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Economic complexity, Environmental Quality and Income Equality: A New Trilemma for Regions?

Rocío Marco

Departamento de Economía Aplicada. Facultad de Ciencias
Económicas y Empresariales. Universidad Autónoma de Madrid.
Email: rocio.marco@uam.es

Carlos Llano-Verduras

Departamento de Análisis Económico: Teoría Económica e Historia
Económica. Universidad Autónoma de Madrid; CEPREDE and L. R.
Klein Institute. Email: carlos.llano@uam.es

Santiago Pérez-Balsalobre

Departamento de Economía Aplicada. Facultad de Ciencias
Económicas y Empresariales. Universidad Autónoma de Madrid;
CEPREDE and L. R. Klein Institute. Email: santiago.perez@uam.es

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Abstract

The objective of this paper is to link the literatures on economic complexity, income equality and environmental quality within the context of the Environmental Kuznets Trilemma. Within this framework, it is possible to measure the presence of an impossible trinity of irreconcilable objectives: economic growth, equal distribution of income and environmental sustainability. Our paper revisits this trilemma by focusing on economic complexity (EC) indexes instead of direct measures of economic growth, and applies this analysis to the sub-national level. We link these three cutting-edge topics by means of novel datasets computed for the Spanish economy at the province level (NUTS-3) for a long period (2002–16). Our paper also sheds new light on the spatial patterns of the trilemma's three dimensions and their implications for the future of Spain's more peripheral regions.

Key Words: Economic complexity; international trade; inter-regional trade; Spain; environmental sustainability; inequality; environmental Kuznets curve.

JEL: R11, D83, O47; F18; F43; F63;

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1. Introduction

Every policymaker would love to raise income per capita while reducing inequality and ensuring the territory's environmental sustainability. Unfortunately, the literature offers plentiful evidence that it is foolhardy to pursue all these objectives simultaneously. Trade-offs definitely arise at the national level. The question is, do they arise within a country's individual regions?

The environmental Kuznets curve (EKC) explains the relation between income level, income inequality and environmental degradation (Grunelwald et al., 2017; Caviglia-Harris et al., 2009; Acemoglu & Robinson, 2002; Heerink et al., 2001).

Within this framework, the objective of this paper is to link the literature on the EKC with the literature on economic complexity (Hausmann & Hidalgo, 2009, 2011; Hausmann et al., 2007; Hartman et al., 2017), income inequality (Piketty & Saez, 2003) and environmental sustainability (Cristea et al., 2013; Cherniwchan et al., 2017; Copeland et al., 2004) and then to establish the existence of an *impossible trinity* of three desirable but irreconcilable goals, in keeping with the specifications of Aizenman et al. (2013).

Thus the contributions of our paper are twofold: first, we revisit the ECK literature, focusing on *economic complexity* (EC) indexes instead of direct measures of economic growth; and second, we narrow our analysis to the sub-national level within a country (Spain), considering very new datasets on international and interregional flows of goods. To the best of our knowledge, this is the first paper to cover this ground.

There is a strong link between the promising literature on EC and the economic growth of countries and regions in the long run. Hausmann & Hidalgo (2009, 2011, 2013) have defined EC as a measure of non-observable capabilities embedded in production. Based on the concept of *revealed comparative advantage*, the complexity indicators capture both the diversification of a country's production and the ubiquity of the products in which the country specializes. The authors also provide evidence that EC indicators perform very well as long-term determinants of national economic growth.

Typically, EC indexes are estimated at the country level from inter-national exports, with little attention paid to regions within countries and their inter-regional trade.

Perez-Balsalobre et al. (2019) have recently developed a new dataset estimating EC indicators for 50 Spanish provinces (NUTS-3) for the period 1995–2016. They use international as well as intra-national flows, showing that these indicators outperform classical factors in explaining

regional long-term growth. They also establish that EC indicators estimated for Spanish provinces from international trade flows are higher than those obtained for their intra-national trade deliveries. The outcome points to that products exported by regions outside national borders are generally more *complex* than those traded domestically. In a related paper, Pérez-Balsalobre (2020) shows that EC is affected by gravity at the regional level, and that products of high complexity can travel longer distances than those of low complexity.

With regard to greenhouse gas (GHG) emissions, we use the rich information developed in the context of the official Spanish Emissions Inventory System of the Ministry of Ecological Transition. This GHG emissions accounting system provides information at the NUTS-2 level of territorial disaggregation, perfectly compatible with the exhaustive accounting for the whole country split by sectors and sources of emissions. The latter follows a standard international methodology — as reported in the IPCC and EMEP / EEA Guides — to estimate emissions by type of gas within each sector of economic activity. This information is available for the period 1990-2019.

As for inequality, there is a lack of homogenous indicators at provincial level over time. To fill this gap, we derive a novel dataset of inequality indicators for the Spanish provinces over the period 2002–16. Specifically, we compute one of the most widely applied metrics, the Gini index (Gini, 1912), for the distribution of before-tax and after-tax personal income at NUTS-3 level. The samples of personal income tax microdata are provided by the Spanish Tax Administration Office. The income database covers the period 2002–16 and the 46 provinces of the common tax territory.

Once these three pieces of new datasets are built, we test for the presence of a trilemma. As we have said, the ultimate goal is to measure the extent to which regions within countries face a new *impossible trinity*: increasing EC indexes through greater openness to international trade; 2) improving environmental quality by reducing the GHG emissions of transport; 3) increasing intra-national equality by compensating for the uneven distribution of income usually associated with higher levels of openness and growth.

Before starting with the body of the paper, we should explain our use of NUTS-3 as the spatial level of analysis. Our analysis sought simply to delve more deeply into the available literature, beyond the standard NUTS-2 level.

For some of the topics considered here (e.g. territorial policy and sustainability) the main political decisions are taken at the European and national level. Spain, however, is a highly

decentralized country, so most of its policies require the collaboration of administrations at a regional (NUTS-2) or even lower spatial level. The bulk of the economic activity and pollution centers on the main metropolitan areas, precisely where the NUTS-3 level captures the best data. Moreover, in Spain, and in most EU countries, the NUTS-3 level is a more homogeneous spatial unit than NUTS-2, and it is more directly associated with the spatial level at which core-periphery structures arise.

In addition, there is a current debate in Spain over the “España vaciada”: that is, peripheral provinces that come in for neglect precisely because the spatial unit of reference is usually NUTS-2, a scale at which certain territorial inequalities are blurred. This is a statistical effect of mixing the capital cities (regional cores) with the most peripheral territories (rural provinces) of the same region. Therefore, although the main decisions about cohesion, sustainability, competitiveness and inequality are taken at the European, national and regional (NUTS-2) level, there is rising awareness of how important it is to consider lower spatial levels in the analysis whenever the data allows.

The structure of the rest of the paper is as follows: Section 2 provides a detailed background of the four literatures interconnected in this paper, defining the expected relations of the variables mixed in the trilemma; Section 3 and 4 explain the construction of the datasets and the methodology, respectively; Section 5 provides an exploratory descriptive analysis of the temporal and spatial dimension of the three indicators; Section 6 provides the results for the econometric analysis; a final section concludes.

2. Background

This paper seeks to interconnect four literatures: i) that of the topics in the trilemma; ii) that of the measurement of economic complexity linked to trade; iii) that of the quantification of income inequality within a country and its regions; iv) that of the quantification of a territory’s environmental sustainability, with a focus on emissions generated by the intra-national and inter-national trade of goods entering/leaving each province. More briefly, it will also review the literature supporting the method we use to test for the existence of a trilemma, which relies on open macroeconomics.

The literature analyzing the link between *economic complexity* and *income equality* is scarce.

Hartman et al. (2017) recently published an innovative paper that relates EC to inequality at the country level. Their analysis combines multivariate analysis, panel data econometrics and

network analysis, finding that countries with more complex exports enjoy lower levels of income inequality than those exporting simpler products. Their results suggest that economic complexity is a significant and negative predictor of income inequality. One possible mechanism to produce this result, they suggest, involves the quality of institutions in the corresponding country. Complex industrial products usually require more *tacit knowledge* and *distributed knowledge* than less complex products, which are based mainly on factor endowments (natural resources or low labor costs). Increased tacit and distributed knowledge can incentivize workers to unionize and help them negotiate high wages, thereby compressing wage inequality. These results show that economic complexity can help explain how a given economy generates and distributes income. They also suggest that a country's productive structure may limit its range of income inequality. The authors analyze 150 countries over a long period, from 1963 to 2008.

