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Distributing the European structural and investment funds from a conflicting claims approach

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Abstract

In order to support economic development across all EU regions, € 351.8 billion –almost a third of the total EU budget– has been set aside for the Cohesion Policy during the period 2014-2020. The distribution of this budget is made throughout five main structural and investment funds, after long and though negotiations among the EU member states. The current paper analyzes the problem of allocating the limited resources of the European Regional Development Fund (ERDF) as a conflicting claims problem (O'Neill, 1982). Specifically, we show how this approach fits this actual problem, and we propose an alternative way of distributing the budget via (i) claims solutions or (ii) the imposition of bounds (guarantees) to each of the regions. We apply this approach to European Union and Spanish evidences. In both cases we obtain that the constrained equal losses rule reduces inequality and promotes convergence more properly.

Keywords: conflicting claims problems; public budget distribution; European Regional Development Fund; EU convergence

1. Introduction

The main objective of the European Union (EU) is to strengthen the social and economic cohesion of the EU regions, as well as to reduce the inequalities among them. In doing so, and in accordance with the objectives of the Europe 2020 strategy, the European Structural and Investment Funds (ESIF) are implemented throughout five main funds: the European Regional Development Fund (ERDF), the European Social Fund (ESF), the Cohesion Fund

(CF), the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund (EMFF).[1]

In order to support job creation, business competitiveness, economic growth, sustainable development, and improve citizens' quality of life, the Regional Policy has set € 351.8 billion -almost a third of the total EU budget- to the Cohesion Policy funds for the period 2014-2020. Following the magazine Panorama Inforegio, the support of the EU's cohesion policy has achieved member states to experience a 5% growth in per capita gross domestic product. [2] The bulk of Cohesion Policy funding, above the 50%, is allocated to less developed European regions in order to help them to catch up and to reduce the economic, social and territorial disparities that still exist in the EU.

It is noteworthy that the available budget does not honor all the claims of the EU regions which are involved. Accordingly, the current paper aims to implement the *conflicting claims problem* approach (originated with O'Neill (1982), and which fits situations such as inheritance problems, divorces, the failure of the company or bank, for instance) in order to achieve the aforementioned goals in a proper way. In doing so, once we define the conflicting claims problem associated to the distribution of EU funds, we apply well known solution concepts, so-called *claims rules*. By comparison, our results provide a claims rule that clearly performs better than the others, and also better than the current allocation.

Among all the aforementioned funds, the present paper focuses on the European Regional Development Fund (ERDF), which represents almost the 44% of the total budget. These funds are allocated at the NUTS 2 level, which is a regional classification providing a harmonized hierarchy of regions: the NUTS classification subdivides each member state into regions at three different levels, from larger to smaller areas. For practical reasons the NUTS classification generally mirrors the territorial administrative division of the member states, which supports the availability of data and the policy implementation capacity. Specifically, the NUTS regulation defines minimum and maximum population thresholds for the size of the NUTS regions: NUTS 2 level corresponds to regions whose population is between 800000 and 3000000 inhabitants. Taking into the account this division, the regional eligibility for the ERDF is calculated on the basis of regional GDP per inhabitant (*per capita*), and NUTS 2 regions were ranked and split into three groups:

1. less developed regions (where GDP *per capita* was less than 75 % of the EU-27 average);
2. transition regions (where GDP *per capita* was between 75 % and 90 % of the EU-27 average); and
3. more developed regions (where GDP *per capita* was more than 90 % of the EU-27 average).

[1] https://cohesiondata.ec.europa.eu/funds

[2] http://ec.europa.eu/regional_policy/es/information/publications/panorama-magazine/2017/panorama-61-cohesion-policy-looks-to-the-future

1.1. ***Related literature***

There are many papers analyzing the importance of ESIF funds in order to achieve greater social cohesion and economic growth among the European Union countries, most of them looking for the results obtained through the policies applied. For instance, Rodríguez-Pose and Fratesi (2004) apply cross-sectional and panel data analyses to observe the impact of European Structural Funds in Objective 1 regions; also Puigcerver-Peñalver (2007) studies the impact of the ESIF funds in the economic growth of the regions; Mohl and Hagen (2010) analyze the economic growth of the European Union countries, using the financial aspect for the NUTS 1 and NUTS 2 regions; Bouayad-Agha et al. (2013) consider an econometric model to analyze the effect of the cohesion policies on the European economies; and Dall'Erba and Fang (2017) apply a meta-analysis with the objective of studying the impact generated for the ESIF funds on the development of the recipient regions.

Our approach complements the aforementioned studies by providing a new point of view of this problem: the implementation of the theoretical conflicting claims approach to the distribution of the ERDF funds. Other economic and social sectors have been analyzed through this approach: in the education sector Pulido et al. (2002) for obtaining an efficient allocation of the university funds; in the fishing sector for searching possible solutions to face fish shortages, where it is proposed to distribute fishing quotas among a number of agents within an established perimeter (Iñarra and Prellezo, 2008; Iñarra and Skonhoft, 2008; Kampas, 2015); or, in the negotiations of the CO2 emissions, a relevant issue nowadays, in which Giménez-Gómez et al. (2016) propose an appealing distribution by using the commonly accepted principles.

We propose the use of claims rules to distribute the EU funds in order to achieve social cohesion, convergence and equality among state members, properly. In doing so, we define some of the usual claims rules and compare them from a convergence perspective by the application of the Lorenz dominance (comparing the inequality of the proposals), the Gini index (comparing the inequality across regions after a proposal is implemented) and a convergence ratio.

Our results show that the allocations proposed by all of the claims rules reduce (i) the divergence among regions, and (ii) the inequality Gini index. Nevertheless, only the constrained equal losses rule performs better than the current allocation.

The remainder of the paper is organized as follows. Next, Section 2 presents the ERDF conflicting claims problem. Section 3 proposes different solutions to the EU evidence. Section 4 compares the different claims rules from the convergence point of view. Section 5 analyzes and compares the proposed allocations from the point of view of equity, and Section 6 studies the problem by ensuring some guarantees (in awards and in losses) to all regions. Section 7 implements our approach to the detailed Spanish evidence. Finally, Section 8 concludes.

