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New empirics about innovation and inequality in Europe

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1. Abstract

The increase of internal inequality is one of the consequences of the recent turbulence of the World economy and the crisis' effects in advanced countries. At the same time, to face the new information age and the phenomena of digitalization and robotization, investment in research and development (R&D) is an indisputable action for economic and social progress. The combination of these two dynamics opens new debates about the still unresolved relationship between innovation and inequality. This paper contrasts the postulates of the existing body of theory and the existing empirical evidence to argue that the positive co-evolution of inequality reduction and technological progress in Europe is not a lineal process, but it requires to analyze its complexity and what sort of combination of factors would best explain it. The findings are based on regressions with panel data from a sample of 20 countries in the period 1995-2017, and they show the relevance of structural and institutional aspects within the European region. In particular, two clusters of countries seem to define a dissimilar behavior in the relationship between inequality and innovation and a virtuous circle defined by the contribution of social protection and innovation policies contributes to a favorable solution of the puzzle between innovation and inequality.

Keywords: Innovation, Inequality, Institutions, Catching-up.

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2. Index

3. Introduction

The global financial crisis of 2007-2008 and the subsequent macroeconomic shocks, such as the international economic recession, have fostered a diverse set of economic policies. The rise of income inequality in the advanced economies, as well as the high concentration at the top of the distribution are two of the main aspects that focus the attention of both policymakers and academics. Although concept of inequality and its effects on economic growth is a controversial topic, there is also certain agreement about the persistence of a negative impact for sustainable growth, as well as for other welfare and social conditions, while some evidence confirms that under certain conditions higher equality rates can foster economic growth (Ostry, Berg and Tsangarides, 2014)

Some crucial facts illustrate the recent evolution of inequality in the last years:

- While the bottom half of adults collectively owns less than 1% of total wealth, the richest decile (top 10% of adults) owns 85% of global wealth, and the top percentile (1%) alone accounts for almost half of all household wealth (47%) (Credit Suisse, 2018).
- Income in hands of the top 10% poorest people have risen less than 3$/year in 1988-2011, while incomes of the top 1% richest have been multiplied by 182 (Credit Suisse, 2016).
- There are still 3.4 billion people (almost half of humanity) living on less than $5.50 a day (OXFAM Intermon, 2019)

Some decades ago inequality was approached as a particular issue of developing countries. However, it becomes a global concern due to the rising inequality trend.

Globalization and technological change are widely supported as the main drivers of this rising trend. However, while it is likely that this relationship affects more to advanced economies, they display different rates of inequality growth. Whether there are other main drivers apart from technological change and globalization, other elements that bias their influence in equality have not been profoundly studied. A different driver beside technological change and globalization is the structure of the welfare State, which works as a counterweight aspect of inequality. There is an intense debate over the topic of welfare State expansion, and whether it is harmful for economic growth and globalization or not. Recent studies show that public social expenditures might actually stimulate economic growth along with lowering inequality (Tridico & Meloni, 2018).

Labor market institutions, such as Union density or collective bargaining, have recently been found to be very good predictors of the rise in equality, so it´s necessary to take them into consideration for a better understanding of the problem (Jaumotte and Osorio, 2015) (Kristal and Cohen, 2016). Innovation institutions can also influence the rise in inequality because this is a process that works as a central engine that fosters technological change, and it´s deeply influenced by globalization (Freeman, 2011).

This is the reason that justifies to analyze here how the internationalization of technology and innovation in the dynamics of global economy may influence inequality. These two phenomena foster job creation (and therefore income), polarization by shifting the global demand of labor force in favor of high qualified workers (Skill Biased Technological Change) and, in the last decades, the reduction of the number of routine related jobs due to automation (Routine Biased Technological Change) (Goos, Manning and Salomons, 2014). Other processes like offshoring or delocalization along the global value chain, are also consequences of the internationalization of technology, and hence affect inequality by increasing capital share while decreasing labor. On the other hand, knowledge and technology spillovers, Foreign Direct Investment (FDI) or social promotion possibilities are also important consequences of technological globalization that should be considered as they can counterbalance the former ones.

As seen in Aghion et al (2015), innovation process generates profits appropriated by the 1% wealthiest at first stage. This influences both inter and intra countries inequality. However, this innovation outcomes can permeate the lowest strata and therefore help to decrease inequality (Aghion, 2016). Thus, it is relevant to identify what mechanisms determine the positive or negative impact of innovation in inequality, whether they perform at a regional or a global scope and whether they can be a matter of economic policy or not.

This paper looks at the determinants of inequality rise in advanced economies, particularly at those that work as counterbalance, focusing on the relationship between innovation institutions and the distribution of incomes. It also analyzes the impact of welfare State through social protection and labor market institutions as they have great influence in the outcomes distribution.

The working hypothesis is that the re-

lationship between innovation and welfare state institutions and inequality relies more profoundly on structural-traditional institutions rather than on conjunctural policies. This statement is supported by the econometric analysis performed.

The findings will reveal that innovation and welfare State institutions are associated with the rise of income inequality in the economies under analysis. Some composite indexes are built to measure these institutions, helping to understand the phenomena as a whole.

Two clusters of countries are identified when looking at the interaction between these institutions and inequality, one is composed by countries with ample innovation and welfare institutions and low inequality, and the other is composed by countries with relatively poorer institutions and higher inequality.

However, it is not possible to affirm that policies fostering R&D expenditures or social protection would necessary work in order to reduce the inequality rise. In fact, in some cases it could result in more harmful distributional outcomes.

Both innovation and welfare State institutions depend strongly on economic policies, which are highly biased by ideology, but also by structural traditional institutions. The possibility of an equal economic growth is an important objective for policymakers, and this also justifies the realization of this study.

Thus, economic policies promoting and developing innovation and welfare state institutions should be decided country by country and taking into accounts other determinants and institutions, which are clearly relevant and should be considered in order to understand the whole phenomenon.

To sum up, the theoretical and empirical reasons for the relevance of the joint analysis of innovation institutions and income distribution are the following:

- Technological change and globalization are main drivers of inequality.
- Internationalization of technology and innovation that results from globalization have effects on inequality.
- Differences in inequality exist between similarly advanced and globalized regions.

These reasons, in addition to the present debate surrounding inequality, the heterogeneous findings in economic literature and the lack of robust results at a global scale encourage this paper to fill this gap.

This paper is not an exhaustive policy brief, but it provides a global vision considering economic and social heterogeneity in the comprehension of the phenomena as well as the orientation of economic policies, that contributes to the debate. This is achieved by performing a harmonized, homogeneous and international analysis drawn on the experience of 20 European economies from 1995 to 2017.

The next section contains a brief literature review that builds the conceptual framework. The third section presents some facts about inequality and its main drivers. The empirical analysis is in section fourth as well as the discussion of estimations results. Finally, conclusions are presented in section fifth.

4. **Background**

The approach to the complex relationship between innovation and inequality requires to take a brief glance at the traditional theoretical framework of economic growth and, secondly, to focus on the more specific literature.