That paper sets the baseline for the discussion, but its results derive from an analysis that compresses a wide variety of countries, whose institutions vary considerably in quality. What if we were to limit, say, the range of complexity, or the quality of institutions, focusing instead on trade between the provinces of a given country (Spain). Here the quality of institutions might not be critical, as every province in Spain must deal with (almost) the same regulations and distribution mechanisms, such as unions or public transfers. Moreover, in this new more homogenous setup, the relationship between complexity and income inequality can shift—as the most complex provinces are associated with the richest and most productive provinces, where income inequality within is larger than in other, less-developed regions. Furthermore, the positive relationship found by Hartman et al. (2017) can vary also when measured within a country as a consequence of two additional strong mechanisms: i) higher labour mobility within countries can moderate income inequality within countries, since people *vote with their feet*, migrating from less complex regions to more complex ones, following the patterns predicted by a core-periphery model combining mobility of goods, capital and labour (Fujita et al., 2001); ii) moreover, the relationship observed between countries can be more diffuse within a country, as there are stronger mechanisms of public transfer within a country than between countries. In this regard, it is critical to differentiate between income inequality before and after public intervention.

That said, the literature on complexity at the regional level is scarce. One of the rare papers, Balland and Rigby (2017), offers an analysis of subnational EC indicators for the United States (US). They address the allocation and diffusion of knowledge complexity of US cities using an

extensive patent database from the US Patent and Trademark Office. Through a city-tech knowledge network, they found that complexity is unevenly distributed across cities.

Similarly, Balland et al. (2019) develop a framework to identify systematically technological opportunities in regions within the EU. Their analysis is based on the OECD-REGPAT database to detect the differences across technological sectors and compute measures of relatedness and complexity. It focuses patent applications for the period 1977–2011 regionalized at the NUTS-2 level by inventor address in the EU-28 plus Iceland, Norway and Switzerland. Their analysis corroborates the intuition that high-complexity regions are also the richest and most open regions, paying the highest wages and presenting the greatest income inequalities.

In principle, highly complex products combine highly skilled labour, found predominantly in the richest regions, with high salaries. Thus, despite the positive relationship between complexity and income equality across countries (Hartman et al., 2017), a negative relationship can exist within a country. As for the dynamics, we also expect regions that increase in complexity will introduce income inequalities.

To the best of our knowledge, there is no previous analysis linking *economic complexity* to *environmental quality*, whether at the national or the regional level. However, the literature on the tension between economic growth and GHG emissions is abundant, with great contributions in recent years. More specifically, given the focus of our analysis on the *trade dimension*, we now revisit some recent papers considering emissions linked to both international and intra-national flows for a given country, or a large sample of them (Alola, 2019; Wang et al., 2019; Yang et al., 2019; Cristea et al., 2013).

Yang et al. (2019) analyze the environmental implications of inter-national and inter-regional trade in China, considering the production and consumption side of the issue, and measuring the potential effect on emissions in a hypothetical no-trade scenario. Their paper manages to isolate the respective emissions burdens of 30 regions in the country, with production allocated as if all flows were provided within each region: that is, in a hypothetical scenario where all inter-regional and inter-national trade is replaced by local production-consumption.

In connection with the previous analysis, Cristea et al. (2013) study the GHG emissions associated with international trade, using origin-destination flows for the whole world. These authors collect data by transport mode and use it to provide detailed comparisons of output-associated GHG emissions against GHG emissions for the international transport of traded goods. According to their analysis, “*international transport is responsible for 33% of world-*

wide trade-related emissions and over 75% of emissions for major manufacturing categories". For the goods internationally exported, their approach allows to compute separately the emissions associated with their production and the emissions derived from their transportation. They conclude that the inclusion of transport radically modifies the ranking of countries by emissions per dollar of trade. They go on to investigate whether including transport trade is crucial to decrease emissions, and how trade patterns may affect global transport emissions. However, a limitation of their research is not to consider domestic freight flows, which represent a large contribution to economic activity in most countries.

Somewhere in between these two approaches, Llano et al. (2018) estimate a database of GHG emissions for inter-regional freight flows for the Spanish regions. The database considers origin-destination flows between Spanish regions at NUTS-3 level from 1995 to 2015, combining sector-specific flows by four transport modes (road, rail, ship and aircraft) with the corresponding GHG emissions factor for each mode, in *tons×km*. With this dataset of GHG emissions, they generate and analyze the temporal, sectoral and spatial pattern of Spanish inter-regional GHG flows, discussing alternative scenarios for the period 2016–30, and suggesting how emissions can be moderated by promoting the substitution of highly polluting flows made by road to more environmentally sustainable alternatives, like railway.

These previous findings suggest that the production of highly complex products usually requires the incorporation of knowledge, sophisticated inputs and value added (high-tech intermediate goods and business services). These are usually associated with highly productive regions but not necessarily with industries that generate relatively high amounts of pollution (oil refining, mining, electric-power generation, etc.). Thus, regions with a smart combination of qualified inputs and high-tech industries will achieve the highest values of complexity. These regions, that might have hollowed-out the dirtiest stages of the production-chains, have swapped production for imports of parts and components sourced in other regions or countries. Typical examples of this are Madrid and Barcelona, which have gradually shifted their heaviest industries to the outskirts or surrounding provinces (Toledo, Guadalajara, Tarragona, etc.). Our measure of economic complexity is limited in this regard, as it excludes the emissions and complexity of production and the trade of services, which can change the relationship.

In trade (freight movements) the relationship between complexity and emissions within a country's provinces is less clear. On the one hand, we expect there to be a positive relation, since highly complex provinces are associated with high income and economic growth. On the other, the positive relationship between complexity and high levels of emissions gets fuzzy as

soon as we consider the transport mix typically used in each type of delivery (long vs. short distance). We have evidence that products of low complexity travel the shortest distances. Two facts support that: i) products of low complexity are highly ubiquitous and require less-exclusive knowledge or skill; ii) products of low complexity are associated with less-productive, less-innovative and less-internationalized firms, which are less likely to survive in a country's core provinces. Conversely, highly complex products travel long distances and can reach farther and more-competitive destinations (within the country and abroad). Rail and ship, moreover, are the cleanest transport modes, while aircraft and road are the dirtiest. Except when dispatched by aircraft, highly complex products can end up using low-pollution transport despite their association with long distances. Meanwhile, the contribution of interregional trade within the country will depend on railway's share in total transport. This is conditioned in part by geography (the size of the country, the presence of islands and remote locations, orography and altitude) and the quality of the competing infrastructures available. Finally, to show the difficult prediction of the sign of this relationship, it is also helpful to consider that complex products can be associated with modern types of consumption and logistics (e-commerce, just-in-time, etc.), which depend almost entirely on the fastest, most-polluting transport modes (trucks and aircraft).

Given all the previous comments, we expect to find a negative but less clear relationship between complexity and environmental quality. This negative relationship should vary across regions by geographical characteristics and sectoral and transport-mode specialization. In terms of evolution, we also expect that increasing the level of complexity will expand a region's share of international trade relative to intra-national trade. The expansion can boost emissions if it concentrates over the shortest distance (Europe) and uses highly polluting transport-modes (road).

Finally, we revisit the literature on the nexus between *income equality* and *environmental quality*.

Grunewald et al. (2017) investigate the trade-off between income inequality and pollution emissions using a larger panel of 158 countries, and longer time period (1980–2008), than previous investigations. Specifically, they examine the theoretically ambiguous link between income inequality and per-capita carbon dioxide emissions, and find that the relationship depends on the level of income. They found a negative relationship between income inequality and emissions for low- and middle-income economies. However, for wealthier countries, inequality is positively associated to per-capita emissions.

Similarly, Hübler (2017) analyzes the positive and concave relationship between households' attributed emissions and income level, finding a negative relationship between emissions and within-country inequality. To test this relationship, the research uses simultaneous quantile regressions with per-capita CO₂ emissions as the dependent variable and draws on country-level panel data (150 countries for the period 1985–2012). The results vary across quantiles. Regressions with pooled data support the negative inequality-emissions link, while fixed-effects estimations call it into question. The paper also finds positive relationships between 'international trade' and 'international investments' with emissions, something that seems reasonable at the country level.