2. The ERDF conflicting claims problem

A *conflicting claims problem* is defined by a set of agents (*regions*), $R_1, R_2, \ldots, R_n$. Each region R_i is identified by its *claim* c_i on the total available *budget* E. The *aggregate claim* C is given by $C = \sum_{i=1}^{n} c_i$. Therefore, the conflicting claims problem appears whenever the claims cannot be simultaneously honored by the available budget: $C > E$. The pair (E, c) represents the claims problem.

As aforementioned, we implement our approach to the ERDF European Union evidence. In this situation, two facts have to be considered. Firstly, each region has a proposal with the amount that they plan to spend on the projects: this is the *claim* each region demands. Secondly, the actual amount that is decided to be assigned to each of the regions, that is the actual expenses that each region has for projects throughout the ERDF funds, which is always lower than the claims, so in a natural manner a conflicting claims problem appears.

Therefore, in our scenario the proposal for the endowment E is the ERDF budget currently allocated to all regions in EU (in absolute terms). The claims c_i correspond to the sum of the total budget demanded by the regions in each category (less developed, in transition and more developed regions) for the period 2014-2020.

In order to compare the claims of these three categories of regions, and the allocations they receive, it is necessary to analyze the problems in terms of *per capita* resources, since the populations are very different. Then we obtain the claims, current allocations and GDP/head. Table 1 reflects these data.

The endowment $\mathbf{E} = 188,007,299,928$			
Absolute	Claim	Current	Population
More developed	61,901,153,827	32,300,565,888	280,056,802
Transition	36,181,081,146	25,396,981,020	51,298,111
Less developed	166,509,560,350	130,309,753,020	118,577,982
Per capita	Claim	Current	GDP
More developed	221.03	115.14	29,713.20
Transition	705.31	495.09	21,332.85
Less developed	1,404.22	1,098.94	10,587.31

Table 1: Current allocation of ERDF budget according to each category of region (€). In the first row we have the estate, in absolute terms. The first column presents the three different regions. The second column provides the claim of each of the regions (first in absolute terms and then in *per capita* terms). The third column shows the actual distribution of the ERDF budget. Finally, last column reflects population of each category of region (inhabitants) and the GDP/head.

3. A way to distribute the ERDF budget

There are many well known solution concepts defined for solving conflicting claims problems, so-called claims rules. A *claims rule* is a single valued function φ such that for each claims problem (E, c) assigns an amount $\varphi_i(E, c)$ to each region R_i, fulfilling:

a) $0 \leq \varphi_i(E, c) \leq c_i$ (*non-negativity* and *claim-boundedness*); and

b) $\sum_{i=1}^{n} \varphi_i(E, c) = E$ (*efficiency*).

That is, the total budget is distributed among the regions and any region receives neither a negative amount, nor an amount exceeding its claim.

We now briefly introduce and analyze the behavior of some commonly used rules: the *proportional*, the *constrained equal awards*, the *constrained equal losses*, the *talmudian* and the $\alpha^{\min}$ rules.

- The **proportional (P)** rule is the most popular one since it divides the available budget proportionally to the claim of the regions.

  For each (E, c) and each region R_i, $\quad P_i(E, c) \equiv \lambda c_i$, where $\lambda = \dfrac{E}{C}$.

- The **constrained equal awards (CEA)** rule (Maimoindes, 1135,1204) equalizes the amount each region receives, such that no region receives more than its demand.

  For each (E, c) and each region R_i, $\quad CEA_i(E, c) \equiv \min\{c_i, \lambda\}$, where λ is chosen so that $\sum_{i=1}^{n} \min\{c_i, \lambda\} = E$.

- The **constrained equal losses (CEL)** (Maimoindes, 1135,1204; Aumann and Maschler, 1985) rule tries to analyze the problem from the point of view of losses (what the regions do not receive with respect to their claims), hence it proposes equalizing losses, such that no region receives a negative amount.

  For each (E, c) and each region R_i, $\quad CEL_i(E, c) \equiv \max\{0, c_i - \lambda\}$, where λ is chosen so that $\sum_{i=1}^{n} \max\{0, c_i - \lambda\} = E$.

- The **talmudian (T)** rule (Aumann and Maschler, 1985), is a combination of the CEA and the CEL rules, which takes in account the half of the aggregate claim C as a reference. If C is lower than the available resource, then the CEA rule is applied over the half-claims. Otherwise, each region receives the half of its claim and the CEL rule is applied in order to distribute the remaining budget with respect to the remaining claims (the other half).

For each (E, c),

$$T(E,c) \equiv \begin{cases} CEA(E, \frac{1}{2}c) & \text{if} \quad E \leq \frac{1}{2}C \\ \\ \frac{1}{2}c + CEL(E - \frac{1}{2}C, \frac{1}{2}c) & \text{if} \quad E \geq \frac{1}{2}C \end{cases}$$

- The $\alpha^{\min}$ rule (Giménez-Gómez and Peris, 2014) guarantees a minimum amount to each region: if possible, all regions first receive an amount that coincides with the lowest claim and then, the remaining budget is distributed proportionally to the reduced claims (the initial claims minus the amount already received). If the budget does not allow each region receiving at least the lowest claim, then all regions receive the same amount. That is:

  For each (E, c),

$$\alpha^{\min}(E,c) \equiv \begin{cases} \frac{1}{n}E & \text{if} \quad E \leq nk, \\ \\ k + P(E - nk, c - k) & \text{if} \quad E \geq nk, \end{cases}$$

  where $k = \min\{c_i\}_{i \in N}$ and n is the number of regions.

3.1. ***Per capita claims rules***

Due to the fact that the considered regions have different population, the determination to which category they belong (less developed, transition, or more developed) is made in GDP/head terms. So, in order to compare the treatment each one receives with respect to its claim, we might use the *claims per capita* and adapt the claims rules, accordingly. It is noteworthy that this adaptation, with differences, is somewhat related to the *weighted constrained claims rules* (Casas-Méndez et al., 2011).

