%. In the 1995-2000 period, seventeen regions present a slight increase in education inequality (the highest increase is in Tâmega, 12.82%) and in the remaining thirteen regions it slightly declines (the highest decline is in Cávado and Grande Lisboa, -5.89%). As far as the education inequality ranking is concerned, the top (most unequal) and the bottom (least unequal) positions were occupied by the same two regions in 1995 and again 2007, Pinhal Interior Sul and Tâmega, respectively, but apart from these two regions, and Alto Trás os Montes and Oeste that also maintained its positions in the ranking, all the other regions changed positions. Madeira, Douro and Baixo Vouga moved from the second to the first half of the ranking (15 more unequal regions) and only Alto Alentejo moved from the first half to the second half of the ranking (15 least unequal regions). Grande Lisboa and Grande Porto, the bigger regions in terms of population, also registered an increase in education inequality. The dispersion in education inequality measured as the coefficient of variation of the Gini coefficient increased for the whole period, but from 1995 to 2000 there was a decrease, which implies that the increase was due to the inequality behavior in the 2000-2007 period.

²³ Theil's and Atkinson's indexes give similar results as far as the ranking of regions and the evolution of inequality are concerned.

Table 3: Education inequality performance in the 30 Portuguese NUTS III regions, 1995-2007

NUTS III	Gini coefficient			Total change (%)		
	1995	2000	2007	1995-2000	2000-2007	1995-2007
Minho-Lima	0.2329	0.2394	0.0884	2.79	-63.07	-62.04
Cávado	0.2833	0.2666	0.1229	-5.89	-53.90	-56.62
Ave	0.2294	0.2507	0.0808	9.29	-67.77	-64.78
Grande Porto	0.2781	0.2802	0.1111	0.76	-60.35	-60.05
Tâmega	0.2028	0.2288	0.0719	12.82	-68.58	-64.55
Entre Douro e Vouga	0.2385	0.2628	0.0902	10.19	-65.68	-62.18
Douro	0.2671	0.2809	0.1056	5.17	-62.41	-60.46
Alto Trás os Montes	0.2886	0.2778	0.1234	-3.74	-55.58	-57.24
Baixo Vouga	0.2589	0.2724	0.0993	5.21	-63.55	-61.65
Baixo Mondego	0.2720	0.2715	0.1046	-0.18	-61.47	-61.54
Pinhal Litoral	0.2653	0.2709	0.0972	2.11	-64.12	-63.36
Pinhal Interior Norte	0.2365	0.2578	0.0798	9.01	-69.05	-66.26
Dão-Lafões	0.2519	0.2629	0.0953	4.37	-63.75	-62.17
Pinhal Interior Sul	0.3148	0.2973	0.1509	-5.56	-49.24	-52.06
Serra da Estrela	0.2424	0.2686	0.0874	10.81	-67.46	-63.94
Beira Interior Norte	0.2609	0.2664	0.0883	2.11	-66.85	-66.16
Beira Interior Sul	0.2713	0.2722	0.0937	0.33	-65.58	-65.46
Cova da Beira	0.2744	0.2795	0.1299	1.86	-53.52	-52.66
Oeste	0.2667	0.2712	0.0954	1.69	-64.82	-64.23
Médio Tejo	0.2639	0.2646	0.0966	0.27	-63.49	-63.40
Grande Lisboa	0.2833	0.2666	0.1229	-5.89	-53.90	-56.62
Península de Setúbal	0.2758	0.2689	0.1028	-2.50	-61.77	-62.73
Alentejo Litoral	0.2987	0.2879	0.1048	-3.62	-63.60	-64.91
Alto Alentejo	0.2837	0.2752	0.0956	-3.00	-65.26	-66.30
Alentejo Central	0.2874	0.2855	0.1046	-0.66	-63.36	-63.60
Baixo Alentejo	0.2874	0.2855	0.0890	-0.66	-68.83	-69.03
Lezíria do Tejo	0.2750	0.2759	0.0973	0.33	-64.73	-64.62
Algarve	0.2725	0.2682	0.1033	-1.58	-61.48	-62.09
Açores	0.2686	0.2664	0.0937	-0.82	-64.83	-65.12
Madeira	0.2704	0.2696	0.1046	-0.30	-61.20	-61.32
Mean	0.2668	0.2697	0.1010			
Coef. of variation	0.0858	0.0503	0.1612			
Min	0.2028	0.2288	0.0719			
Max	0.3148	0.2973	0.1509			

Source: authors calculations based on data from *Quadros de Pessoal* database.