The inclusion of technological change as an exogenous or endogenous factor is the touchstone that will help to classify the more traditional theories of economic growth.

Theories that consider technological change as an exogenous factor do not look at it as a component of growth, and therefore depends on given investment rates. At this point, there are three main theoretical models:

Harrod-Domar model emphasizes labor and capital stock and productivity natural growth rates as drivers of economic growth. Divergence from these growth rates would cause short term distortions and economic cycle. Innovation depends on investment, which is a constant (Harrod, 1939; Domar, 1946).

On the other hand, Kaldor model emphasizes the role of manufacturing sector and states that capital accumulation relates to technical progress through investments done by high-rent capitalists. Therefore, innovation relies on their propensity to save (Kaldor, 1957)

And Solow model, which emphasizes long-term growth and aims to explain it by looking at capital accumulation, labor force growth, and increases in productivity. The last is assimilated to technical progress and usually is assumed to remain constant (Solow, 1956; Swan, 1956).

Theories that consider technical change as an endogenous factor hold that investment in human capital, knowledge and innovation are relevant components of economic growth.

However, some models prioritize some agents over others. For example, models prioritizing human capital are: first, Romer I model, that emphasizes capital diminishing

returns and externalities and holds that technical change is not a constant and depends on capital accumulation. Innovation fosters progress via technical change, so in this model a negative relation between innovation and inequality is implied (Romer, 1986). Barro and Romer II model modifies Romer I model by introducing education as a direct determinant of production level. Innovation here is the result of R&D investment, and therefore defined by agents' election. Thus, innovation causes progress, so the negative impact in inequality is still present (Romer, 1994).

On the other hand, Aghion and Howitt model focuses on innovation and human capital, and analyzes the relationship the other way around too, holding that inequality inhibits knowledge accumulation and consequently innovation (Aghion & Howitt, 2009). Lucas model also emphasizes human capital and holds that technology is a public good, and thus it may have a redistributive factor (Lucas, 1988).

There are models that prioritize companies over human capital, such as the Guellec and Ralle model, which holds that innovative companies and temporary monopolies are responsible of technical change, and might increase inequality via patent monopolies (Guellec & Ralle, 1991).

The evolutionary model of Nelson & Winter (1987), focuses on behaviors conducted by companies that determine innovation rates and directly affect economic growth and progress.

At this point, it´s important to review the concept of innovation by Schumpeter who states that it is the central engine of the capitalist system. This last one is an irregular system with business cycles that depend on entrepreneurs' role and creative destruction. It's a process that describes how the entrepreneur creates markets by innovating, what expels old companies and business models (Schumpeter, 1961)

There is also specific literature that is more heterogeneous, although some key points can be presented as follows:

- Innovation is in fact related to inequality and fosters social mobility (Aghion, 2016). The relation is though complex and conflicting evidence is found in the related literature.
- It depends on multiple variables such as policies, regulations, innovation typology, asymmetric information or market decisions among others (Zweimüller, 2000; Anderton & Oscarson, 2002; Donegan & Lowe, 2008; Arocena & Sutz, 2009; Valdivia, 2010; Lazonick & Mazzucato, 2013; Li, Sato & Sicular, 2013; Cozzens & Thakur, 2014; Aghion et al., 2015; Mongelli & Rullani, 2017).
- There is empirical evidence that profit generated by innovation is appropriated by the wealthiest top 1% in first term, but on the long run inequality diminishes because benefits are redistributed (Aghion, 2016).
- No significant evidence is found in UE, while it actually is in the USA and in India. However, the relationship between innovation and inequality is positive in the first case (Lee & Rodríguez-Pose, 2012) and negative in the second case (Ojha, Pradhan & Ghosh, 2013). The relationship has also been studied with less clear results in UK & USA (Aghion, 2002; Anderton & Oscarson, 2002; Aghion, 2015); Latin America (Arocena & Sutz, 2009); Canada (Kogler & Breau, 2014); and China (Li, Sato & Sicular, 2013).
- It´s important to study other faces of inequality, particularly those related with gender (Karatas-Özkan & Chell, 2013) or education (Aghion, 2002).
- Innovation promotes knowledge spread reaching every population strata (Lucas, 1988; Aghion and Howitt, 1992; Radosevic & Yoruk, 2016).
- Automation has triggered wage polarization in the last decades via increase of the demand of high-skilled workers (Skill Biased Technological Change) (Autor, 1999) or via substitution of routine-based jobs (Routine Biased Technological Change) (Goos, Manning & Salomons, 2014), but it can potentially create more jobs than it has destroyed (Berger & Frey, 2016).

5. Some relevant facts

Inequality

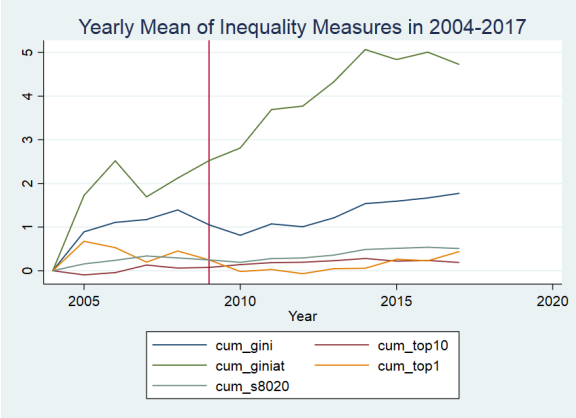
There are multiple indicators that allow us to approach inequality empirically. The most relevant indicators are Gini Coefficient after social transfers, the S80/S20 Ratio and the Top 10 Income; other measures such as Gini Coefficient before social transfers, or the Top 1 Income are also taken into consideration here for control purposes.

Graph 1 illustrates the rise of inequality during the period for which data is broadly available. The variables represented are accumulated growth rates of aggregated yearly means of Gini Coefficient after social transfers (cum_gini), Top 10 Income (cum_top10), Gini Coefficient before social

transfers (cum_giniat), Top 1 (cum_top1) and Income Ratio S80/S20 (cum_s8020).

The option has been to point out the year 2009 to indicate the year when the financial crisis shock reached Europe.

Graph 1. Evolution of inequality measures, 2004-2017



Sources: Eurostat, World Inequality Indicators. Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

The most relevant appreciation is that, regardless the measure, inequality has risen in this period in Europe, but this trend is also observable on the previous decades as it has been analyzed elsewhere (Iversen & Soskice, 2009; Jaumotte and Osorio, 2015; Kristal and Cohen, 2016; Ahlquist & Ansell, 2017).

The only measure of inequality that doesn't consider welfare state institutions is the Gini Coefficient before social transfers, and its slope is the steepest; then, it's plausible to assume that social protection has a large impact on inequality.