Specifically, consider n categories of regions $R_1, R_2, \ldots R_n$, with respective populations $p_1, p_2, \ldots, p_n$ that claim $c_1, c_2, \ldots, c_n$ of a budget E. Then, the *per capita* claim is

$$c_i^H = \frac{c_i}{p_i} \qquad i = 1, 2, 3$$

Therefore, the claims rules are accordingly defined, such as, the P rule equalizes the portion of the claim that is satisfied, i.e., $P_i^H = \frac{c_i^H}{\sum_{j=1}^n c_j^H}\lambda$, λ such that $\sum_{i=1}^n p_i P_i^H = E$; the CEA rule tries to equalize the awards, $CEA_i^H = \min\left\{c_i^H, \lambda\right\}$, λ such that $\sum_{i=1}^n p_i CEA_i^H = E$; or the CEL rule tries to equalize the losses, $CEL_i^H = \max\left\{0, c_i^H - \lambda\right\}$, λ such that $\sum_{i=1}^n p_i CEL_i^H = E$.

Straightforwardly, the same adaptation is applied to the remaining claims rules, and the results are shown in Table 2.

Per capita	Claim	Current	P	CEA	CEL	T	$\alpha^{\min}$
More developed	221.03	115.34	157.05	221.03	50.82	50.82	221.03
Transition	705.31	495.09	501.16	705.31	535.10	535.10	722.41
Less developed	1,404.22	1,098.94	997.78	758.36	1,234.01	1,234.01	750.96

Table 2: Allocation of ERDF budget according to each considered rule (€). The first column presents the three different regions. Within each region, rows provide the *per capita* allocations recommended to each of the three considered regions. The second column provides the *per capita* claim of each of the regions.

Once the problem of distributing the ERDF funds among the EU regions has been translated into a claims problem, and the allocations are calculated in terms of the per capita claims, Table 3 shows the distribution of the budget proposed by the claims rules in absolute terms, i.e., the final distribution of the total ERDF budget. Furthermore, and for the sake of facilitating the analysis, Table 4 provides data about the percentage of the claims that rules allocates to each of the regions.

Absolute	Claim	Current	P	CEA	CEL
More developed	61,901,153,827	32,300,565,888	43,984,239,115	61,901,153,827	14,231,803,350
Transition	36,181,081,146	25,396,981,020	25,708,685,964	36,181,070,669	27,449,468,078
Less developed	166,509,560,350	130,309,753,020	118,314,374,848	89,925,075,432	146,326,028,500

	T	$\alpha^{\min}$
More developed	14,231,803,350	61,901,153,827
Transition	27,449,468,078	24,660,387,099
Less developed	146,326,028,500	101,445,759,002

Table 3: Allocation of ERDF budget according to each considered rule in absolute terms (€). The first column presents the three different regions. Within each region, rows provide the *absolute term* allocations recommended to each of the three considered regions. The second column provides the *absolute term* claim of each of the regions.

Absolute	Claim (€)	Current	P	CEA	CEL	T	$\alpha^{\min}$
More developed	61,901,153,827	52.2%	71.1%	100%	23%	23%	100%
Transition	36,181,081,146	70.2%	71.1%	100%	75.9%	75.9%	68.2%
Less developed	166,509,560,350	78.3%	71.1%	54.0%	87.9%	87.9%	60.9%

Table 4: Percentages of claims satisfied by current allocation and rules proposals. The first column shows the three different regions. Each row presents the percentages of claim satisfied by each allocation rule for each of the three regions.

In order to choose one proposal among all the considered allocations, the following two sections compare the different claims rules in terms of convergence and equity.

4. Convergence among regions

As aforementioned, one of the main objectives of the EU through the ERDF funds is to promote convergence among regions of different categories. So, how the introduced claims rules affects this concerns is our natural next step. Specifically, consider two regions R_i and R_j with the following features:

- R_i belongs to the less developed regions, has a GDP/head r_i and a claim *per capita* c_i.
- R_j belongs to the more developed regions, has a GDP/head r_j and a claim *per capita* c_j.
- $r_j > r_i$.
- $c_j < c_i$ (the claim *per capita* is greater for the less developed region, in order to obtain convergence).
- Hence, some funds E should be allocated to these regions taking into account their claims.

Firstly, on the one hand, we measure the initial divergence d^0 between these regions by,

$$d^0 = 1 - \frac{r_i}{r_j}$$

It is noteworthy that each of the proposed claims rule satisfies the so-called *order preservation* property, that is, the larger the claim, the larger the resources allocated to the region. Formally, if we denote by x_i, x_j the *per capita* allocation to regions R_i and R_j, respectively, made by a claims rule φ, then $x_i \geq x_j$.

Secondly, after the claims rule φ is applied to allocate the funds, the new divergence ratio $d^1(\varphi)$ is obtained by,

$$1 - d^1(\varphi) = \frac{r_i + x_i}{r_j + x_j} \geq \frac{r_i + x_j}{r_j + x_j} > \frac{r_i}{r_j} \quad \Rightarrow \quad d^1(\varphi) < d^0$$

Therefore, the proposed claims rules always reduce the divergence ratio.

On the other hand, it is easy to observe that $c_i > c_j$ implies that the application of the CEL rule always provide to the less developed region an allocation greater or equal that the one provided by other rules:

$$CEL_i > \varphi_i \qquad \text{for} \quad \varphi = P, CEA, T, \alpha^{\min}$$

so,

$$d^1(CEL) < d^1(\varphi) \qquad \text{for} \quad \varphi = P, CEA, T, \alpha^{\min}$$

that is, the rule better promoting convergence is CEL.

If we compute the divergence ratio (in percentages) from Table 2 we observe these facts. Indeed, Table 5 highlights that the more reducing proposal is given by CEL rule (that, in this case coincides with the T rule). Note that it is the only claims rule that reduces all divergence ratios with respect to the current allocation.

Divergence	Initial d^0	Current d^1	$d^1(P)$	$d^1(CEA)$	$d^1(CEL)$	$d^1(T)$	$d^1(\alpha^{\min})$
$R_2VS.R_1$	28%	27%	27%	26%	27%	27%	27%
$R_3VS.R_1$	64%	61%	61%	62%	60%	60%	62%
$R_3VS.R_2$	50%	46%	47%	49%	46%	46%	48%

Table 5: This table provides the divergence ratio after applying current allocation and rules proposals. In the first column, R_1 corresponds to the more developed regions, R_2 for transition regions and R_3 for less developed regions. The rows show the percentage value of the divergence ratio corresponding to each of the claims rules applied.