To judge by this previous paper, the relationship between income equality and environmental quality can be either positive or negative, depending on different sub-samples of provinces within a country and their predominant sectoral specialization (heavy industries vs. high-tech and services).

From these considerations, we expect to find empirical evidence of the existence of the *equality-sustainability-complexity* trilemma at the regional level. The trilemma notion can be illustrated with a triangle (Figure 1). The corners represent peak levels of economic complexity, environmental quality and income equality. Standing on any side of the triangle amounts to fully achieving two of the three objectives (the two corners of the side). Hence, it is impossible to achieve the three aims fully. Inner points represent trilemma combinations in which each policy goal is neither fully reached nor neglected. Points closer to a corner or side represent moves away from the others. In other words, the trilemma constraint is a matter of trade-offs between trilemma goals.

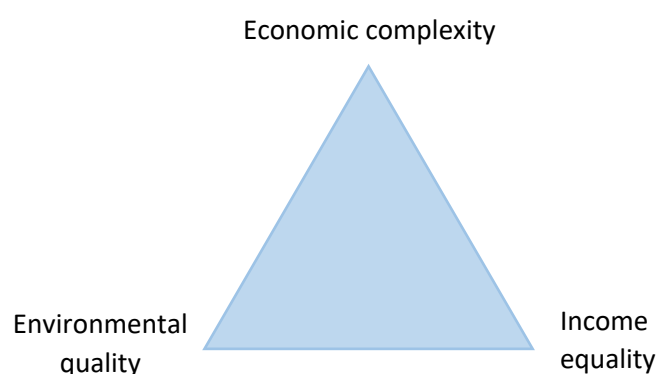


Figure 1: Trilemma representation

Spain will be our laboratory for this first empirical investigation, and we will test the verification of the trade-offs that appear when policymakers opt for two of the three options. Methodologically, we follow Aizenman et al. (2013) that have developed a clever strategy with which to detect an *impossible trinity*. As we will see in the next section, we will end up considering a ‘quadrilemma specification’, as the indicators related to complexity and economic growth complement each other.

3. Data

We should state at the outset that none of the three datasets needed for the empirical analysis described are available in Spain or in any other country of our context. Most countries do not collect detailed information at the sub-national level (NUTS-3) with which to estimate economic complexity (requires detailed internal and external trade), income equality (requires personal income data for each region) or GHG emissions. We will therefore resort to three novel and powerful datasets that we have either developed for this paper (income inequality and total GHG emissions) or published elsewhere.

3.1. Complexity Index

This section relies on Perez-Balsalobre et al. (2019), who developed a new dataset estimating EC indicators for 50 Spanish provinces (NUTS-3 level)¹ with a 29-sector disaggregation for the period 1995–2016, using international as well as intra-national flows. In line with previous research (Reynolds et al., 2017; Gao and Zhou, 2018), Perez-Balsalobre et al. (2019) provide a methodology for the elaboration of sub-national complexity indicators. However, this study represents the first attempt to compute a complexity index at the sub-national level considering both its international and its domestic trade dimensions.

The estimation process uses as a starting point the product complexity index provided by the *Atlas of Economic Complexity* (2013), for detailed product categories (HS 6 digits) and for each country in the world. The product complexity indexes determine the level of complexity of each product traded in Spain, considering both the province-product specific flow with both each

¹ The proximity of the provinces (NUTS-3) to the real production locations makes them the best territorial representation for the economic complexity framework. Furthermore, their size and geographical characteristics makes them more comparable than the NUTS-2 regions. Additionally, NUTS-3 are the closest comparable spatial units with urban areas, for which there is no trade data available.

country and every other province within Spain. The international trade flows data come from the official Border Custom database and provide a huge level of product disaggregation. For the intra-national trade flows, we use a unique database of domestic flows for Spain that allows us to categorize domestic flows into inter-regional and intra-regional bilateral flows. This database was compiled and processed using the methodology explained in Llano et al. (2010) and published within the framework of the C-intereg project (www.c-intereg.es). The database covers bilateral trade and freight flows at the provincial level (NUTS-3) with a breakdown of 29 sectors and four modes of transport (road, rail, ship and plane). There is no alternative equivalent database for Spain. The source of the intra-national flows data is a set of official statistics that collect origin-destination transport by road (Permanent Survey on Road Transport of Goods, by the Ministerio de Fomento), railway (Complete Wagon and Containers flows, RENFE), ship (Spanish Ports Statistics, Puertos del Estado) and aircraft (O/D Matrices of Domestic Flows of Goods by Airport of Origin and Destination, AENA). In addition, the dataset removes hidden re-export structures in domestic freight flows, avoiding the double counting of transit flows.

3.2. Greenhouse gas emissions

The Spanish Emissions Inventory System of the Ministry of Ecological Transition offers information on the GHG emissions of NUTS-2 Spanish regions. This database covers a historical series from 1990 to 2019. The GHG emissions data by region are a disaggregation of the official emissions data at the national level, which covers all dimensions of the economy, including production of goods and services, and the transportation activities related to the movement of goods and people.

According to its methodological note, the official database treats individually the emitting sources that, by the size of their activity and the characterisation of their processes, are the most relevant to the estimation of priority pollutants. For example, when possible, emissions are located geographically by the log-lat coordinates of the economic activity that generates them. This “bottom-up” approach is applicable only when there is information at the most disaggregated spatial levels. By contrast, for activities or issuers for which no geographical information is available, the database uses a “top-down” approach, with territorial disaggregation by the best primary data available.

Taking the official estimates as given, our main contribution is to downscale the dataset from NUTS-2 to NUTS-3, the level at which the rest of the analysis is conducted. We accomplish the territorial disaggregation by using regional GDPs, as shown in the following equation:

$$GHG_{it} = GHG_{It} * \left(GDP_{it} / GDP_{It} \right) \quad (1)$$

where GHG_{it} refers to the GHG emissions of province i (NUTS-3) in year t , and GHG_{It} refers to the GHG emissions of the NUTS-2 region I to which the province belongs. GDP_{it} and GDP_{It} refer to the GDP of the corresponding province (NUTS-3) and region (NUTS-2) in year t . Note that our use of GDP is coherent with the top-down approach used in the original GHG dataset.

3.3. Income Inequality

Several variables have traditionally been used to characterize and measure economic inequality using individual databases. Most of them are related to income. A common option is household income per consumption unit. This variable is framed in the European Union Statistics on Income and Living Conditions dataset (EU-SILC), and therefore allows researchers to get homogenous socioeconomic indicators between and within European countries and regions. In the best case, depending on the country, spatial disaggregation within countries corresponds to NUTS-2 regions. This is the case for Spain: the lack of sample representativeness at the NUTS-3 territorial level makes it impossible to compute provincial indicators with this source.

To overcome the scarcity of inequality metrics at the sub-national level, other authors (Piketty and Saez, 2003; Atkinson, Piketty and Saez, 2011; Onrubia and Picos, 2013; Hortas-Rico and Rios, 2019) have used personal income tax data as a proxy for inequality. The Spanish Tax Administration Office (*Agencia Estatal de Administración Tributaria, AEAT*) and the Institute of Fiscal Studies (*Instituto de Estudios Fiscales, IEF*) provide a yearly sample of microdata corresponding to personal income tax returns and to individuals not obligated to declare.² The samples are representative at the provincial level, covering the period 2002–16, with large samples sizes (from 1 million in 2002 to 2.7 million in 2016). Geographically, they cover the 46 provinces belonging to the common tax regime territory. Unfortunately, the Comunidad Foral de Navarra and the País Vasco are not included in the study, because they have their own tax regime and do not provide access to their income tax data.

² *Muestra IRPF IEF-AEAT (Declarantes)* and *Muestra IRPF IEF-AEAT (No Declarantes)*, years 2002 to 2016.