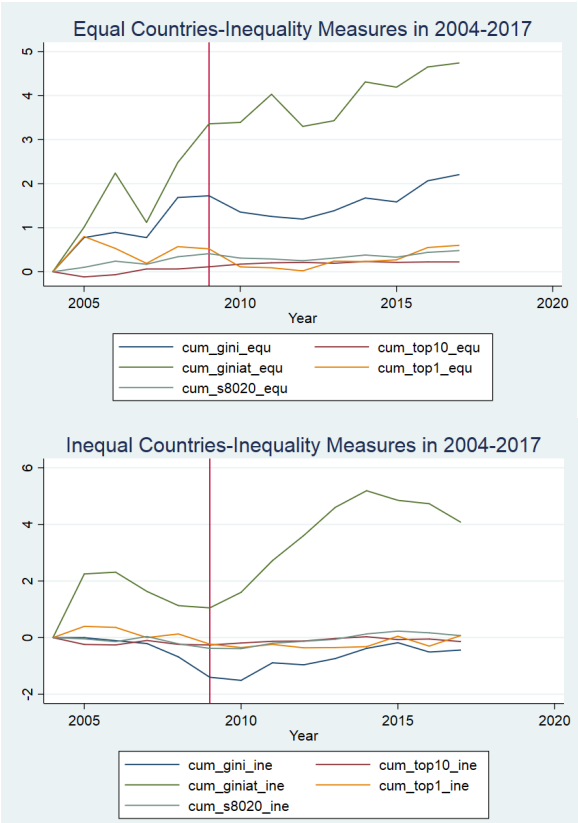
However, as stated before and accordingly to some thesis like the neoamerican-Renan models by Michel Albert (1992) or like the two-clusters statement found in Iversen & Soskice (2009), not all countries have followed the same pattern of inequality rise. In fact, they are clustered in two groups that are defined according the following aspects:

- A group formed by the most advanced countries, these geographically located in the center of the continent.
- And another group formed by relatively less advanced countries and the Anglo-Saxon countries included in this study (United Kingdom and Ireland).

Therefore, both groups are analyzed separately in Graph 2, and differences are appreciable in the evolution of the different inequality indicators previously mentioned.

The first noticeable difference is that while in most advanced economies inequality has risen regardless of the measure, in those less advanced only Gini Coefficient before social transfers has risen and the measures that take welfare state institutions into consideration remain stable or even show a decreasing trend. It's striking that the years with the biggest decrease rate in inequality measured by Gini Coefficient are those right after the crisis stroke Europe. The most plausible explanation for this, seems to be that more advanced countries have lower levels of inequality than less advanced ones, and that makes it harder to reduce inequality substantially. In addition, the global economic shock triggered the countercyclical mechanisms of social protection in less advanced economies because of the rise in unemployment and other economic afflictions suffered in a greater way in these countries. This would mean that as the less advanced economies are getting closer to the more advanced ones, convergence is taking place at a slow path.

Graph 2. Inequality evolution by countries, 2004-2017



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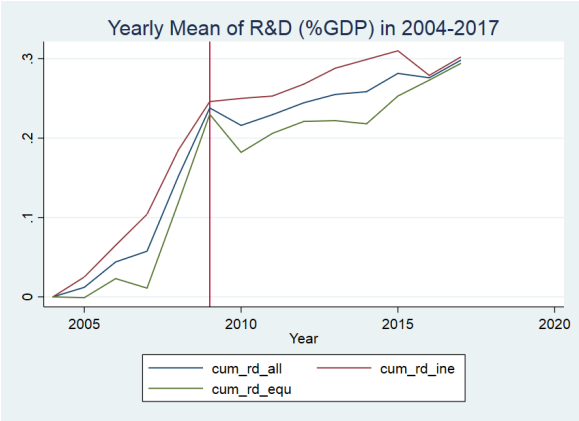
Innovation

Innovation is a complex process to measure, and thus three main related variables are jointly analyzed here. Two of them are resources, or inputs for carrying out innovation. In particular, Research & Development (R&D) expenditures as percentage of Gross Domestic Product and R&D personnel and researchers as percentage of total labor force. The other variable that is also a good indicator for innovation outputs, is the number of patent applications at the European Patent Office per million of active population. Other variables related to innovation like broadband subscriptions per 100 people, exports complexity or gross fixed capital formation are also taken into consideration in order to complete the picture. To have a first general glance at innovation, Graph 3 displays accumulated growth rates of aggregated yearly mean of R&D expenditures as percentage of GDP.

Graph 3. Evolution of R&D expenditures, 2004-2017



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There is a clear trend shift right after the financial crisis strike, because of the increase in social protection spending that countries needed to carry out. However, it seems that R&D expenditures have permanently slowed down its increasing path. An interesting fact is that the less advanced economies have been increasing its R&D expenditures relatively faster than the more advanced ones, probably because they had, and still show lower values in this indicator. This means that they are converging, and hence succeeding in the catching-up process (Abramovitz, 1986; Fagerberg & Godinho, 2003).

With the objective of analyzing innovation as just one, though complicated phenomenon, a composite index is elaborated including multiple variables as follows[1]:

$$Inno_{index}=(Broadband_{norm} + R\&D_{norm} + Pat_{norm} + Perso_{norm} + ECI_{norm})/5$$

This composite index is built by performing an arithmetic average of the normalized values of the variables studied. The motivation behind it is the scarcity of available data regarding composite measurements for innovation. The variables selected are representative of different components from indexes like European Innovation Scoreboard or Global Innovation Index; particularly, the next four are included:

- ICT connectivity conditions: (Broadband) Fixed Broadband subscriptions per 100 people
- Knowledge Investment: (R&D) R&D expenditure as percentage of GDP
- Technological performance: (Pat) Patent applications to the EPO per M. of active population.
- Human resources: (Perso) R&D personnel and researchers as percentage of total labor force
- Economic Complexity Index[2] (ECI)

Welfare State

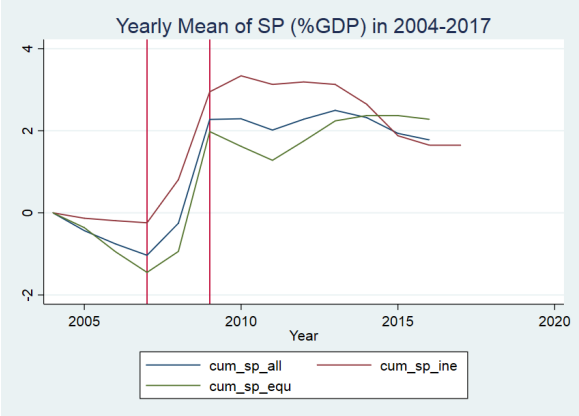
Welfare state is approached by the accumulated growth rates of aggregated yearly mean of expenditures in social protection as percentage of GDP, distinguishing between more and less advanced economies.

In Graph 4, years 2007 and 2009 are pointed out because social protection expenditures shift towards a big increase in the first year and stagnates and returns to its decreasing path in the second year. A plausible explanation for this fact would be that in 2007 the financial crisis started in the USA, and hence triggers social protection mechanisms in the studied economies. In 2009, austerity measures start to show up in some European countries, and these were consolidated around 2010. Moreover, less advanced economies have higher growth rates of social protection expenditures, probably because they start from lower rates, but in the last years of the sample, the more advanced economies sur-

1. Composite Indexes are built following the "Handbook on Constructing Composite Indicators", by OECD, 2008.
2. Economic Complexity Index (ECI) measures the knowledge intensity of an economy by considering the knowledge intensity of the products it exports. It´s elaborated by the Observatory of Economic Complexity

pass the less advanced ones in accumulated growth rate of social protection expenditures, as a consequence of austerity measures in south-European countries (Krugman, 2012).