In Charts 1-3 we plot the average annual growth rate of real per capita GDP over the period 1995-2007 against the main determinants considered in this study, initial earnings inequality, initial education inequality and initial real per capita GDP, respectively. Prior inspection of the data reveals a positive correlation between inequality and growth among NUTS III regions, stronger for earnings than for education inequality (see Charts 1 and 2), an indication that mechanisms such as higher propensities to save (that lead to more capital accumulation) and to consume new goods (that foster innovation) for richer individuals are in action. Additionally, the evidence also seems to indicate that the convergence process is also coming to a halt at the regional level, based on the weak negative correlation between initial income and growth (see Chart 3). In the next section we investigate more deeply these correlations.

Chart 1: Average real GDP per capita growth 1995-2007 and initial (1995) earnings inequality (Gini)

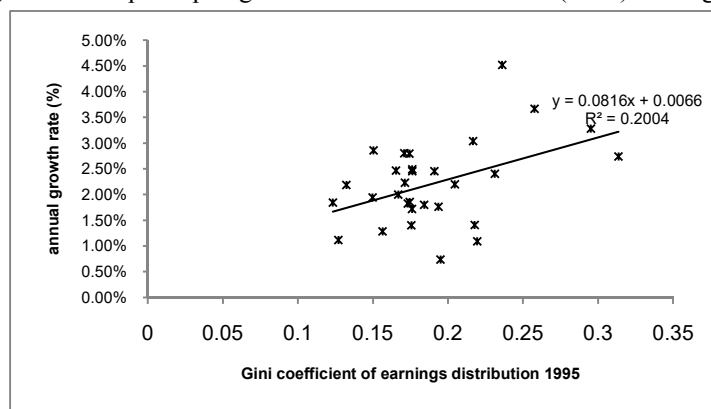


Chart 2: Average real GDP per capita growth 1995-07 and initial (1995) education inequality (Gini)

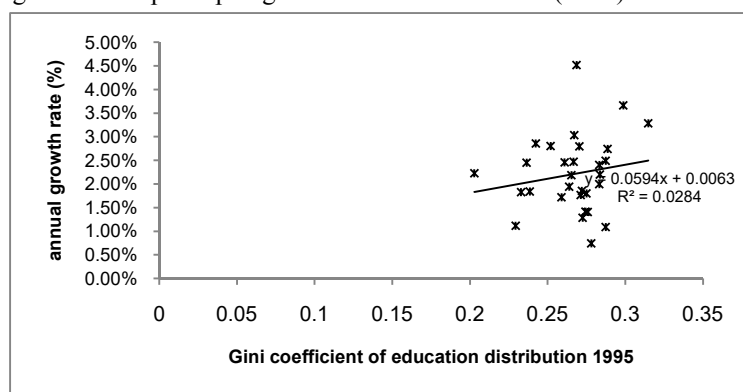
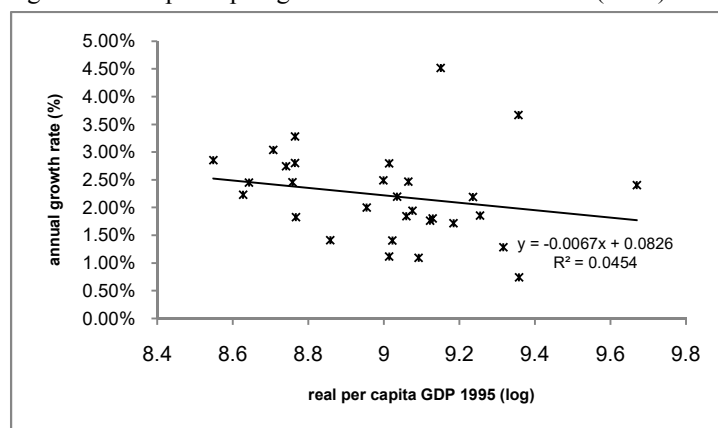