Using income tax microdata has several advantages. First, it allows us to compute homogeneous inequality indicators across time and spatial sections.³ Second, the richness of the microdata allows us to compute income inequality indicators before and after tax. We apply the Gini index (Gini, 1912), one of the most popular measures of income inequality. Specifically, we compute the *before-tax Gini index* on total income received by individuals, and the *after-tax Gini index* on personal income after tax, subsidies and deductions (e.g., unemployment or maternity benefits). We differentiate between before- and after-tax income inequality, since public intervention generally leads to lower after-tax indexes. However, because the redistribution policy is applied equally on the common tax regime territory, and the autonomous communities have comparatively little room to manoeuvre, we expect a large correlation between before- and after-tax inequality measures in the within country framework. We will verify the role of both indexes in the next sections but focus mainly on the after-tax inequality index, since we want to account for the effect of the redistributive policy on the trilemma constraint.

4. Methodology

First, we introduce the trilemma indexes to assess how the binding of policy goals has constrained them during the analysed period. Each of the benchmark indicators is normalized between 0 and 1 with the minimum and maximum values observed in the panel (see minimum and maximum values in Table A1, in Appendix). The indexes should therefore be interpreted as relative values, with higher values indicating greater achievement of the objective.

4.1. Income Equality

In our empirical strategy, income inequality is measured by the Gini coefficient. The relative normalized income equality index for region i and year t is computed as:

$$IE_{it} = 1 - \frac{GINI_{it} - GINI_{min}}{GINI_{max} - GINI_{min}} \quad (2)$$

where IE_{it} denotes the income equality index for province i and year t , and $GINI$ is the Gini coefficient. From this equation, the highest equality reached is represented by the value 1.

³ We are aware that income tax inequality indicators may be down biased since they involve individual incomes above a certain threshold, leaving out the bottom tail of the income distribution. We partially avoid this bias by including the sample of individuals not obligated to declare, who issue their tax reports to recover their income tax withholdings. Despite this potential bias, the risks are low given the within-country context of our analysis as well as the homogeneity of our methodology and data source over time and regions.

4.2. Environmental Quality

The index of environmental quality is based on CO₂ emissions per capita and is constructed as follows:

$$EQ_{it} = 1 - \frac{CO_{2,it} - CO_{2,min}}{CO_{2,max} - CO_{2,min}} \quad (3)$$

where EQ_{it} denotes the environmental quality index for region i and year t , $CO_{2,it}$ refers to per-capita emissions for a certain province in a year, and $CO_{2,max}$ and $CO_{2,min}$ refer to the maximum and minimum emissions per capita of the whole sample. Hence, the region with highest quality in the sample will reach the value 1 and the lowest province the value 0.

4.3. Complexity Index

The economic complexity indicator for region i at time t (ECl_{it}) is normalized between 0 and 1 by using the maximum and minimum economic complexity values observed in the entire panel:

$$CI_{it} = \frac{ECl_{it} - ECl_{min}}{ECl_{max} - ECl_{min}} \quad (4)$$

where CI_{it} refers to the normalized complexity index for province i in year t , and ECl_{min} and ECl_{max} respectively denote the maximum and minimum values over the period. That way, the most complex region in the sample will reach the value 1 in the CI and the least complex province the value 0.

We also compute the economic growth index for the provinces, based it on real GDP per capita:

$$EG_{it} = \frac{Y_{it} - Y_{min}}{Y_{max} - Y_{min}} \quad (5)$$

where EG_{it} denotes the economic growth index and Y_{it} stands for real GDP per capita (constant 2016 euros) for province i at time t . The maximum (Y_{max}) and minimum (Y_{min}) income values come from the actual data. Table A1 in the Appendix summarizes the main descriptive statistics of the indexes.

4.4 Validity of the trilemma

Once all the indexes are computed, it is time to assess the existence of trade-offs among the three policy goals. The trilemma framework does not impose any functional form on the expression of relationships between variables. Following Aizenman et al. (2013), we propose

the linear hypothesis of the trilemma. If this is verified, there is a constraint such that a rise in one of the goals will produce a negative setback in one or both of the other two goals. In Figure 1, this corresponds to a move from one point to another within or on the triangle.⁴ Thus, a simple linear equation can test the validity of the trilemma hypothesis. The linear version implies that the weighted sum of the three policy variables adds up to a constant, and the three coefficients are positive. In particular, the trilemma we propose here links income equality, environmental quality and economic complexity:

$$1 = \alpha_j IE_{it} + \beta_j EQ_{it} + \gamma_j CI_{it} + e_{it} \quad (6)$$

The j subscript refers to the different subsamples in which the dataset can be partitioned by time subperiods or groups of provinces. High goodness of fit in the regression indicates that the linear specification can explain the trade-off among the confronted variables. The better the fit of the regression equation, the stronger the support for the trade-off between the three dimensions. Additionally, the estimated coefficients may be read as approximate estimates of the weights that regions put on the different policy goals (Aizenman et al., 2013).

The binding within the traditional *equality-sustainability-growth* trilemma is empirically verified within Spanish provinces as well. Additionally, we consider an augmented equation by adding economic complexity to the traditional trinity to explore complexity's role in it. The resulting quadrilemma equation (Ainzenman et al., 2013) is:

$$1 = \alpha_j IE_{it} + \beta_j EQ_{it} + \gamma_j EG_{it} + \delta CI_{it} + v_{it} \quad (7)$$

A variable would relax the trilemma if its coefficient were negative and significant. In this case, the sum of the three traditional trilemma coefficients ($\alpha + \beta + \gamma$) would be greater in the quadrilemma equation than in the trilemma equation.

As a robustness check, following Canale et al. (2017) and Choi et al. (2018), we estimate the logarithmic version of the trilemma as an alternative specification, where the value 1 is added previously to each index to avoid the zero-value problem:

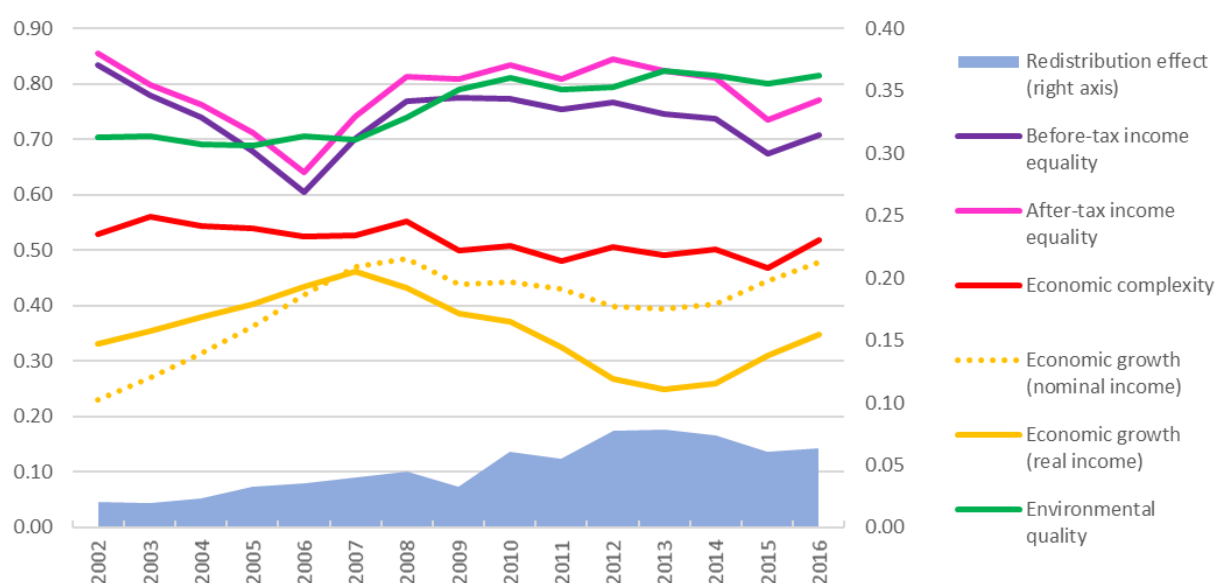
$$1 = \alpha_j \ln IE_{it} + \beta_j \ln EQ_{it} + \gamma_j \ln CI_{it} + u_{it} \quad (8)$$

⁴ As it is explained in Canale et al. (2018), the trilemma constraint in Eq (6) geometrically represents the sum of the perpendicular distances from a generic point in the triangle to its sides. This is valid for any point, and, according to Viviani's theorem, the sum of the three distances is always a constant equal to the altitude of the triangle. In our case, the altitude is equal to 1.