Graph 4. Evolution of social protection, 2004-2017

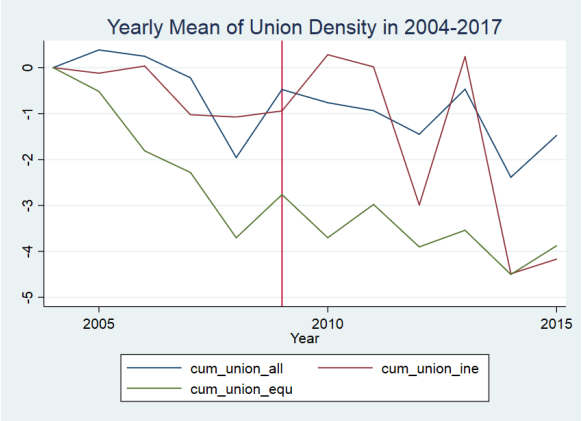


Sources: Eurostat. Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

Labor market

Labor market institutions are measured with two variables widely studied in the related literature: Union density and collective bargaining (Card, Lemieux, & Riddell, 2004; Iversen & Soskice, 2009; Jaumotte and Osorio, 2015, Kristal & Cohen, 2016). Graph 5 illustrates the accumulated growth rates of aggregated yearly mean of Union density, distinguishing between more and less advanced economies. Due to scarcity of data, the graph is not accurate and thus only the general trend can be analyzed. There is a clearly negative and fast speed behavior since the last decades of the XXth Century (Card, Lemieux, & Riddell, 2004; Iversen & Soskice, 2009; Jaumotte and Osorio, 2015, Kristal & Cohen, 2016).

Graph 5. Evolution of Union Density, 2004-2017



Sources: OECD Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

Correlation graphs

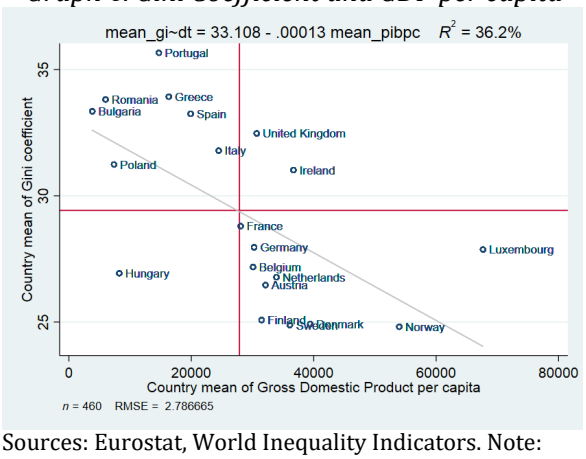
To observe the potential influence of social protection and welfare state in inequality, several graphs presented in the Annex illustrate the relationship existing between both Gini Coefficients before and after social transfers and the different phenomena of interest in this study: Innovation, social protection expenditures and labor.

All three phenomena display a much more significant and negative correlation with inequality if this last is measured with Gini Coefficient after social transfers. This is plausibly related to the redistributing power of innovation, social protection and labor.

This seems to be quite reasonable since social protection expenditures is the base for social redistribution, and then, the weak correlation found with Gini Coefficient before social transfers is likely due to structural reasons. Therefore, this mainly refers to differences between countries.

For a better understanding of the studied phenomena, Graphs 6 and 7 illustrate correlations, first, between country means of Gini Coefficient after social transfers and GDP, secondly regarding innovation, and also with labor and social protection expenditures:

Graph 6. Gini Coefficient and GDP per capita



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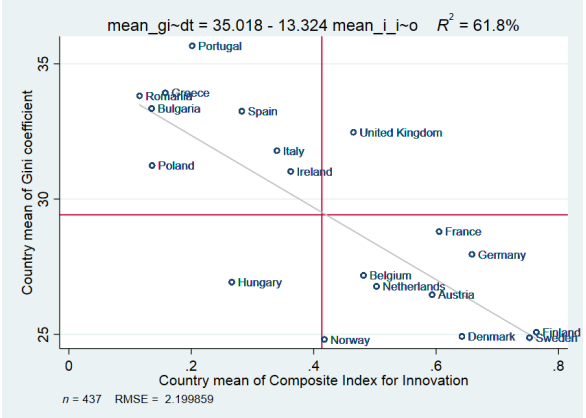
Regarding the relationship between countries' Gini and GDP per capita, the two clustered groups seem to emerge. Anglo-Saxon countries (United Kingdom and Ireland) are outliers because although being relatively wealthy, they tend to present high levels of inequality because of structural and traditional tendencies (Albert, 1992). Hungary is also a special outlier due to its low inequality rates that have their roots in Communism times.

Second, the relationship between Gini Coefficient and the Composite Innovation Index show in Graph 7 a picture in which the clusters are even more noticeable. It happens the same when looking at innovation inputs such as R&D expenditure and R&D personnel and at a technological output like patent applications at EPO separately (see Annex).

Graph 7. Gini Coefficient and Composite Index for Innovation



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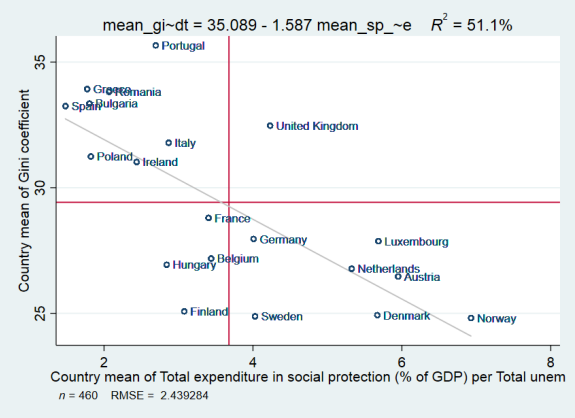
At this point, the question is whether it is plausible to accept that the two clusters remain significant, and how innovation actually is still a good predictor of inequality between countries. Hungary and United Kingdom consolidate as outliers. It also happens at the Nordic countries but Norway, which could make a group apart as they gather in the bottom right corner, meaning that they have ample innovation institutions and hold the lowest inequality rates of the sample.

However, no assumption can be made if other relevant variables are not considered. Therefore, Gini Coefficient is interacted with social protection and labor market institutions in the following paragraphs.

When correlating social protection expenditures and unemployment rate with Gini Coefficient (see Annex), a substantial relationship is found, and, though less significantly, the two clusters examined above are appreciable too. The social protection expenditures variable can distort the results if the dimension of beneficiary population is not taken into consideration; then, the problem is treated using the relative social protection expenditure per unemployment rate. This new variable helps to analyze the direct impact of social protection in inequality, instead of the countries' spending effort.