Chart 3: Average real GDP per capita growth 1995-2007 and initial (1995) real GDP per capita



4. EMPIRICAL MODEL AND ECONOMETRIC ANALYSIS

In order to assess the contribution of earnings and education inequality for growth in the 30 Portuguese NUTS III regions over the period 1995-2007, we estimate what is known in the inequality-growth empirical literature as a reduced-form equation (see e.g. Perotti (1996)) where output growth is regressed on a measure of initial inequality, initial output and a set of other explanatory variables considered to be relevant growth determinants for the units (regions) under analysis²⁴.

We estimate the impact of inequality on growth using a variation of the following cross-regional econometric specification:

$$\text{Growth_RGDPC}_{i,2007-1995} = \text{constant} + \beta \ln \text{RGDPC}_{i,1995} + \text{INEQ}_{i,1993} \gamma + X_{i,1995} \Psi + \varepsilon_i \quad (1)$$

where $\text{Growth_RGDPC}_{i,2007-1995}$ is the annual average growth rate of real GDP per capita in the Portuguese NUTS III region i between 1995 and 2007; $\ln \text{RGDPC}_{i,1995}$ is the natural logarithm of initial real GDP per capita; $\text{INEQ}_{i,1993}$ is a vector of initial inequality measures that might include, simultaneously, measures of earnings and education inequality, introduced with 2-year lags to address possible endogeneity; X is a parsimonious²⁵ vector of additional control variables that are assumed to influence regional growth, which might include the initial average number of years of education of the workforce (educational attainment) included in Quadros de Pessoal database, the regional productive structure measured as the regional employment share in agriculture, manufacturing or the services sectors, and regional dummies, specifically a dummy for the interior or landlocked regions (with coastal regions as the omitted group); and ε is the disturbance term, all measured for NUTS III region i . By estimating a cross-section model where the dependent variable is income growth measured during a long period of time we are identifying a long-run effect of inequality on economic growth²⁶, which some authors defend as the appropriate time frame to analyze growth influences (see e.g. Forbes (2000), Banerjee, Marcellino and Osbat (2004), Partridge (2005), and Rodríguez-Pose and Tselios (2010)) in order to overcome business cycle effects.

²⁴ These regressions can thus also be classified as “Barro” or *ad hoc* growth regressions from the perspective that they include inequality as a regressor along another set of independent variables that are believed to influence economic growth, based on the predictions of relevant theoretical growth models. See e.g. Barro and Sala-i-Martin (2004).

²⁵ The choice of the additional explanatory variables was determined by the predictions of growth models and the availability of regional data for the Portuguese NUTS III regions.

²⁶ Through the variation occurred across regions over the period of time under analysis.

Table 4 presents the results of estimating equation (1) using Ordinary Least Squares (OLS)²⁷. Regressions 1-6 consider only the impact of earnings inequality on regional growth using the Gini coefficient as the earnings inequality measure. The estimated coefficient on initial real per capita GDP is negative as expected but not significant, which confirms the absence of convergence among the Portuguese regions, similar to what has happened at the national level between Portugal and the other EU member states. As far as earnings inequality is concerned, the results point to a positive influence of initial inequality on subsequent regional economic growth since the estimated coefficient on the initial (lagged 2 periods) Gini coefficient of earnings is positive and significant. This result is robust to the introduction of additional control variables²⁸ (except in regressions 3 and 4 when considering, respectively, the employment shares in agriculture and manufacturing), supporting the view of the classical theories of inequality and growth that higher inequality favours growth due to a higher propensity to save of the rich relative to the poor that leads to higher capital accumulation and thus growth and also since it is good for incentives. As for the additional control variables, apart from the estimated coefficient on the employment share in agriculture, positive and statistically significant, a somewhat puzzling sign, all the other estimated coefficients of the additional control variables are not statistically significant. The estimated coefficient on educational attainment, measured as the average number of years of schooling of the workforce included in *Quadros de Pessoal* database although positive as expected, based on the predictions of both exogenous and endogenous growth model, is not statistically significant.