5. Reducing the inequality: fair criteria

Following Robert (1974), "the complete principle of distributive justice would say simply that a distribution is just if everyone is entitled to the holdings they possess under the distribution." Hence, in order to find out the claims rule that induces a larger commitment among the different regions involved in the ERDF budget distribution, we introduce some equity criteria.

Lorenz dominance is a criterion used to check whether a solution is more favourable to smaller claimants relative to larger claimants.[3] So, a Lorenz dominant solution is intended to equalize the allocations among claimants, regardless of their claims. Let $\mathbb{R}^n_{\leq}$ be the set of positive n-dimensional vectors $x = (x_1, x_2, \ldots, x_n)$ ordered from small to large; i.e., $0 < x_1 \leq x_2 \leq \ldots \leq x_n$. Let x and y be in $\mathbb{R}^n_{\leq}$. We say that x *Lorenz dominates* y, denoted by $x \succ_L y$, if for each $k = 1, 2, \ldots, n-1$

$$x_1 + x_2 + \cdots + x_k \geq y_1 + y_2 + \ldots + y_k \quad \text{and} \quad \sum_{i=1}^{n} x_i = \sum_{i=1}^{n} y_i.$$

If $x \succ_L y$ and $x \neq y$, then at least one of these $n-1$ inequalities is a strict inequality. Given two claims rules, φ and ψ, it is said that φ *Lorenz dominates* ψ, $\varphi \succ_L \psi$, if $\varphi(E,c) \succ_L \psi(E,c)$, for each claims problem (E,c).

[3]The Lorenz criterion is a key concept in the literature on income distribution. See, e.g., Sen (1973).

Hence, a Lorenz dominated rule, in some sense, respects the claims. Bosmans and Lauwers (2011) obtain a Lorenz dominance comparison among several claims rules:[4]

$$CEA \succ_L \alpha^{\min} \succ_L P \succ_L T \succ_L CEL$$

So, the CEA rule distributes the budget as egalitarian as possible, maintaining the existent differences before the budget was allocated. On the contrary, the CEL rule provides the less egalitarian distribution of the funds. Then, if one of the objectives is reducing previous inequalities, the CEL solution may be more appropriate.

Next, Figure 1 depicts the graphical expression of this dominance, the so-called Lorenz curve.[5] Note that the CEA rule is the closest to the line of perfect equality, whereas the CEL rule is the farthest one, thus the two extreme allocations are proposed by the CEA and CEL rules, the most and the least equitable distributions, respectively. Furthermore, the Lorenz dominance suggest to select the dominated solution (that is, the more unequal proposal in order to favour the less developed regions). Since we depart from an unequal situation (unequal GDP/head regions) thus the most unequal Lorenz solution (the CEL rule) provides greater convergence.

Apart from the above mentioned divergence ratio, it is noteworthy that there are different indexes widely used to measure the inequality among regions: the Atkinson index (Atkinson, 1970), the generalized entropy index (Theil, 1967), and the Gini index (Gini, 1921). Among them, the latter is the most popular one, vastly used in both official and scientific reports, and considered in the literature as the best single measure of inequality (see, for instance, Atkinson, 1970, and Aaberge and Brandolini, 2015). Formally, given k regions with population n_1, n_2, ..., n_k, and (analyzed) variables r_1, r_2, ..., r_k, the **Gini index (Gi)** (Gini, 1921) of these variables in that regions is defined by

$$Gi = \frac{1}{N^2\mu} \sum_{i=1}^{k} \sum_{j<i} |r_i - r_j| n_i n_j.$$

where $N = n_1 + n_2 + \ldots + n_k$ and μ is the average of r_1, r_2, ..., r_k.

The Gini index takes values in the interval $[0, 1]$, where $Gi = 0$ means perfect equality, and $Gi = 1$ means complete inequality, so the lower the index the more equality the allocation. We analyze how the allocations provided by all the introduced rules modify the Gini index

[4]The following result is true whenever the aggregate claim C does not exceed twice the estate E, $C \leq 2E$, which is the case in our applied problem. In the general case, the proportional and talmudian rules are not related, but the other relationships are also true.

[5]It it noteworthy that we represent the allocation provided by different claims rules and we do not represent the final situation of each region.

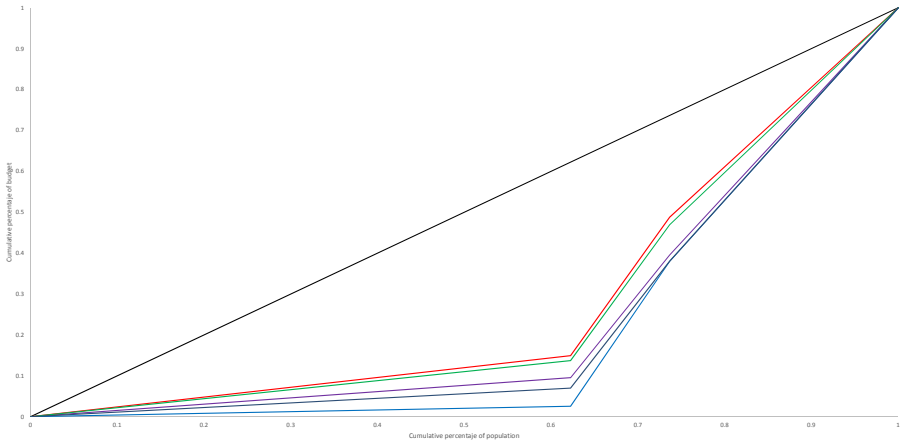

Figure 1: Lorenz representation of the allocations proposed by the considered claims rules. The black line means the perfect equality and the dark blue is the current allocation. The purple line corresponds to the P rule; the red line is the CEA rule; the blue line is equivalent to the CEL and T rule. Finally the green line corresponding to $\alpha^{\min}$ rule.

in our applied problem. It is clear that favouring regions with lower GDP/head (that is, favouring the agents with higher claims) reduces the Gini index and so the inequality among regions. As happened with the divergence ratio, The CEL rule is the one that more reduces the Gini index.