5. Exploring the trilemma indexes

Before assessing the existence of the trilemma and complexity's role in it, let us explore the relationships between the indexes across time and groups of regions. For the shake of brevity, we will focus on the main relationships.

The best way to illustrate the leitmotif of this article is to analyze the evolution of our indicators over time.



Source: own elaboration.

Figure 2: Time evolution of the main indicators: Income equality, Economic growth, Environmental quality, and Economic complexity

As Figure 2 illustrates, the economic complexity (CI) and economic growth (EG) indexes evolve in parallel, with slight variations before the crisis (2008) and a clearer co-movement afterwards. Meanwhile, the income equality indexes (before- and after-tax IE) evolve very similarly to environmental quality (EQ). Comparing these variables over time, before and after the 2008 crisis, we observe an asymmetric evolution by pairs: EG and CI versus IE and EQ. Despite the outlier of IE in 2006,⁵ the minimum difference between the two groups is observed in 2007, the year when real income reached its maximum, preceding the largest negative shock

⁵ Despite the tax reforms introduced in Spain during the period analyzed (2002, 2006 and 2014), previous analyses on the evolution of income equality in Spain have reported a fall in 2006. As noted by Onrubia and Picos (2013), the Gini rose severely between 2002 and 2006 because of the economic boom, while in 2006 a strong rise was observed in capital gains, just before the Spanish Real Estate bubble burst in 2007/2008. The effect was fueled also by the announcement of the tax reform to be applied in 2007, which would punish such capital gains before 21 January 2006.

suffered by the Spanish economy since the Spanish Civil War (1936–39), and before the current COVID-19 impact. It is also remarkable how the public sector's redistributive effect, measured as the difference between before-tax and after-tax IE, increased during the years after the 2008 shock: that is, when the public sector had to counteract the private sector's drop in activity and high unemployment rates.

The trade-offs suggested by the time evolution of the indexes are shown in radar and diamond charts that plot the average values of the indexes to show their variation over time or by income group. Figure 3 Panel A shows the overall average values for the four indicators. The origin (0.0) represents the minimum values of CI, EG, IE and EQ observed for the entire period.

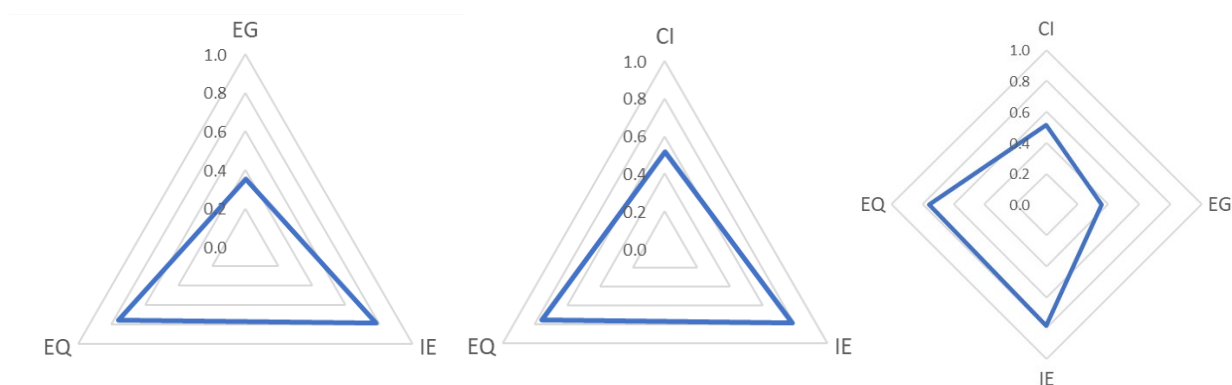
Figure 3 Panel B depicts the variation of the links between the indexes over time, effects of the financial crisis included. The diagram suggests that the crisis involved trade-offs between all dimensions. The impact is asymmetric, since the post-crisis negative adjustment in EG and/or CI seems to become profitable with slight improvements in EQ and IE.

Figure 3 Panel C presents the trilemma for three different groups of provinces—low-, middle- and high-income regions—according to the terciles computed over their overall 2002–16 average of real GDP per capita (see Table 2A in Appendix to see the classification of each province). On inspection of the averages, IE seems unrelated to income level: there is almost no difference between the average after-tax IE across groups. On comparison of the three diamonds, high-income regions appear to have reached greater EG with larger CI, keeping IE levels but losing EQ. On the other hand, low- and middle-income groups get lower EG at a lower CI, also keeping the average IE but gaining in EQ.

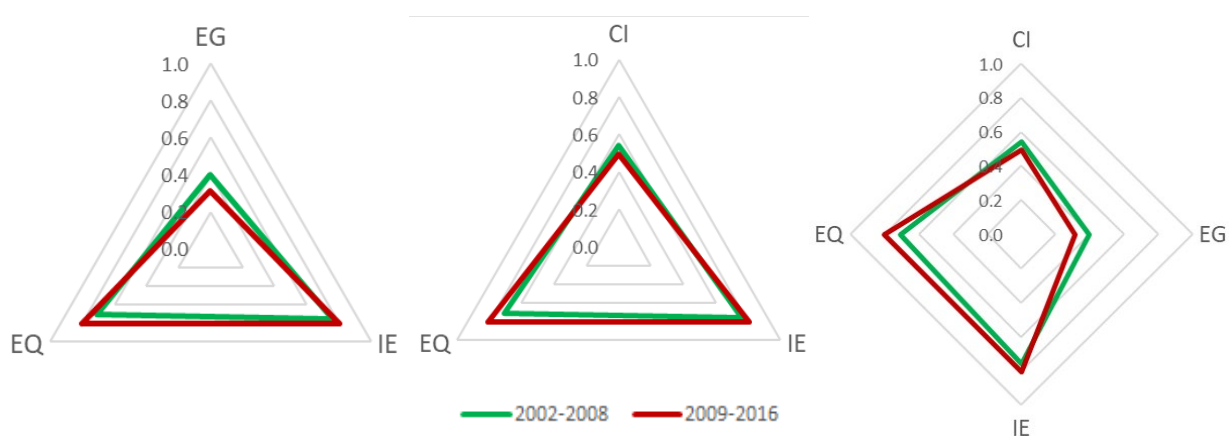
All in all, exploratory analysis suggests the main trade-off for all groups is between economic growth and environmental quality. In the *equality-sustainability-complexity* trilemma, the trade-off is between complexity and environmental quality in the middle- and high-income groups. Low-income provinces get larger environmental quality at similar complexity and income equality than middle-income provinces.

Next, we want to offer a more detailed view of the trade-offs by comparing the main indexes.

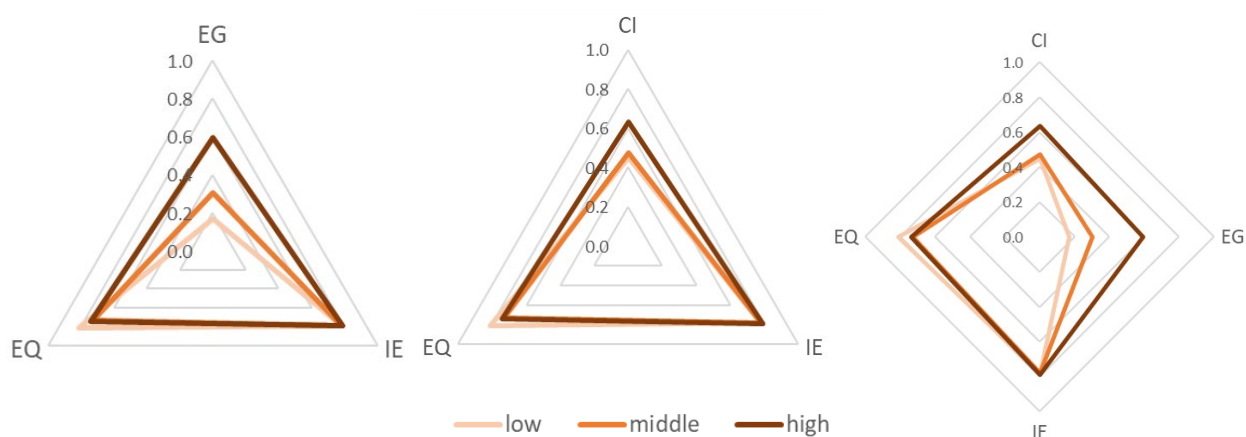
Panel A: Full sample (2002-2016)