Regressions 7-12 in Table 4 estimate separately the impact of education inequality on regional economic growth. Again, in all regressions the estimated coefficient on initial real per capita GDP is negative as expected and this time statistically significant (except in regressions 9-11, when considering as additional control variables the regional productive structure measures) indicating this time the existence of convergence among regions. The estimated coefficient on initial education inequality (lagged 2 periods) is positive and statistically significant, except in regressions 8-10 when considering as additional control variables educational attainment and the regional productive structure measures, respectively, the agriculture and the manufacturing employment shares, and higher than for the earnings inequality Gini, again confirming

²⁷ All the regressions were estimated with STATA 10.0.

²⁸ Introduced one at a time due to the limited number of observations.

the classical theories predictions according to which inequality creates an incentive to invest more in human capital in order to get higher returns and belong to the wealthier groups of society. This also means that in the Portuguese regions the level of human capital might be high enough in the sense that there is not the risk of falling in a low human capital investment trap in the presence of borrowing constraints. The estimated coefficient on educational attainment is now negative, although not significant, when many growth models show that a higher level of human capital leads to higher income levels and even higher income growth rates since it facilitates the absorption of technologies developed in technologically more advanced countries/regions as well as accelerating discovery or invention (see e.g. Sianesi and van Reenen (2003)). Apart from the estimated coefficient on the employment share in agriculture, again positive and statistically significant, all the other estimated coefficients of the additional control variables are not statistically significant.

In regression 13 we estimate the combined impact of earnings and education inequality. When we consider both inequality measures as regressors, the estimated coefficients on the Gini coefficient of earnings and on the Gini coefficient of education are not statistically significant. Contrary to the results of some other previous studies (Birdsall and Londono (1997), Barrio-Castro, López-Bazo and Serrano-Domingo (2002), Castelló-Climent and Doménech (2002)) the consideration of the education inequality measure does not improve the results. In fact, based on the information from the R-squared and AIC and BIC information criteria (see regressions 1 and 7), earnings inequality has a higher explanatory power indicating that this is the relevant inequality measure to explain regional growth in Portugal during the period under analysis.

Finally, in regression 14 we estimate our regional growth regression considering as the sole explanatory variable the initial Gini coefficient of earnings since none of the other variables were significant (except for the employment share in agriculture). The estimated coefficient remains positive and statistically significant as expected²⁹ but the magnitude of the impact remains small.

²⁹ We also run regressions 1 and 14 adding the square of the Gini coefficient as a regressor to test for a non-linear relationship between inequality and growth. The estimated coefficient although negative was not statistically significant.