We now compute this index for the initial situation (considering the 2013 GDP/head of the three categories of regions) and the result after the application of the current proposal and the allocations provided by claims rules. Table 6 shows the Gini index for each of the considered rules. If we compare these indices, we observe that all distributions of the ERDF funds reduce the inequality (in terms of the Gini index), but only the one provided by CEL and talmudian rules (which coincide) reduce the Gini index of the current allocation. So, this index also supports the implementation of the CEL rule.

	Initial	Current	P	CEA	CEL	T	$\alpha^{\min}$
Gini index	19.74%	18.23%	18.38%	18.62%	17.99%	17.99%	18.62%

Table 6: Gini inequality index (in percentage) of the initial and the current allocations, as well as each of the allocations proposed by the considered claims rules.

6. Establishing guarantees

An alternative approach that appears in the claims problems literature consists on ensuring a certain amount to each agent (region), which depends on the total budget and the quantity that each region claims (indeed, the definition of a claims rule imposes a lower bound by the non-negative constraint). This amount is known as *lower bound* (or *guarantee*). Some commonly used lower bounds that perfectly fit in our context are the *fair lower bound* (Moulin, 2002) and the min-*lower bound* (Dominguez, 2013).

- The **Fair (FB)** lower bound (Moulin, 2002) establishes that all regions should receive at least the amount assigned to each of them in an equal division, or their full claim. Formally,

  For each $(E, c) \in \mathcal{B}$ and each region R_i,

  $$f_i(E, c) = \min\left\{c_i, \frac{E}{n}\right\}.$$

- The **Minimum (MB)** lower bound (Dominguez, 2013) proposes that all regions receive an equal amount that consists (if possible) in the *n-th* part of the smallest claim (in other case, it guarantees an equal division of the endowment). Formally,

  For each $(E, c) \in \mathcal{B}$ and each region R_i,

  $$\min_i(E, c) = \frac{1}{n}\min\left\{\min_j c_j, E\right\}.$$

If we analize the problem from the point of view of losses (the unsatisfied part of the claim), then ensuring a lower bound in losses is equivalent to establish an upper bound in awards. In this sense we define the following upper bound. We denote by L the aggregate losses, that is $L = \sum_i c_i - E$.

- The UP upper bound establishes that all regions should incur in the same loss, restricted to the fact that no region may end with a negative allocation. Formally,

  For each $(E, c) \in \mathcal{B}$ and each region R_i,

  $$UP_i(E, c) = \max\{0, c_i - L\}.$$

Table 7 provides these lower and upper bounds to each of the regions. It is noteworthy that the FB and MB bounds guarantee a more egalitarian distribution of the budget, whereas the upper bound benefits to the less developed region (since it has the larger per capita claim). If we try to apply jointly one of the lower bounds and the upper bound, we observe that

Per capita	Claim	Current	FB	MB	UP
More developed	221.03	115.34	56.74	56.74	50.82
Transition	705.31	495.09	56.74	56.74	535.10
Less developed	1,404.22	1,098.94	56.74	56.74	1,234.01
Absolute	Claim	Current	FB	MB	UP
More developed	61,901,153,827	32,300,565,888	15,889,783,492	15,889,783,492	14,231,803,350
Transition	36,181,081,146	25,396,981,020	2,910,537,689	2,910,537,689	27,449,468,078
Less developed	166,509,560,350	130,309,753,020	6,727,843,950	6,727,843,950	146,326,028,500

Table 7: Guarantees assigned to each region by lower bounds (€). The first column presents the three different economic regions. Within each region, rows provide the guarantees recommended to each of the three considered economic regions. The second column provides the claim of each of the regions in per capita terms. The third column shows the actual distribution of the health budget in per capita terms, meanwhile the rest of the columns show the allocations recommended by each of the bounds for each economic region. Finally, note that rows 2-4 show the values are in per capita terms, and rows 6-8 the values are in absolute terms.

it is not possible for the more developed regions category (since the lower bound is greater that the upper bound). With respect to the other regions, we obtain an interval that should contain the final allocation.

In order to distribute the remaining budget, if any, Giménez-Gómez et al. (2017) propose some axioms that depend on the lower bound being used. They show that by asking for some natural properties, we recover the usual claims rules.[6]

An alternative approach to distribute the non-allocated budget is by recursively applying the obtained guarantees. This process is defined in the following way: once the first guarantee is allocated to the regions, we compute new guarantees in the problem defined by the non distributed budget and the unsatisfied claims (the initial claim minus the received guarantee). Once these new guarantees are allocated to the regions, we repeat the process until the budget is completely distributed. As Table 8 shows, by recursively applying the previously introduced bounds to our problem we recover either the CEA rules (by using FB and MB) or the CEL rule (through UP).

Therefore, we obtain, as in the previous section, that those bounds that favor the largest claimant end-up a more equitable distribution of the budget in terms of convergence, since they favor the less developed region (which is the largest claimant in per capita terms).

[6]In particular, they show that the *fair* and min-*lower bound* provide the CEA rule, whereas the UP upper bound recovers the CEL rule. See Giménez-Gómez et al. (2017) for further details.

Per capita	Claim	Current	FB	MB	UP
More developed	221.03	115.34	221.03	221.03	50.82
Transition	705.31	495.09	705.31	705.31	535.10
Less developed	1,404.22	1,098.94	758.36	758.36	1,234.01
Absolute	Claim	Current	FB	MB	UP
More developed	61,901,153,827	32,300,565,888	61,901,153,827	61,901,153,827	14,231,803,350
Transition	36,181,081,146	25,396,981,020	36,181,070,669	36,181,070,669	27,449,468,078
Less developed	166,509,560,350	130,309,753,020	89,925,075,432	89,925,075,432	146,326,028,500

Table 8: Recursive application of guarantees (€). The first column presents the three different economic regions. Within each region, rows provide the allocation recommended to each of the three considered economic regions. The second column provides the claim of each of the regions in per capita terms. The third column shows the actual distribution of the health budget in per capita terms, meanwhile the rest of the columns show the allocations recommended by each of the recursive application of the bounds for each economic region. Finally, note that rows 2-4 show the values are in per capita terms, and in rows 6-8 the values are in absolute terms.