The issue is that when interacting social protection expenditures and unemployment rate, clusters are even more evident in Graph 8. It is obvious that advanced (or Renan-type) countries don't form a well-defined cluster, and this is due to two main reasons: the existence of policy divergences between these countries regarding social protection, and the fact that United Kingdom is an outlier case.

Graph 8. Gini Coefficient and Social protection expenditures / unemployed population



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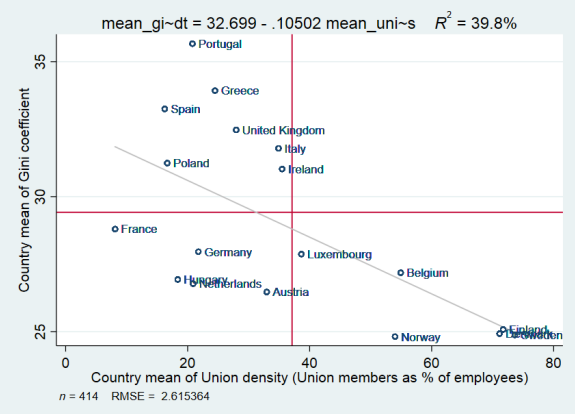
Union density vs Gini Coefficient in Graph 9 still display the less advanced plus Anglo-Saxon economies group and the Nordic but Norway group, but the continental or Renan economies exhibit divergences in Union density rates. In fact, the negative correlation displayed is caused by Nordic countries with very high union density and low inequality, versus Mediterranean countries (Spain, Portugal and Greece) with the opposite.

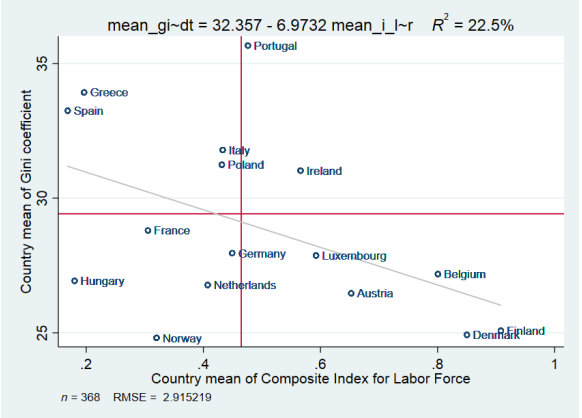
Graph 9. Gini Coefficient and Union Density



Sources: OECD, World Inequality Indicators. Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

When looking at collective bargaining power (see Annex) or labor composite index in Graph 10, no appreciable clusters are found, only a slightly negative correlation, due to Union density component:

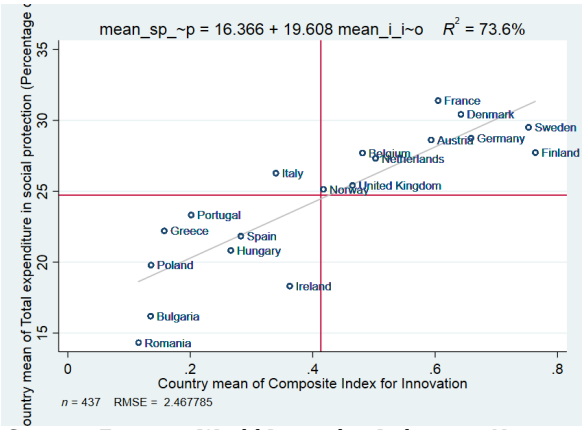
Graph 10. Gini Coefficient and Composite Index for Labor Force



Sources: OECD, World Inequality Indicators. Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

It seems that both innovation and social protection is a combination that allows us to define two clusters of countries. These two dimensions are correlated and the relationship can be seen in Graph 11:

Graph 11. Social protection expenditures and Composite Index for Innovation



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The correlation is high (74%) and positive. Countries that perform better in innovation variables spend more in social protection, and also have lower inequality rates as seen above. These are three nuances of progress, and seems reasonable to think that policies affecting one of them could have implications in the others; this question will be addressed in next section of this paper.

Although the two clusters are well defi-

ned, a couple of aspects should be mentioned. United Kingdom is part of the most advanced economies cluster because it has a good performance in innovation and it's slightly above the mean in social protection expenditures. Meanwhile, Italy is an outlier because, as it happens in other macroeconomic aspects, it is defined by some characteristics of a Mediterranean country, such as the case of innovation performance, and at the same time some characteristics of a Renan or continental country, as in the case of social protection expenditures.

6. Empirical Analysis and Discussion of Results

To analyze how the previously referred variables are related with inequality evolution in countries, panel regressions have been chosen. Different specifications are used to contrast the potential impact of the relationships under certain assumptions and these are explained below.

The empirical analysis is based country-level time series and cross section data with a sample of 20 European countries covering the period from 1995 to 2017.

A simple scan of the dataset indicates the presence of multiple missing data, in some cases randomly distributed while not in some others. The option of interpolation has been rejected to avoid an artificially narrowing process of standard errors.

In the baseline models the dependent variables in the different estimations are first, natural logarithms of Gini Coefficient after social transfers; second, S80/S20 Ratio; and third, Top 10 Income share. The independent variables are innovation institutions, social protection, labor market institutions and a vector of controls, including other determinants of inequality such as GDP per capita and Gross Fixed Capital Formation. Country fixed effects are included in order to capture country specific determinants.

The general equations for estimation purposes is presented below:

$$ln(gini\_dt)_{it} = \alpha_1 X_{it} + \beta_1 Y_{it} + \gamma_1 Z_{it} + \delta_1 S_{it} + \mu_{1i} + \epsilon_{it}$$

$$ln(s80s20)_{it} = \alpha_2 X_{it} + \beta_2 Y_{it} + \gamma_2 Z_{it} + \delta_2 S_{it} + \mu_{2i} + \epsilon_{it}$$

$$ln(Top10)_{it} = \alpha_3 X_{it} + \beta_3 Y_{it} + \gamma_3 Z_{it} + \delta_3 S_{it} + \mu_{3i} + \epsilon_{it}$$

where,

* i Denotes the country
* t Denotes the year
* X Denotes the innovation institutions variables
* Y Denotes the social protection variable
* Z Denotes the labor market institutions variables
* S Denotes the vector of control composed by other determinants of inequality
* μ Denotes the country fixed-effects.

With the aim of developing a rigorous econometric analysis, some of the best-known panel data tests have been performed.

First, a Hausman specification test is run to evaluate the consistency of a random-effects estimator versus a less efficient fixed effects estimator. It consists in the evaluation of the presence of unobserved heterogeneity, i.e. existence of correlation between the unique errors and the regressors in the model. The p-value of the test is less than 0.05, what means that the null hypothesis of random-effects consistency can be rejected and the presence of unobserved heterogeneity can be assumed.