Table 4: Results of the estimation of the reduced-form specification

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Constant	.0463 (.0501)	.048 (.0593)	-.0145 (.0512)	.0612 (.0545)	.046 (.0594)	.0756 (.0561)	.0962 (.0471) ^a	.096 (.0488) ^a	.0063 (.0590)	.0920 (.046) ^a	.0817 (.0573)	.1197 (.0581) ^a	.0588 (.0621)	.0114 (.0045) ^a
lnRGDPC	-.0038 (.0054)	-.0041 (.0072)	.0029 (.0056)	-.0046 (.0056)	-.0037 (.0066)	-.0070 (.0059)	-.0111 (.0054) ^a	-.0110 (.0056) ^a	-.0005 (.0068)	-.0087 (.0057)	-.0094 (.0066)	-.0138 (.0065) ^a	-.0058 (.0074)	
Gini earnings	.0504 (.0246) ^a	.0493 (.0317) ^c	.0299 (.0330)	.0327 (.0350)	.0504 (.0249) ^a	.0577 (.0218) ^a							.0391 (.0380)	.055 (.0210) ^a
Gini education							.1012 (.0451) ^a	.1031 (.0725)	.0600 (.0504)	.0521 (.0644)	.1078 (.0460) ^a	.1086 (.0466) ^a	.0327 (.0605)	
Educational attainment		.0002 (.0021)						-.0001 (.0028)						
Employment share in agriculture			.0187 (.011) ^c						.0208 (.0086) ^a					
Employment share in manufacturing				-.0132 (.0106)						-.0147 (.0098)				
Employment share in services					-.0001 (.0128)						-.0048 (.0134)			
Dummy Interior						-.0030 (.0031)						-.002 (.0034)		
R-squared	0.1577	0.1580	0.2067	0.2440	0.1577	0.1785	0.1343	0.1344	0.2037	0.1735	0.1375	0.1436	0.1614	0.1444
AIC	-204.22	-202.23	-204.01	-203.46	-202.22	-202.96	-203.39	-201.4	-203.9	-202.78	-201.50	-201.72	-202.35	-205.74
BIC	-200.01	-196.62	-198.41	-197.86	-196.61	-197.36	-199.19	-195.79	-198.29	-197.18	-195.9	-196.11	-196.74	-202.94
Observations	30	30	30	30	30	30	30	30	30	30	30	30	30	30

Notes: Heteroscedasticity-consistent standard errors in parentheses (Huber (1967); White (1980)). ^a, ^b, and ^c indicates significance at the 1%, 5% and 10% level, respectively.

In Table 5 we examine the sensitivity of our results to the inequality measure used to assess earnings and education inequality across the Portuguese NUTS III regions. Most empirical studies on the relationship between inequality and growth use the Gini coefficient as the proxy for inequality. However, the Gini coefficient is quite sensitive to changes in the middle of the distribution, so we use Theil's first measure and Atkinson's index³⁰ as alternative inequality measures, since these are more sensible to changes in the bottom and the top of the distribution, respectively. Additionally, the Gini, Theil and Atkinson's are aggregate measures of distribution, but the relationship between inequality and economic growth might depend on inequality in different groups of the distribution (top vs. bottom). This issue has been addressed in empirical studies by using alternative measures of inequality, e.g. the share or ratios of certain quintiles or percentiles, and comparing the results with the ones from the estimations that consider the aggregate measure, arriving at some important differences in some cases (see Barro (2000), Panizza (2002), Voitchovsky (2005)). We thus also investigate the explanatory power of the ratios between percentiles 90% and 50% (P90/P50) and between percentiles 50% and 10% (P50/P10) that provide information on the impact of inequality in different parts of the distribution, top and bottom, respectively.

Regressions 1-4 present the results for the alternative earnings inequality measures. The results do not come significantly altered by considering the alternative measures of earnings inequality³¹, although in regression 3 that considers the ratio P90/P50 the R-squared is higher than when we consider the Gini coefficient, an indication that it is higher inequality at the top of the distribution that drives faster growth. Additionally, in regression 4, that considers the ratio P10/P50, the estimated coefficient on this variable is not statistically significant.

Regressions 5-8 present the results for the alternative education inequality measures. Again, the results do not come significantly altered by considering the alternative measures of earnings inequality³². The only exception concerns the results when using the ratio P90/P50 of the distribution of education, which presents a higher explanatory power indicating, in accordance with the results for the earnings inequality measures, that inequality in education at the top of the distribution is the relevant measure to

³⁰ With the coefficient of risk aversion to inequality equal to 0.5.

³¹ The results also do not change when we introduce the additional control variables with the alternative inequality measures. These results can be obtained from the authors upon request.

³² The results also do not change when we introduce the additional control variables with the alternative inequality measures. These results can be obtained from the authors upon request.

explain regional growth, a result that reinforces the higher propensities to save of the richer and the incentives mechanisms of transmission from inequality to growth.