7. The ERDF Spanish evidence

For the sake of going deeply in the analysis by NUTS 2, and due to the impossibility of exposing the analysis of the total number of the EU NUTS 2 regions, we implement the aforementioned approach to the Spanish evidence that help to introduce insights in the detailed problem. That is, as Figure 2 depicts, Spain is formed by 19 regions, divided into three different groups, but analyzed in a individual way. Therefore, in our scenario the proposal for the endowment E is the ERDF budget currently allocated to all regions in Spain (in absolute terms) and its claims c_i correspond to the sum of the total budget they demanded for the period 2014-2020.

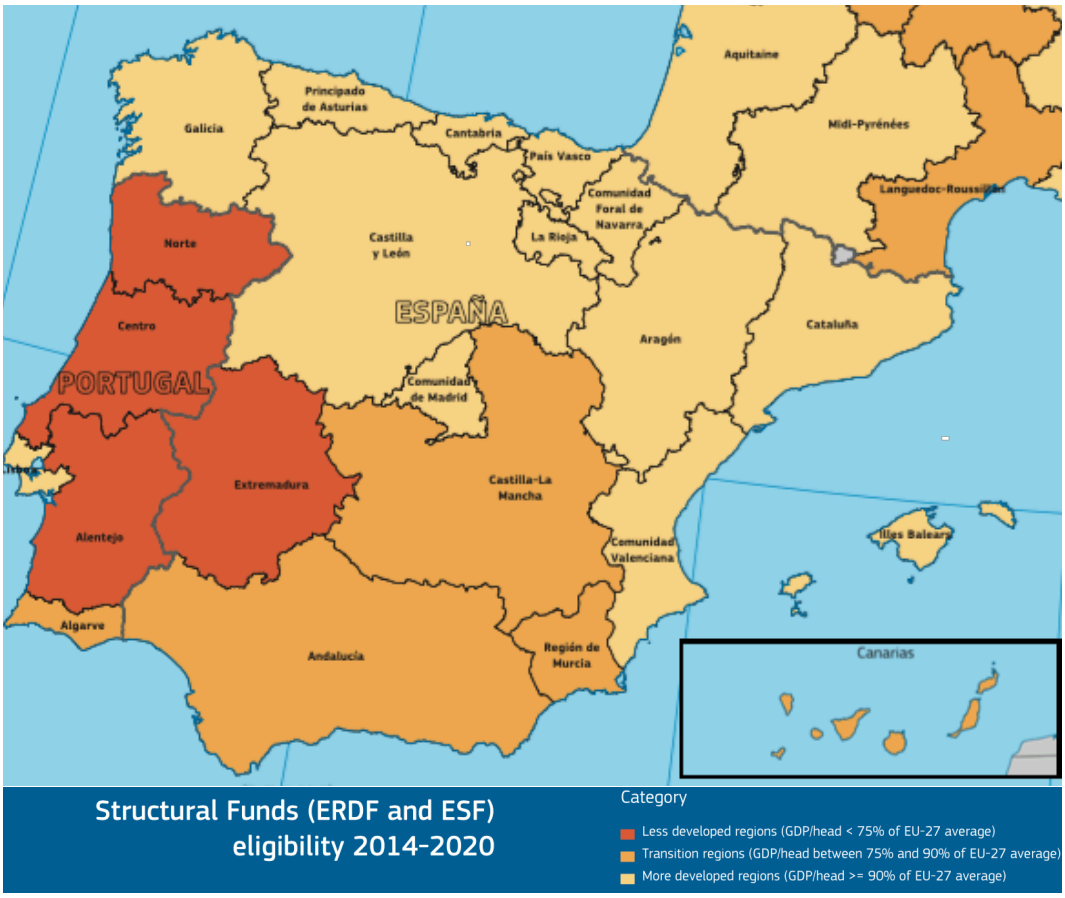

Figure 2: NUTS 2 regions in Spain: different development levels. The orange area denotes the less developed region, meanwhile the yellow and the light yellow areas highlight the transition and more development regions, respectively. Source: www.ec.europa.eu/regional_policy, www.ec.europa.eu/esf.

In order to compare the claims of these 19 regions, and the allocations they receive, it is necessary to analyze the problems in terms of *per capita* resources, since the populations are very different. Then we obtain the claims, current allocations and population. Note that the regions are ordered with respect to their claim per capita (from lowest to highest). Table 9 reflects this data.

The endowment $\mathbf{E} = 9,760,853,165.00$			
Absolute	Claim	Current	Population
Comunidad de Madrid	474,688,914	249,844,457	6,476,838
Navarra	89,018,434	44,509,217	640,353
País Vasco	352,899,958	176,449,979	2,167,323
Aragón	239,894,676	119,947,338	1,316,072
Cantabria	112,598,206	56,299,103	581,490
La Rioja	67,613,030	33,806,515	312,624
Catalua	1,671,234,350	835,617,175	7,441,284
Islas Baleares	267,392,822	133,696,411	1,150,962
Comunidad Valenciana	1,180,510,000	590,255,000	4,935,182
Castilla y Len	669,877,226	334,938,613	2,435,951
Región de Murcia	416,855,908	333,484,725	1,472,991
Asturias	329,723,791	263,779,031	1,034,302
Castilla-La Mancha	747,447,717	597,958,172	2,040,977
Galicia	1,142,109,802	913,687,840	2,710,216
Andalucía	3,990,192,722	3,200,907,333	8,408,976
Islas Canarias	1,220,044,945	1,037,038,201	2,154,978
Ceuta	56,721,428	45,377,141	85,034
Melilla	65,830,519	52,664,377	84,946
Extremadura	925,740,673	740,592,537	1,077,525
Per capita	Claim	Current	GDP
Comunidad de Madrid	73.29	38.58	30,188
Navarra	139.01	69.51	247,442
País Vasco	162.83	81.41	28,858
Aragón	182.28	91.14	24,417
Cantabria	193.64	96.82	19,965
La Rioja	216.28	108.14	23,726
Catalua	224.59	112.29	25,945
Islas Baleares	232.32	116.16	22,924
Comunidad Valenciana	239.20	119.60	19,176
Castilla y Len	275.00	137.50	20,688
Región de Murcia	283.00	226.40	18,122
Asturias	318.79	255.03	19,445
Castilla-La Mancha	366.22	292.98	17,557
Galicia	421.41	337.13	19,508
Andalucía	474.52	380.65	16,379
Islas Canarias	566.15	481.23	18,761
Ceuta	667.04	533.64	18,434
Melilla	774.97	619.97	16,670
Extremadura	859.14	687.31	15,280

Table 9: Claim and current allocation of ERDF budget according to each Spanish region (€).