Second, a Pesaran test is run to evaluate the consistency and if the fixed effects estimator is unbiased. It does so by evaluating the presence of cross sectional dependence in the errors. Pesaran test is selected because it's the most efficient test for unbalanced panel data in which the number of observations is bigger than the years (N>T) (De Hoyos & Sarafidis, 2006). The p-value of the test is less than 0.05, what means that the null hypothesis of cross-sectional errors independency can be rejected.

Third, a Wooldridge test is run to evaluate the presence of serial-correlation that could bias the standard errors and therefore cause the results to be less efficient. Wooldridge test is selected because it can be applied under general conditions and is easy to implement (Drukker, 2003). The p-value of the test is less than 0.05, what means that the null hypothesis of no serial-correlation in the idiosyncratic errors can be rejected.

Last but not least, a Breusch-Pagan and a White test are run to evaluate the presence of heteroscedasticity, i.e. variability of the variances of the standard errors. The p-values of the tests are both less than 0.05, what means the null hypothesis of homoscedasticity can be rejected.

Given the presence of correlation between the unique errors and the regressors, cross sectional dependence, serial-correlation and heteroscedasticity, and following the recommendations of Beck & Katz (1995), the estimator selected is the Ordinary Least Squares with Panel Corrected Standard Errors. The variables are used in natural logarithms in order to

estimate elasticities produced by the independent variables. The output of the estimation of the baseline model is presented in Table 1:

Table 1. Estimation results. Baseline model

	Ln(Gini coefficient)	Ln(S80/S20 ratio)	Ln(Top10 income)
Ln(GDP per capita)	0.040	0.116	0.065***
	(0.573)	-1.034	-3.622
Ln(GFCF)	-0.103	-0.222**	-0.048**
	(-1.585)	(-2.288)	(-2.338)
Ln(Economic Complexity Index)	0.005	-0.000	0.007
	(0.221)	(-0.004)	(0.736)
Ln(Patent applications)	-0.022	-0.065	-0.020*
	(-0.901)	(-1.502)	(-1.829)
Ln(R&D exp)	-0.159***	-0.219**	-0.031*
	(-3.038)	(-2.361)	(-1.752)
Ln(R&D personnel)	0.057	-0.011	0.012
	-1.346	(-0.131)	(0.826)
Ln(Broadband)	0.011**	0.018*	-0.003*
	-2.137	-1.782	(-1.916)
Ln(SP exp. per unemployed)	0.036	0.025	-0.007
	-1.008	(0.458)	(-0.899)
Ln(Union density)	0.110	0.164	-0.005
	-1.491	-1.401	(-0.217)
Ln(Right to bargain)	-0.137*	-0.264**	-0.046**
	(-1.928)	(-2.228)	(-2.522)
Constant	3.634***	2.052	2.507***
	-4.081	-1.491	-11.745
R-squared	0.997	0.974	0.999

* p<0.1, ** p<0.05, *** p<0.01

The estimates of the baseline model -Table 1- show that the natural logarithm of Research and Development expenditures as percentage of GDP, the natural logarithm of fixed broadband subscriptions per 100 people and the natural logarithm of the right to bargain as percentage of labor force result significant. The coefficients are consistent with the theory in the cases of R&D spending and Bargaining Power, but this is not the case for Broadband subscriptions, because it exhibits a positive correlation with Gini Coefficient, but negative with S80/S20 Ratio and Top 10 Income Share.

A 1% increase in R&D expenditures decreases inequality by 0.16%, 0.22% and 0.03% measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share, respectively.

A 1% decrease in the workers with the right to bargain increases inequality by 0.14%, 0.26% and 0.05% measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share respectively.

To study this phenomena more deeply, the next model alternatively uses the composite indexes presented above to estimate the correlation with inequality:

$$ln(gini\_dt)_{it} = \alpha_4 X_{it} + \beta_4 Y_{it} + \gamma_4 Z_{it} + \delta_4 S_{it} + \mu_{4i} + \epsilon_{it}$$

$$ln(s80s20)_{it} = \alpha_5 X_{it} + \beta_5 Y_{it} + \gamma_5 Z_{it} + \delta_5 S_{it} + \mu_{5i} + \epsilon_{it}$$

$$ln(Top10)_{it} = \alpha_6 X_{it} + \beta_6 Y_{it} + \gamma_6 Z_{it} + \delta_6 S_{it} + \mu_{6i} + \epsilon_{it}$$

where,

* i Denotes the country
* t Denotes the year
* X Denotes the Innovation Index
* Y Denotes the social protection variable
* Z Denotes the Labor Index
* S Denotes the vector of control composed by other determinants of inequality
* μ Denotes the country fixed-effects.

The output of the estimation of the Indexes model is presented in table 2:

Table 2. Estimation results. Composite Indexes TSCS model

	Ln(Gini coefficient)	Ln (S80/ S20 ratio)	Ln(Top10 income)
Ln(GDP per capita)	0.050	0.106	0.040**
	(0.781)	(0.929)	-2.509
Ln(GFCF)	-0.119**	-0.248**	-0.032*
	(-1.998)	(-2.553)	(-1.648)
Ln(Innovation Index)	-0.068*	-0.173***	-0.035***
	(-1.840)	(-2.729)	(-3.385)
Ln(SP exp. per unemployed)	0.030	0.003	-0.013
	(0.852)	(0.049)	(-1.383)
Ln (Labor Force Index)	-0.095	-0.200*	-0.045***
	(-1.538)	(-1.958)	(-2.862)
Constant	3.027***	0.897	2.318***
	-4.424	(0.761)	-14.702
R-squared	0.998	0.974	0.999

* p<0.1, ** p<0.05, *** p<0.01

Regarding the results of estimation of this model, in Table 2, it is noticeable that the estimated coefficient of one of the control variables, Gross Fixed Capital Formation, is significant and relatively high. One possible explanation is that less advanced countries are those that are reducing inequality and in the process of catching-up a set of variables show a positive evolution. One of them is the reduction of inequality and another one is investment since this can be understood as one basic aspect for technological change. Innovation Composite Index is also significant, what is coherent with the theory. Meanwhile, social protection expenditures per unemployment rate doesn't result significant, neither does Labor Composite Index in the estimation of the Gini Coefficient.

A 1% increase in Gross Fixed Capital Formation decreases inequality by 0.12%, 0.25% and 0.03% measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share respectively.

A 1% increase in the Innovation Composite Index decreases inequality by 0.07%, 0.17% and 0.04% measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share respectively.

A 1% decrease in the Labor Composite Index increases inequality by 0.20% and 0.05% measured by S80/S20 Ratio and Top 10 Income Share respectively.

These results provide some evidence of the theoretical argument stated above. Nonetheless, another approach is being taken because as it was seen in the correlation graphs, it seems to be the existence of two clusters of countries, an aspect that depends on the country structural characteristics and that may serve as a plausible explanation for the differences found in the estimations.

If this is the case, it is adequate to use a Between-country effects estimator that would fit better the model; the results are then presented in Table 3.