Panel B: Pre-crisis (2002-08) versus post-crisis (2009-16)



Panel C: By income groups (2002-2016)



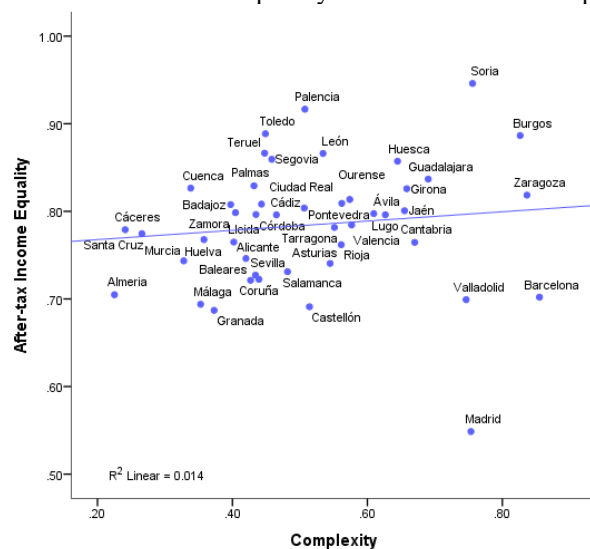
Source: own elaboration.

Note: CI: complexity index; EG: economic growth (real income); IE: after-tax income equality; EQ: environmental quality.

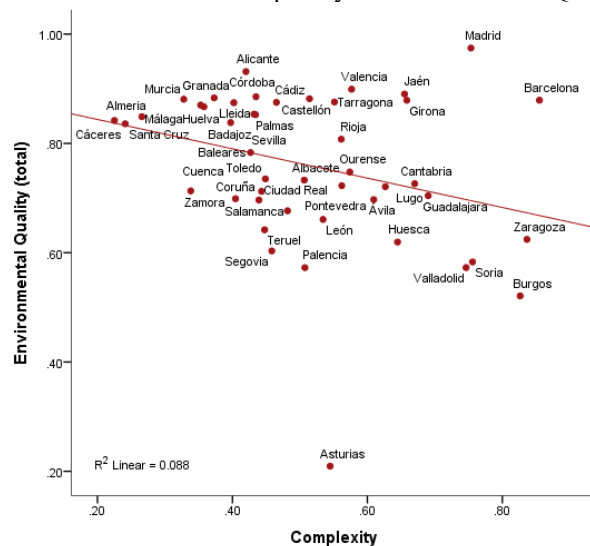
Figure 3: The trilemma in diamond charts

In three complementary panels, Figure 4 shows the relationships in pairs. Panel A confronts the economic complexity and the after-tax income equality indexes, using regional averages for the whole period 2002–16. Here the relationship is slightly positive, in line with the findings of Hartman et al. (2017) in their cross-country analysis. Panel B focuses on the relation between economic complexity and environmental quality. Section 2, above, suggests the possibility of finding *a negative but less clear relationship between complexity and sustainability*. The correlation between these two indexes for the Spanish provinces is slightly negative, as clearly shown in the corresponding scatterplot. Finally, Panel C focuses on the relation between income equality and environmental quality. In this case, most provinces show a negative relationship that is clearly determined by the extreme position of Madrid. The interpretation of this relation is not straightforward and can be linked to the sectoral specialization predominant in these few cases. Focusing on Madrid, the low level of income equality is associated with the presence of sophisticated services and high-tech industries (finance, business services, pharmaceutical products, headquarters of multinationals corresponding to the energetic and petrochemical industry, etc.) able to pay higher wages than the average. In contrast, the high levels of environmental quality are related to Madrid's status as a service sector, with less intensity of GHG emissions due to low levels (relative to its GDP) of inter-regional and inter-national exports of goods.

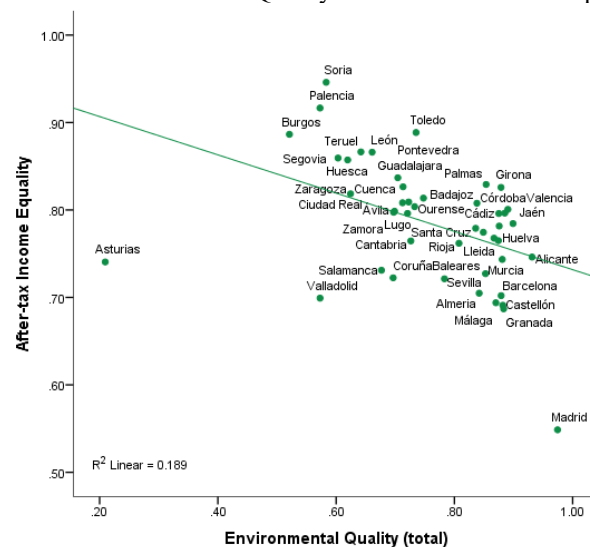
A: Economic Complexity vs After-tax Income Equality



B: Economic Complexity vs Environmental Quality



C: Environmental Quality vs After-tax Income Equality



Source: own elaboration.

Figure 4: The trade-offs vis a vis. Average: 2002-2016.

Figure 5 shows a conditional map for the main three indexes to add a cartographic characterization to the trilemma. On the horizontal axis, we have the terciles for the economic complexity index (CI); on the vertical axis, the ones for the after-tax income equality index (IE), while the colour palette corresponds to a Box-Map (Hinge: 1.5) using the environmental quality index (EQ). Let us focus first on Panel IX on the horizontal axis, which includes Madrid, Barcelona and Valencia as a group of provinces with high complexity (CI) and low income equality (IE). These are the top three regions in terms of international trade. Within this group, Madrid stands out for its higher EQ, which is probably due to its lower level of industrial activity (service economy). It is also enlightening to examine Panel VII, where Orense, Palencia, Guadalajara, Burgos, Huesca and Girona are identified as provinces with high complexity and high-income equality. Here Orense stands out its high environmental quality (EQ). Most readers with deep knowledge of Spain will suppose that the country's most active people prefer to live in a region in Panel IX (core provinces) rather than in Panel VII (peripheral ones). In our opinion, this is probably because people in general value high income (efficiency) more than equal distribution of income, and are accustomed to paying a price for the quality of the environment. Another interesting example is Panel III, where several Mediterranean coastal provinces and the Balearic Islands are grouped as the provinces with the lowest complexity and income equality. Again, non-experts on Spain might consider such provinces the worst places to live, yet their cities—Mallorca, Sevilla, Málaga and Granada, for instance—usually appear highly ranked as preferred spots. As this brief note shows, our analysis is still partial.