Taking into the account the data in Table 9, the introduced claims rules recommend the allocations shown by Tables 10 and 11 in per capita and absolute terms, respectively. Furthermore, Table 12 shows the percentage of the claims satisfied by each of the claims rules.

Per capita	Claim	Current	P	CEA	CEL	T	$\alpha^{\min}$
Comunidad de Madrid	73.29	38.58	51.02	73.29	0.00	36.65	73.29
Navarra	139.01	69.51	96.78	139.01	44.51	69.51	112.63
País Vasco	162.83	81.41	113.36	162.83	68.33	81.41	126.88
Aragón	182.28	91.14	126.90	182.28	87.78	91.14	138.53
Cantabria	193.64	96.82	134.81	193.64	99.14	96.82	145.32
La Rioja	216.28	108.14	150.57	216.28	121.78	113.72	158.87
Catalua	224.59	112.29	156.36	224.59	130.09	122.03	163.85
Islas Baleares	232.32	116.16	161.74	232.32	137.82	129.76	168.48
Comunidad Valenciana	239.20	119.60	166.53	239.20	144.70	136.65	172.60
Castilla y Len	275.00	137.50	191.45	246.68	180.50	172.44	194.02
Región de Murcia	283.00	226.40	197.02	246.68	188.50	180.44	198.81
Asturias	318.79	255.03	221.94	246.68	224.29	216.23	220.23
Castilla-La Mancha	366.22	292.98	254.96	246.68	271.72	263.66	248.62
Galicia	421.41	337.13	293.38	246.68	326.91	318.85	281.66
Andalucía	474.52	380.65	330.35	246.68	380.02	371.96	313.44
Islas Canarias	566.15	481.23	394.15	246.68	471.65	463.59	368.29
Ceuta	667.04	533.64	464.39	246.68	572.54	564.49	428.68
Melilla	774.97	619.97	539.53	246.68	680.47	672.41	493.28
Extremadura	859.14	687.31	598.12	246.68	764.64	756.58	543.66

Table 10: Allocation of ERDF Spanish budget according to each considered rule (€).

Absolute	P	CEA	CEL	T	$\alpha^{\min}$
Comunidad de Madrid	330,473,481.57	474,688,914.00	0.00	237,344,457.00	474,688,914.00
Navarra	61,973,707.29	89,018,434.00	28,504,820.25	44,509,217.00	72,122,606.73
País Vasco	245,685,277.93	352,899,958.00	148,087,070.57	176,449,979.00	274,995,688.16
Aragón	167,012,176.71	239,894,676.00	115,525,347.39	119,947,338.00	182,310,651.50
Cantabria	78,389,699.14	112,598,206.00	57,647,169.21	56,299,103.00	84,504,341.82
La Rioja	47,071,487.80	67,613,030.00	38,069,937.38	35,551,095.89	49,667,836.68
Catalua	1,163,495,960.98	1,671,234,350.00	968,030,045.79	908,074,908.28	1,219,255,484.55
Islas Baleares	186,156,099.77	267,392,822.00	158,626,454.21	149,353,043.20	193,911,671.21
Comunidad Valenciana	821,858,775.76	1,180,510,000.00	714,133,333.76	674,370,099.96	851,797,527.15
Castilla y Len	466,361,552.95	600,892,276.93	439,678,885.49	420,052,195.10	472,625,579.46
Región de Murcia	290,210,744.69	363,352,512.38	277,657,671.34	265,789,641.85	292,847,433.60
Asturias	229,550,271.67	255,138,171.42	231,981,839.71	223,648,369.49	227,787,335.54
Castilla-La Mancha	520,365,321.46	668,547,053.37	554,574,576.94	538,130,229.87	507,434,142.14
Galicia	795,124,957.56	503,461,406.52	885,993,309.67	864,156,839.92	763,349,117.13
Andalucía	2,777,930,644.85	2,074,298,183.85	3,195,541,138.06	3,127,789,213.46	2,635,735,851.05
Islas Canarias	849,382,593.01	531,582,793.39	1,016,398,664.99	999,035,800.96	793,660,575.75
Ceuta	39,488,867.84	20,975,903.82	48,685,681.10	48,000,554.03	36,452,423.04
Melilla	45,830,522.19	20,954,196.27	57,803,088.14	57,118,670.09	41,902,064.27
Extremadura	644,491,021.83	265,800,277.06	823,914,130.98	815,232,408.91	585,803,921.22

Table 11: Allocation of ERDF budget according to each considered rule in absolute terms (€).