Table 3. Estimation results. Composite Indexes Between Countries model

	Ln(Gini coefficient)	Ln(S80/S20 ratio)	Ln(Top10 income)
Ln(GDP per capita)	0.126*	0.204	0.043*
	-2.208	-1.831	-1.871
Ln(GFCF)	-0.094	-0.212	0.017
	(-0.667)	(-0.761)	(0.295)
Ln(Innovation Index)	-0.135*	-0.254*	-0.059**
	(-2.170)	(-2.196)	(-2.447)
Ln(SP exp. per unemployed)	-0.170**	-0.257**	-0.061**
	(-3.110)	(-2.429)	(-2.791)
Ln(Right to bargain)	0.092**	0.108	0.021
	-2.600	-1.564	-1.507
Ln(Union density)	-0.052	-0.058	-0.006
	(-1.642)	(-0.923)	(-0.502)
Constant	2.238**	-0.118	2.131***
	-2.795	(-0.076)	-6.682
R-squared	0.864	0.813	0.835

* p<0.1, ** p<0.05, *** p<0.01

In this model, the Innovation Composite Index results significant, and so does the social spending per unemployed rate. Labor market institutions do not result significant (and neither does Labor Composite Index).

In particular, a 1% difference between countries in the Innovation Composite Index means a 0.14%, 0.25% and 0.06% lower inequality measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share respectively.

Meanwhile, a 1% difference between countries in social expenditures per unemployment rate means a 0.17%, 0.26% and 0.06% lower inequality measured by Gini Coefficient, S80/S20 Ratio and Top 10 Income Share respectively.

7. Conclusions

The study of the relationship between several measures of inequality and innovation, is extended in this paper including the relevant role of institutions. This contributes to analyze the existence of different clusters of countries according to "continental-Renan" style and "peripheral-Anglo Saxon" style. The first cluster is integrated by countries that exhibit ample social protection systems, as well as strong innovation institutions and low rates of inequality. The opposite happens to the other cluster of less advanced economies, those which have a relatively narrower social protection system, weaker innovation institutions and higher rates of inequality.

The fact is that the cluster composed by the relatively more advanced economies (continental-Renan type) has experienced a higher rise in inequality than the other, this composed by the relatively less advanced economies (peripheral-Anglo Saxon type) and where the initial rates of inequality were much lower than in the first group. However, both clusters have some peculiarities:

- The more advanced economies include the Nordic countries and this is a special group because of their initial inequality rates, which were (and still are) the lowest in the world. Among them, there are some remarkable common facts observed such as very high GDP per capita, strong innovation institutions, high Union density rates and collective bargaining coverage, also combined with relatively high social protection per unemployed population expenditures. The same cluster also includes the Renan-type economies, countries with higher but still low initial rates of inequality that have not raised much, and even in some cases they have actually decreased. Nonetheless, they form a very well-defined cluster in some aspects such as high GDP per capita, strong innovation institutions or very high social protection expenditures but they show relative differences regarding labor force institutions.
- The cluster that is integrated by less advanced economies include two Anglo-Saxon countries, Ireland and United Kingdom. They behave as less advanced economies regarding inequality rates, patents and Union density, but display frontier-effects or outliers regarding other innovation institutions, as well as social protection expenditures, collective bargaining coverage and GDP per capita. Moreover, their inequality rates have not risen in the studied period. This cluster also includes the peripheral-type countries. These countries exhibit high inequality rates (except Hungary) and behave as a well-defined cluster in each indicator with the exception of collective bargaining coverage. Inequality has not increased in these countries (except Bulgaria) in the entire period, but two trends are appreciated: On the one hand, before the financial crisis, inequality rates were decreasing at a substantial path, and after it stroke Europe, the trend has reversed and inequality has risen ever since. On the other, these countries have weak innovation institutions, as well as low Union density rates and low social protection expenditures per unemployed population.

To be able to elaborate a set of policy recommendations it's important to focus both on the exploratory analysis on the real cases studied and on the results of econometric analysis. Time series-cross section analysis, combined with between countries effects analysis, allows us to better understand the phenomena studied; the fact is that while some variables affect just one country's evolution others explain differences between countries. At the same time, the composition of indexes facilitates the interpretation of the phenomena as wholes.

Our findings confirm the existence of a strong negative relationship between innovation institutions and inequality, regardless of the indicator employed or the development grade of the country analyzed. This relationship seems to be present both inter and intra countries, what means that the nature of the innovation institutions can be used to explain different growth rates of inequality between countries and also the evolution of an individual country's inequality path. This is a contribution to the existing literature, because this relationship has not been yet profoundly analyzed.

Innovation institutions and inequality define the broader gap between the two clusters of countries, and this finding may be useful to definitely orientate economic policies of a particular country to reduce its inequality levels. Investment in innovation institutions can reduce or at least slow down the growth of inequality rate both in the mid and in the long run. However, less advanced economies should not cease to invest in gross fixed capital since it is necessary

for succeeding in the catching up process and this also has significant effects on the reduction of inequality.

Social protection systems explain differences in inequality rates between countries, as they usually are related to the country's structural institutions. Hence, the more advanced economies, which are less unequal, tend to exhibit higher social protection expenditures.

In addition, countries spending more on social protection have held back the increase in inequality, as can be observed when looking at the gap between Gini Coefficient before and after social transfers. Individual country's average expenditures do not predict the evolution of its rise in inequality in the period studied. This way, we can conclude that the increase in social protection expenditures is necessary to press back the devastating effects of crisis in inequality, and maintaining a high level of expenditures is the base for an ample Welfare state. Nonetheless, it remains indispensable to keep a sustained level of investments in order to walk towards a more equal country.

It's also important to remark that labor market institutions relate to the evolution of the inequality rates intra-country, but not between countries. This is mostly due to the presence of Nordic countries in the sample, which have reduced significantly their Union density starting from very high rates, at the same time that they have experienced a rise of inequality though remaining at low rates. Hence, no conclusive economic policy prescription regarding labor market institutions can be made from our analysis.

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9. Annex

Graph 12. Gini Coefficient before and after social transfers and Composite Index for Innovation

Sources: Eurostat, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

Graph 13. Gini Coefficient before and after social transfers and Social protection expenditures per unemployed population

Sources: Eurostat, World Inequality Indicators

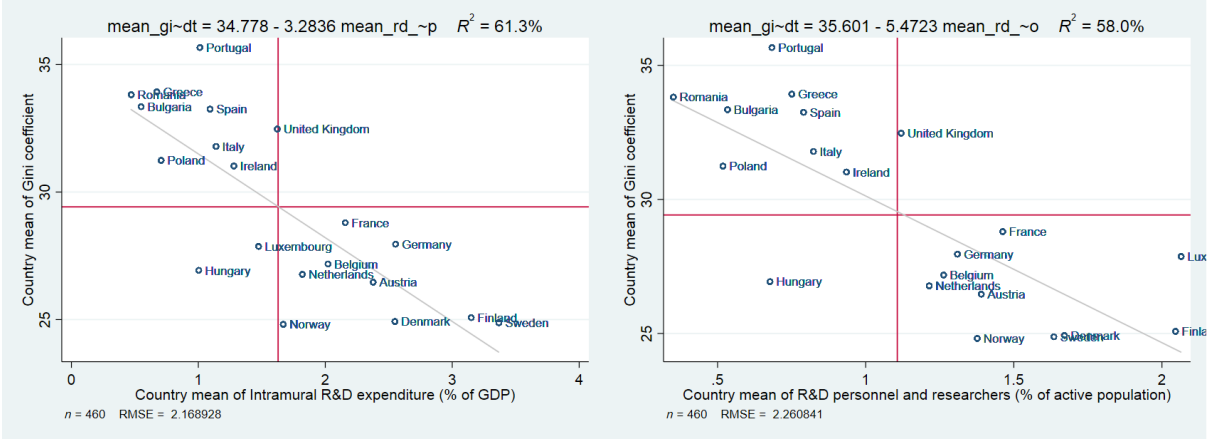
Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