Using either the earnings or the education alternative inequality measures, apart from the results with the P90/P50 ratios, the Gini coefficient presents a higher explanatory power, based on the information from the R-squared and the AIC and BIC information criteria.

Table 5: Results of the estimation of the reduced-form specification with alternative inequality measures

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Constant	.0531 (.0492)	.0535 (.0494)	.0486 (.0531)	.0759 (.0494)	.0977 (.0458) ^a	.0915 (.0465) ^a	.0720 (.0535)	.1214 (.0631) ^a
lnRGDPC	-.0039 (.0054)	-.004 (.0054)	-.0044 (.0055)	-.0049 (.0058)	-.0101 (.0052) ^a	-.0094 (.0052) ^b	-.0070 (.0057)	-.0100 (.0063)
Atkinson earnings	.1229 (.0550) ^a							
Theil earnings		.0597 (.0289) ^a						
P90/P50 earnings			.0080 (.0039) ^a					
P50/P10 earnings				-.0139 (.0125)				
Atkinson education					.2514 (.1322) ^b			
Theil education						.1247 (.0652) ^b		
P90/P50 education							.0055 (.0023) ^a	
P50/P10 education								-.0101 (.0116)
R-squared	0.1463	0.1400	0.1624	0.0871	0.1388	0.1320	0.1836	0.0869
AIC	-203.81	-203.59	-204.38	-201.80	-203.55	-203.31	-205.15	-201.79
BIC	-199.61	-199.39	-200.18	-197.6	-199.35	-199.11	-200.95	-197.59
Observations	30	30	30	30	30	30	30	30

Notes: Heteroscedasticity-consistent standard errors in parentheses (Huber (1967); White (1980)). ^a, ^b, and ^c indicates significance at the 1%, 5% and 10% level, respectively.

5. CONCLUSIONS

Although Portugal ranks as one of the most unequal countries (in terms of income distribution) relative to its fellow EU member states, inequality has never been considered as an explanatory factor in the studies that aim at explaining economic growth in the Portuguese economy, including studies devoted to the analysis of regional growth. To fill this gap, this study investigated the contribution of earnings and education inequality for growth in the 30 Portuguese NUTS III regions over the period 1995-2007, by estimating a cross sectional reduced-form specification where output growth is regressed on a measure of initial inequality, initial output and a set of other explanatory variables considered to be relevant regional growth determinants.

The results point to a positive relationship between initial inequality and regional growth, stronger for education than for earnings inequality, but with earnings inequality measures revealing a higher explanatory power. Moreover, the ratio P90/P50 for the earnings and the education distribution of education presents a higher explanatory power indicating that inequality at the top of the distribution is the relevant measure to explain regional growth, a result that reinforces the higher propensities to save of the richer and the incentives mechanisms of transmission from inequality to growth. Additionally, the evidence does not support the existence of convergence among Portuguese NUTS III regions during the period 1995-2007. These findings are robust to the introduction of most additional control variables and the consideration of alternative measures of earnings and education inequality.

Based on this evidence, the mechanisms that seem to explain the relationship between inequality and growth in the Portuguese NUTS III regions are those proposed by the classical theories on the subject: inequality is good for growth since richer individuals have higher marginal propensities to save, thus leading to higher capital accumulation, and because it creates an incentive to belong to the wealthiest classes of society leading to higher working effort, both resulting in faster growth.

As far as the policy implications of these results are concerned, we do not recommend policies aimed at increasing regional inequality in Portugal since these might lead to a situation where inequality reaches a much too high level in the sense that it discourages the higher working effort or leads to social instability³³. The identification of such thresholds for the changing influence of inequality requires a more

³³ Let us not forget also that Portugal has a high poverty rate.

detailed analysis. Additionally, the impact of inequality on regional growth is small therefore policies aiming at changing inequality should not be a priority.