Absolute	Claim (€)	Current	P	CEA	CEL	T	$\alpha^{\min}$
Comunidad de Madrid	474,688,914.00	53%	70%	100%	0%	50%	100%
Navarra	89,018,434.00	50%	70%	100%	32%	50%	81%
País Vasco	352,899,958.00	50%	70%	100%	42%	50%	78%
Aragón	239,894,676.00	50%	70%	100%	48%	50%	76%
Cantabria	112,598,206.00	50%	70%	100%	51%	50%	75%
La Rioja	67,613,030.00	50%	70%	100%	56%	53%	73%
Catalua	1,671,234,350.00	50%	70%	100%	58%	54%	73%
Islas Baleares	267,392,822.00	50%	70%	100%	59%	56%	73%
Comunidad Valenciana	1,180,510,000.00	50%	70%	100%	60%	57%	72%
Castilla y Len	669,877,226.00	50%	70%	90%	66%	63%	71%
Región de Murcia	416,855,908.00	80%	70%	87%	67%	64%	70%
Asturias	329,723,791.00	80%	70%	77%	70%	68%	69%
Castilla-La Mancha	747,447,717.00	80%	70%	89%	75%	72%	68%
Galicia	1,142,109,802.00	80%	70%	44%	78%	76%	67%
Andalucía	3,990,192,722.00	80%	70%	52%	80%	78%	66%
Islas Canarias	1,220,044,945.00	85%	70%	44%	83%	82%	65%
Ceuta	56,721,428.00	80%	70%	37%	86%	85%	64%
Melilla	65,830,519.00	80%	70%	32%	88%	87%	64%
Extremadura	925,740,673.00	80%	70%	29%	89%	88%	63%

Table 12: Percentages of claims satisfied by current allocation and rules proposals for the ERDF Spanish evidence.

Next, Figure 3 and Table 13 provide insights about the equity behavior of the claims rules and the final allocation.

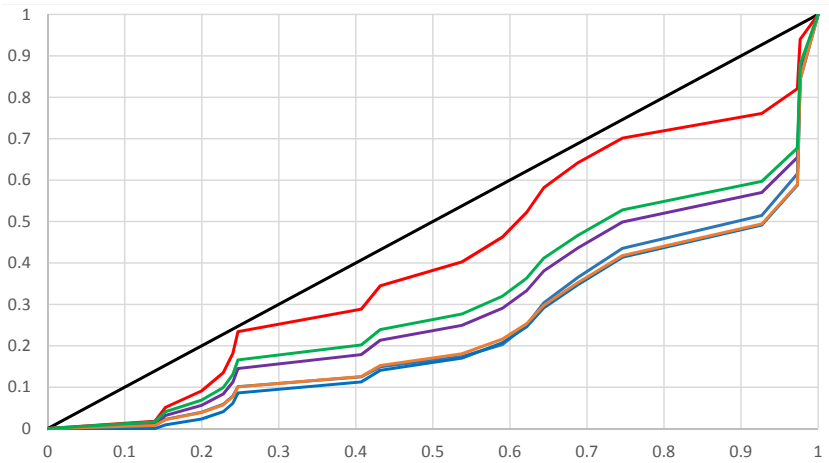

Figure 3: Lorenz representation of the allocations proposed by the considered claims rules for the ERDF Spanish evidence. The black line means the perfect equality and the dark blue is the current allocation. The purple line corresponds to the P rule; the red line is the CEA rule; the blue line is equivalent to the CEL and T rules. The green line corresponds to the $\alpha^{\min}$ rule.

	Initial	Current	P	CEA	CEL	T	$\alpha^{\min}$
Gini index	13.11%	12.91%	12.95%	13.04%	12.90%	12.91%	12.97%

Table 13: Gini inequality index (in percentage) of the initial and the current allocations, as well as each of the allocations proposed by the considered claims rules.

As shown by Tables 14 and 15, the CEL rule is the one that further reduce the divergence among regions. For the sake of clarity, we only provide what happens to the richest and the poorest regions in Spain (Madrid and Extremadura, respectively). The rest of the data may be provided by the authors under request.

Madrid VS.	AND	ARA	AST	CAN	C-L	C-M	CAT	CEU	CV
GDP/H	184%	124%	155%	151%	146%	172%	116%	164%	157%
GDP+current/H	180%	123%	153%	151%	146%	169%	116%	159%	157%
GDP+CEL/H	180%	123%	153%	150%	145%	169%	116%	159%	156%
	EXT	GAL	I-B	I-C	RIO	MEL	NAV	P-V	MUR
GDP/H	198%	155%	132%	161%	127%	181%	110%	105%	167%
GDP+current/H	189%	152%	131%	157%	127%	175%	110%	104%	165%
GDP+CEL/H	188%	152%	131%	157%	127%	174%	110%	104%	165%

Table 14: Divergence ratio afther applying current allocation and rules proposals for Madrid (the Spanish richest region).

Extremadura VS.	AND	ARA	AST	CAN	C-L	C-M	CAT	CEU	MAD
GDP/H	7%	37%	21%	23%	26%	13%	41%	17%	49%
GDP+current/H	5%	35%	19%	20%	23%	11%	39%	16%	47%
GDP+CEL/H	4%	35%	18%	20%	23%	10%	38%	16%	47%
	CV	GAL	I-B	I-C	RIO	MEL	NAV	P-V	MUR
GDP/H	20%	22%	33%	19%	36%	8%	44%	47%	16%
GDP+current/H	17%	20%	31%	17%	33%	8%	42%	45%	13%
GDP+CEL/H	17%	19%	30%	17%	33%	8%	42%	45%	12%

Table 15: Divergence ratio afther applying current allocation and rules proposals for Extremadura (the Spanish poorest region).

Finally, by applying the guarantees introduce in Section 6, the results remain valid. That is, the FB and MB lower bounds retrieve the CEA rule, and the UP upper bound, the CEL rule.

8. Final Remarks

The European Union tries to promote the social and economic cohesion of the countries members, as well as to reduce the inequalities among them. By doing so, it uses some financial instruments, being one of them the the European Regional Development Fund (ERDF).

In this paper we focus on these funds, due to their important social impact. By implementing the classical conflicting claims problem approach (O'Neill, 1982), we propose an alternative way of allocating the budget among the different regions in EU, and, in a detailed way, to the Spanish regions case.

We analyze the most usual claims rules in order to obtain alternative allocations of the budget. In order to compare different proposals, we observe, throughout different equity criteria, that the CEL rule performs better when looking for convergence and reducing inequalities across regions. By using the Lorenz dominance, a divergence ratio or the well known Gini index, always the CEL rule is the better proposal: it is the most unequal (then reducing initial inequalities), it is the one that reduces divergence the most and provides the lowest inequality Gini index. So, this way of allocating resources may be proved to be a strong candidate for future policy changes concerning the allocation of the EU funds.

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