Graph 14. Gini Coefficient before and after social transfers and Composite Index for Labor Force

Sources: Eurostat, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

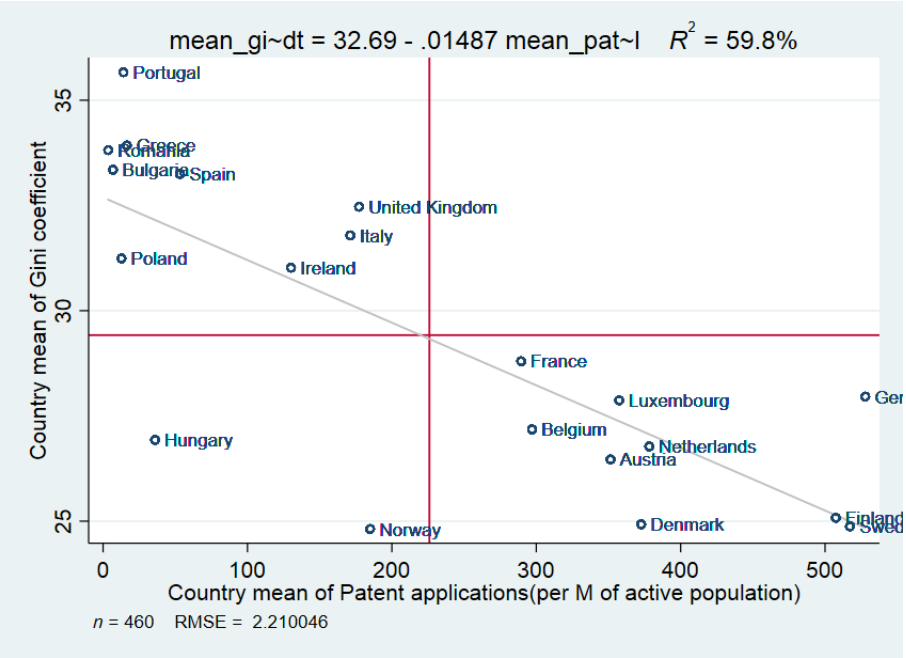
Graph 15. Gini Coefficient and R%D expenditures and personnel



Sources: Eurostat, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

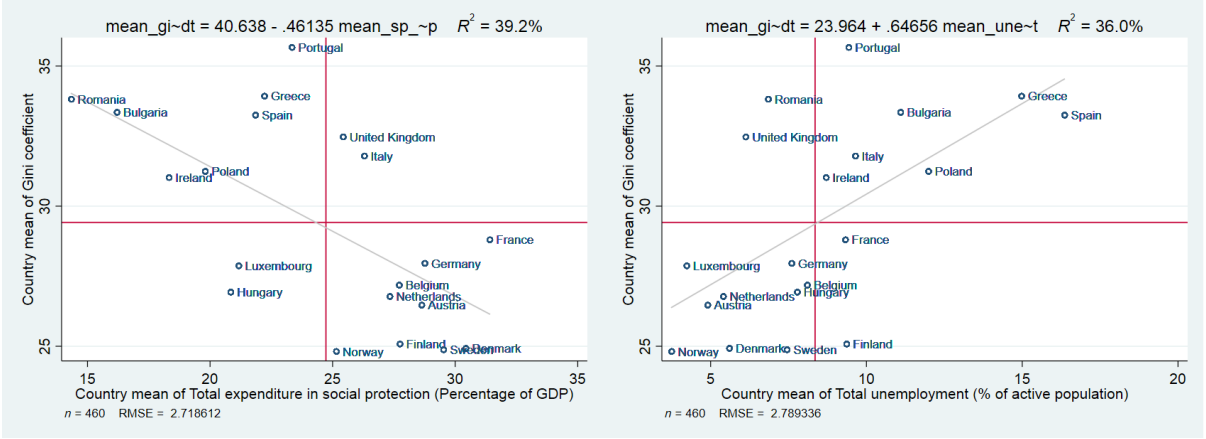
Graph 16. Gini Coefficient and patent applications at EPO per million of active population



Sources: Eurostat, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

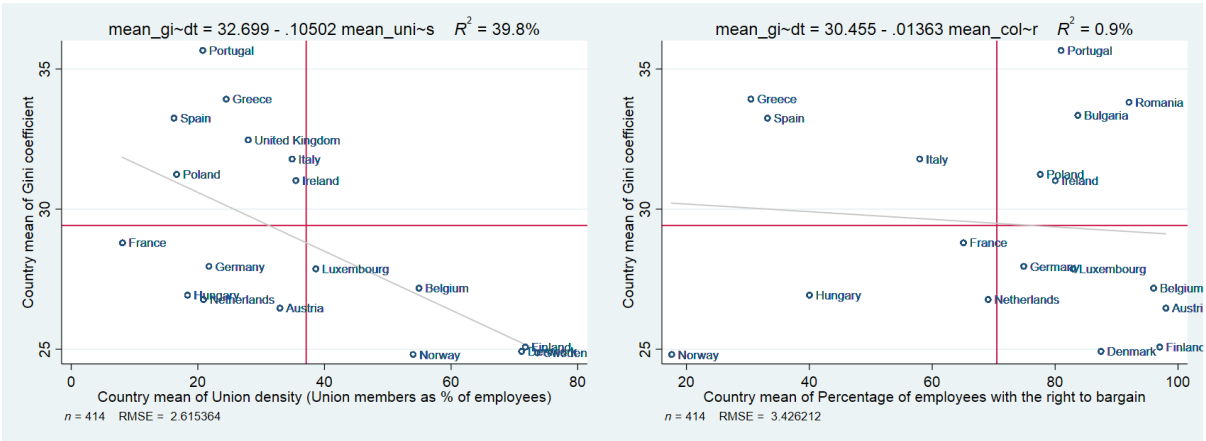
Graph 17. Gini Coefficient and Social protection expenditures and total unemployment



Sources: Eurostat, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

Graph 18. Gini Coefficient and Union Density and Bargaining power



Sources: OECD, World Inequality Indicators

Note: Economies included: Austria, Belgium, Bulgaria, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden and United Kingdom

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