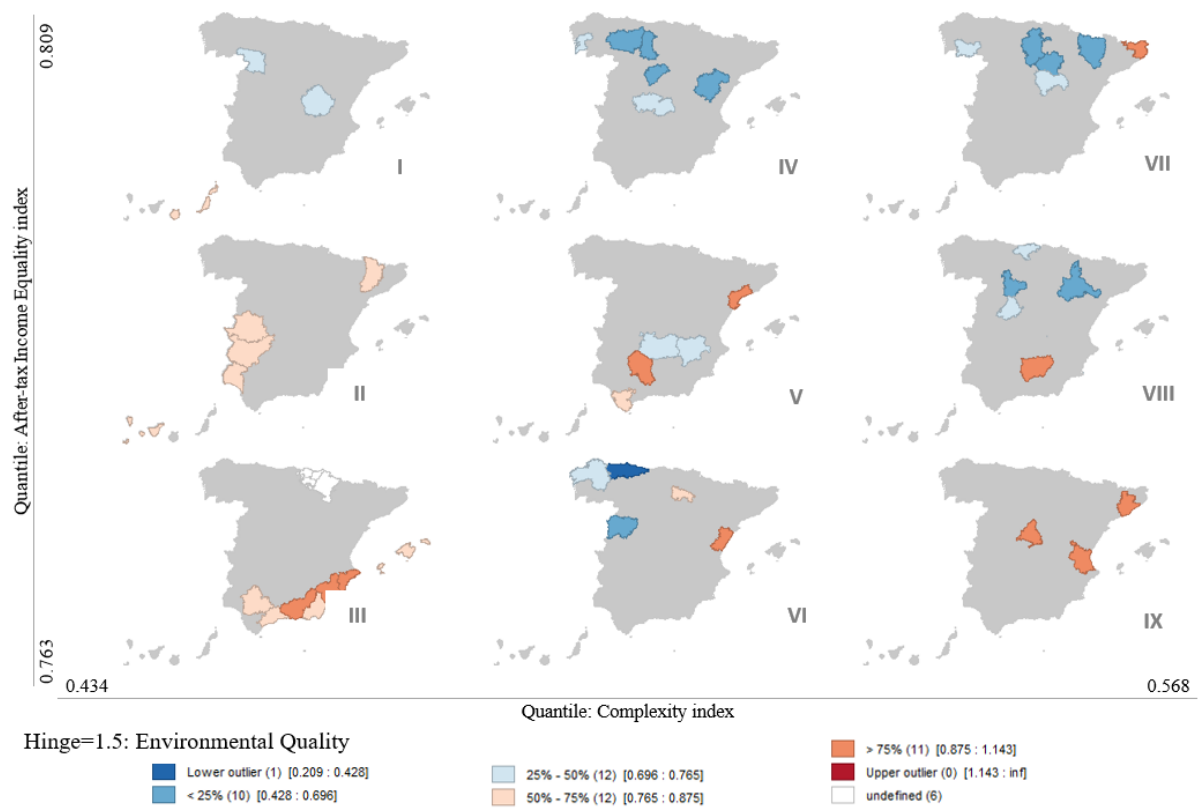


Figure 5: The trilemma in a conditional map. Average values for the period 2002-2016, standardized

In conclusion, this descriptive analysis suggests clear trade-offs in the time evolution of our trilemma's indexes, but also weak correlations when we confront the variables one by one using regional averages for the whole period. We now consider how these relationships perform when subject to more rigorous econometric analysis.

6. Assessing the validity of the trilemma

This section presents and discusses our empirical findings on the existence of the trilemma constraint. All tables include trios of regressions: the traditional *equality-sustainability-growth* trilemma, the trilemma where complexity replaces economic growth and, finally, the quadrilemma equation, which adds complexity to the original trinity. The results are presented in three subsections, one devoted to the full sample and the others to time subsamples and groups of regions.

6.1. Full sample

Table 1 contains the trilemma results for the entire panel under the linear specification (Eq. 6 and 7). In all specifications, the high goodness of fit strongly suggests that the linear

model is capturing the trade-off between alternative goals (adjusted R^2 above 99% in all cases). The results support binding between the traditional *equality-sustainability-growth* trinity (Columns 1). For Spanish provinces during the 2002–16 period, improvement in one goal has come at the expense of another or of a combination of the other two. We observe the same result when complexity replaces economic growth as aim of the trilemma equation (Column 2). This implies that an improvement in complexity would mean a setback in one or both other goals. Pursuing complexity does compete with IE or EQ, or both. As the estimated coefficients represent proxy estimates of the policy weights in the trilemma configuration, results suggest that the main focus has been on income equality over the entire 2002–16 period. When both CI and EG are confronted with IE and EQ under a quadrilemma context, all the four variables are highly statistically significant. The estimated coefficients have a positive sign, and the general fit is good (Column 3). The existence of the quadrilemma cannot be denied, so these four policy goals are binding in the context of the Spanish regions. Looking at the estimated coefficients, the weights of IE and EQ remain stable in the trilemma and quadrilemma configurations.

In contrast, the sum of both CI and EG weights in Column 3 corresponds roughly to the weight of EG (Column 1) or CI (Column 2) under the trilemma specification. This finding suggests that CI and EG share the same political space in the quadrilemma configuration.

Table 1. Trilemma and Complexity: full sample

	(1)	(2)	(3)
Income equality	0.783*** (0.033)	0.695*** (0.037)	0.707*** (0.037)
Environmental quality	0.413*** (0.033)	0.437*** (0.031)	0.422*** (0.031)
Economic growth	0.180*** (0.016)		0.109*** (0.017)
Complexity		0.222*** (0.025)	0.153*** (0.029)
$\alpha + \beta + \gamma$	1.3765	1.3544	1.2379
Adjusted R^2	.9917	.9919	.9922

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Number of observations = 690.

As a robustness check, Table 2 shows the estimates for the trilemma and quadrilemma linear equations when the equality index refers to before-tax income distribution. Overall, the results are the same as when we consider the after-tax income equality index (Table 1). The adjusted- R^2 for before-tax IE are slightly lower than the regressions including after-tax IE, meaning a stronger binding when we consider the redistributive policy.

Table 2. Trilemma and Complexity: before-tax income equality index

	(1)	(2)	(3)
Before-tax income equality	0.726*** (0.030)	0.633*** (0.032)	0.648*** (0.033)
Environmental quality	0.504*** (0.029)	0.520*** (0.027)	0.503*** (0.027)
Economic growth	0.209*** (0.017)		0.125*** (0.018)
Complexity		0.251*** (0.025)	0.172*** (0.029)
$\alpha + \beta + \gamma$	1.4393	1.4062	1.2761
Adjusted R^2	.9914	.9916	.9921

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Number of observations = 690.

Table 3 presents the trilemma and quadrilemma estimates when the effect of lagged complexity on current trilemma is taken into account. Estimates considering temporal lags from $t-1$ to $t-7$ do not change the conclusions with respect to both the sign and the significance of the coefficients. For space reasons, only estimates for the $t-5$ complexity lag are shown. Only when the CI is lagged $t-4$ and $t-5$ do we observe an improvement in the $adj-R^2$ with respect to the model with current CI (Column 1). That a lagged CI in (2) produces a higher $adj-R^2$ than (1) can be interpreted to mean that the economic complexity is linked more to future equality and sustainability levels than to current ones. The results are extended to the context of the quadrilemma. This finding is in line with results in the previous ECI literature, where the complexity indicator is to predict long-run growth. The same approach with before-tax IE instead of after-tax IE produces very similar results.

Table 3. Trilemma and Lagged Complexity: full sample

	(1)	(2)	(3)	(4)
Income equality	0.695*** (0.037)	0.754*** (0.036)	0.707*** (0.037)	0.760*** (0.034)
Environmental quality	0.437*** (0.031)	0.430*** (0.032)	0.422*** (0.031)	0.423*** (0.031)
Economic growth			0.109*** (0.017)	0.095*** (0.017)
Complexity	0.222*** (0.025)		0.153*** (0.029)	
Complexity $t-5$		0.101*** (0.019)		0.044** (0.018)
$\alpha + \beta + \gamma$	1.3544	1.2855	1.2379	1.2766
Adjusted R^2	.9919	.9954	.9922	.9957
Observations	690	460	690	460

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

As a further robustness check, Table 4 shows the estimate results under the alternative logarithmic specification (Eq. 8) for the entire panel. Overall, the results coincide with the linear model (Table 1), supporting the aforementioned conclusions.

Table 4. Trilemma and Complexity: logarithmic equation

	(1)	(2)	(3)
Income equality	1.091*** (0.060)	0.974*** (0.067)	0.985*** (0.070)
Environmental quality	0.541*** (0.059)	0.565*** (0.056)	0.550*** (0.062)
Economic growth	0.211*** (0.020)		0.129*** (0.022)
Complexity		0.282*** (0.038)	0.195*** (0.042)
$\alpha + \beta + \gamma$	1.8420	1.8205	1.6640
Adjusted R ²	.9941	.9942	.9945

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively. Number of observations = 690.

In sum, the adjusted- R^2 lies above 99% in all specifications, which suggests the constraint exists in both the original trilemma and in the *equality-sustainability-complexity* trilemma at either linear or loglinear specification. In other words, provinces face an *impossible trinity* in economic growth, income equality and environmental quality that is also verified between complexity, income equality and environmental quality. The significance of complexity and economic growth when both are taken into account under the quadrilemma reinforces the links between them, as they seem to have complementary roles in the weights that regions put on different policy goals.