Future research on the subject should check the robustness of the results to the use of: a short-run framework that explores the information concerning the time series variation within regions by means of panel data techniques; alternative sources of data on personal income/earnings and education such as the European Household Community Panel (ECHP) or the Household Budget Surveys carried out by INE; and explore in more detail the transmission mechanisms that might explain the relationship between inequality and growth at the regional level in Portugal.

APPENDIX

Figure 1:

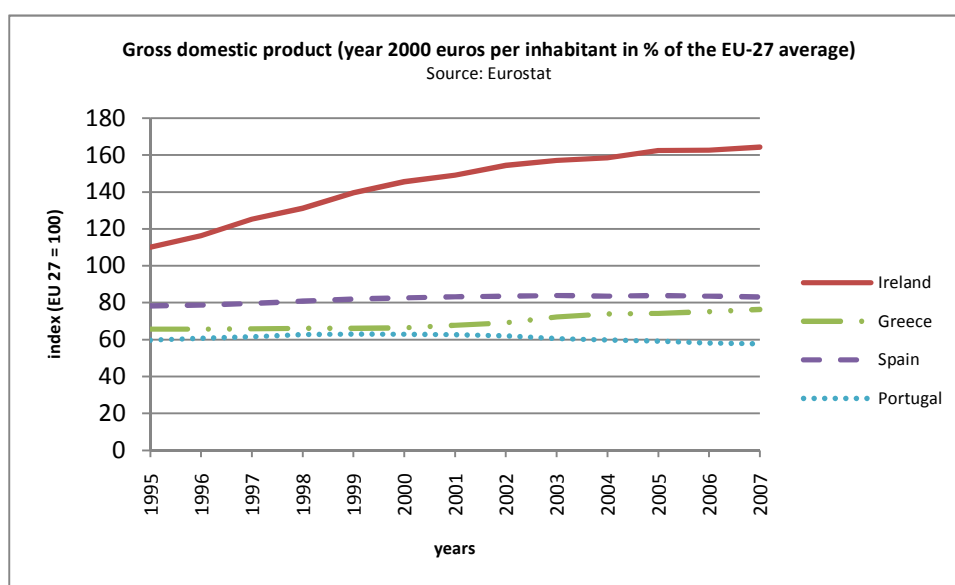
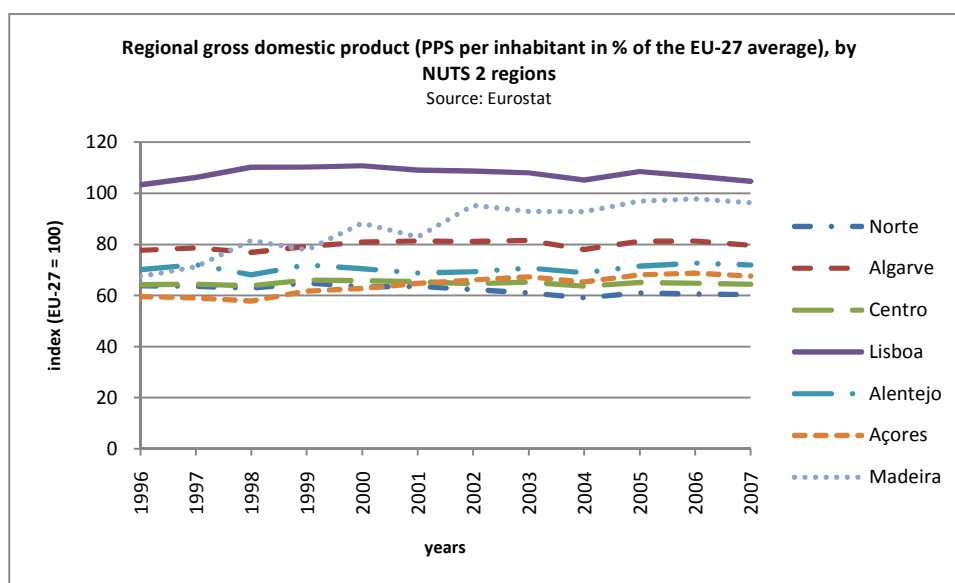


Figure 2:



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