6.2. Crisis effects: time subsample analyses

We turn now to the effect of the financial crisis in this regard. Table 5 provides the results for the pre- and post-crisis subsamples. More specifically, given the jumps for 2006 in the series of income equality, we opted to consider four alternative time windows: 2002–06 (boom), 2007–08 (pre-crisis), 2009–12 (double deep recession), 2013–16 (recovery). The results show that policies in all these periods are constrained under the traditional trilemma as well as under the *equality-sustainability-complexity* trinity. Comparing all subsamples, we observe in the post-crisis 2009–12 recession (Columns 7, 8 and 9) larger *adj-R*² and smaller sums of the trilemma coefficients ($\alpha + \beta + \gamma$) than in the previous samples, meaning that the constraint tightened and the policy space shrunk after the crisis.

Table 5. Trilemma and Complexity: time subsamples

	2002 - 2006			2007 - 2008			2009 - 2012			2013 - 2016		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Income equality	0.783*** (0.056)	0.631*** (0.062)	0.651*** (0.066)	0.858*** (0.061)	0.7944*** (0.070)	0.817*** (0.063)	0.803*** (0.041)	0.797*** (0.046)	0.797*** (0.044)	0.738*** (0.054)	0.706*** (0.054)	0.710*** (0.052)
Environmental quality	0.433*** (0.062)	0.486*** (0.055)	0.458*** (0.056)	0.325*** (0.070)	0.358*** (0.072)	0.326*** (0.068)	0.398*** (0.040)	0.401*** (0.041)	0.398*** (0.040)	0.488*** (0.049)	0.493*** (0.049)	0.490*** (0.048)
Economic growth	0.244*** (0.032)		0.108*** (0.039)	0.209*** (0.032)		0.175*** (0.033)	0.055*** (0.018)		0.050** (0.020)	0.066** (0.026)		0.042 (0.028)
Complexity		0.319*** (0.044)	0.251*** (0.056)		0.219*** (0.055)	0.086* (0.050)		0.040** (0.020)	0.012 (0.028)		0.079** (0.029)	0.055* (0.030)
$\alpha + \beta + \gamma$	1.4607	1.4355	1.2172	1.3928	1.3718	1.3187	1.2557	1.238	1.2454	1.292	1.2790	1.242
Adjusted R^2	.9864	.9879	.9883	.9950	.9941	.9952	.9975	.9959	.9975	.9927	.9958	.9928
Observations	230	230	230	92	92	92	184	184	184	184	184	184

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

We see some differences regarding the quadrilemma, since the role of CI and EG changed after the 2008 crisis. During the recession (2009–12), CI did not play a statistically significant role (Column 9), which suggests in turn that complexity has not tightened the trilemma constraint in the post-crisis period. During the recovery of 2013–16, economic growth did not imply trade-offs in terms of income equality, sustainability or complexity (Column 12). In this regard, it is worth mentioning that after the crisis Spain experienced a *miraculous recovery*, thanks to a huge increase in exports (Almunia et al., 2018). Paradoxically, however, this effort to vent-out was associated with a progressive decrease in Spain's international complexity indexes, as registered by the Economic Complexity Atlas, whose data we rely on.

6.3. Trilemma by income level

Finally, we turn to the performance of the trilemma when groups of provinces, classed by income, are considered separately (Table 6).

Table 6. Trilemma and Complexity: analysis by income level

	Low-income provinces			Middle-income provinces			High-income provinces		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Income equality	0.488*** (0.097)	0.516*** (0.119)	0.434*** (0.108)	0.804*** (0.053)	0.848*** (0.066)	0.738*** (0.056)	0.699*** (0.020)	0.612*** (0.028)	0.631*** (0.024)
Environmental quality	0.638*** (0.076)	0.613*** (0.079)	0.634*** (0.068)	0.253*** (0.050)	0.295*** (0.057)	0.269*** (0.047)	0.252*** (0.030)	0.469*** (0.024)	0.282*** (0.029)
Economic growth	0.579*** (0.110)		0.523*** (0.086)	0.595*** (0.066)		0.535*** (0.057)	0.431*** (0.035)		0.334*** (0.035)
Complexity		0.210*** (0.078)	0.122** (0.053)		0.239*** (0.056)	0.123*** (0.040)		0.259*** (0.027)	0.141*** (0.026)
$\alpha + \beta + \gamma$	1.7051	1.3385	1.5910	1.6514	1.3816	1.5414	1.3820	1.3394	1.2478
Adjusted R^2	.9959	.9944	.9961	.9930	.9904	.9934	.9947	.9936	.9953
Observations	225	225	225	240	240	240	225	225	225

Note: robust standard errors are reported in parentheses. The symbols *, ** and *** denote statistical significance at the 10%, 5% and 1% levels, respectively.

The binding between the original trinity variables is verified in all the three groups (Columns 1, 4 and 7), as well as in the *equality-sustainability-complexity* trinity (Columns 2, 5 and 8).

All income groups face a quadrilemma (Column 3, 6 and 9): CI is a goal that competes against one or a combination of the elements in the *equality-sustainability-growth* trinity. In all cases, the constraint is strongest for low-income regions (largest $adj-R^2$). It is worth noting the different weights of the policy goals. Low-income regions keep the emphasis on economic growth and environmental quality. Middle- and high-income provinces put income equality and economic growth ahead of environmental quality. In most cases the sum of the EG and CI coefficients under the quadrilemma configuration roughly equals the weight of EG under the trilemma, which reinforces the role shared by complexity and EG as they pursue the same goal.

7. Conclusions

The Environmental Kuznets curve explains the relation between income level, income inequality and environmental degradation, suggesting the presence of an impossible trinity of irreconcilable objectives in these three variables.

The main contribution of our paper is to revisit this trilemma focusing on economic complexity indexes instead of direct measures of economic growth, and to apply this analysis to the sub-national level in Spain. The economic complexity indexes used are based on very new datasets on international and intra-national trade, while the GHG emissions are rooted in official national and regional statistics, which are generated with an international standardized methodology. We have also estimated new indexes of income equality at the province level (NUTS-3), considering a long period (2002–16).

The descriptive analysis of the indexes obtained shows a clear tension in the evolution of two groups of variables: economic growth and complexity versus income equality and environmental quality. Our econometric analysis verifies the presence of the classic trilemma of *equality-sustainability-growth*, but also of our new version: *equality-sustainability-complexity*. That complexity substitutes for economic growth in the trilemma equation reinforces the links between both. We enrich our analysis by considering pre- and post-crisis subsamples, estimating robustness checks for three province income groups, and using linear and non-linear specifications. Furthermore, we have also tested the presence of a quadrilemma, discussing the role that a province's level of complexity tends to play in the aforementioned tensions between growth, inequality and sustainability. The results are promising and open new avenues for the smart specialization of regions within countries—specialization defined in a wider sense to take into account the environmental and social costs of promoting only growth by focusing excessively on the internationalization of each region.

This result is especially relevant at present, with the COVID-19 crisis putting globalization to the test, and showing that any national or sub-national boundary can in the blink of an eye bring just about all economic and social interaction to a halt.

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Appendix

Table A1. Main descriptive statistics

	Mean	Median	Std. Deviation	Minimum	Maximum	Observations
Before-tax Income Equality index	.737	.755	.120	.000 Salamanca 2004	1.000 Soria 2002	690
After-tax Income Equality index	.784	.797	.105	.000 Salamanca 2004	1.000 Palencia 2012	690
Economic Growth index (nominal income)	.399	.361	.185	.000 Badajoz 2002	1.000 Madrid 2016	690
Economic Growth index (real income)	.354	.303	.206	.000 Jaén 2012	1.000 Madrid 2007	690
Environmental Quality index (total emissions)	.759	.795	.153	.000 Asturias 2005	1.000 Madrid 2015	690
Complexity index	.517	.500	.176	.000 Cáceres 2015	1.000 Zaragoza 2003	690

Table A2. List of provinces by income group.

Classification criteria: terciles of real GDP per capita over the mean of period 2002–16.

Low (15)	Middle (16)	High (15)
Badajoz; Jaén; Cáceres; Córdoba; Granada; Cádiz; Málaga; Toledo; Huelva; Ávila; Albacete; Zamora; Ourense; Alicante; Salamanca.	Sevilla; Cuenca; Ciudad Real; Guadalajara; Almería; Murcia; Pontevedra; Palmas; León; Lugo; Santa Cruz; Asturias; Coruña; Cantabria; Valencia; Segovia.	Soria; Castellón; Palencia; Valladolid; Teruel; Zaragoza; Rioja; Huesca; Baleares; Burgos; Tarragona; Girona; Lleida; Barcelona; Madrid.