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Power Inequality in Inter-communal Structures: The Simulated Impact of a Reform in the Case of the Municipalities in Western France

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Abstract. This paper deals with an important issue concerning democratic government: how delegates are to be allocated among jurisdictions in a federal system. More precisely, we analyze the effect of the 2010 inter-municipal reform in France, which changed the allocation of delegates between municipalities within their inter-communal structures. Using the theory of power indices and a unique set of data gathering 377 inter-municipal structures for three French regions, we compare the fairness of the distribution of municipal delegates prior to the 2010 reform to that of the new distribution, by simulating the impact of the 2010 reform. We show that this inter-communal reform may have increased power inequalities among municipalities belonging to the same inter-communal structure.

Keywords. Federalism, Power indices, Banzhaf index, Municipalities.

Classification JEL. D7

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L'inégalité de pouvoir dans les structures intercommunales: l'impact simulé d'une réforme dans le cas des communes de l'ouest de la France

Résumé. Cet article s'intéresse à une dimension importante d'un gouvernement démocratique : la répartition des délégués élus entre collectivités dans une fédération. Plus précisément, nous analysons l'effet d'une réforme votée en France en 2010 et qui a modifié la répartition des délégués des communes au sein de leur intercommunalité. En mobilisant la théorie des indices de pouvoir et un jeu de données uniques renseignant les caractéristiques de 377 structures intercommunales dans trois régions françaises, nous comparons l'équité de la répartition des délégués municipaux avant la réforme de 2010 et l'équité après cette réforme, en simulant ses effets. Nous montrons que la réforme des intercommunalités a dû accroître les inégalités de pouvoir entre communes membres d'une même intercommunalité.

Mots clés. Fédéralisme, Indices de pouvoir, Indice de Banzhaf, Municipalités.

Classification JEL. D7

1 Introduction

With 36,681 municipalities in 2010, France has the largest number of municipalities in Europe, as well as a highly fragmented structure of local government. This particularity of the French municipal organization was shaped after the French Revolution: Unlike many other countries, France did not sharply reduce its number of local governments over time.¹ However, the country followed another route to deal with these issues: inter-communal cooperation as a local government reform. This cooperation practice has a long history in France, where the first law promoting inter-communal cooperation was established in 1890. This law enabled municipalities to form groups, called *Syndicat Inter-communal à Vocation Unique (SIVU)* and *Syndicat Intercommunal à Vocation Multiple (SIVOM)* in order to jointly manage some public goods and services. These were the first so-called *Établissements Publics de Coopération Inter-communale (EPCIs)*.

In France, since the nineteen-nineties, several important laws and reforms have been carried out in order to enhance cooperation and promote the formation of inter-communal structures. These laws and reforms aim at resolving the following issues: *i)* reducing the intensity of tax competition between municipalities, *ii)* dealing with the lack of fiscal revenues in some municipalities *iii)* and providing public goods more efficiently.² Nowadays, the main types of French EPCIs are *Communautés de Communes (CC)*, *Communautés d'Agglomération (CA)*, *Communautés Urbaines (CU)* and *Métropoles*.³

One of the most recent laws, the *Loi n° 2010-1563 de réforme des collectivités territoriales* (hereafter the 2010 law), was an achievement in the long process of the development of cooperation: It required all the municipalities to join an inter-communal structure with tax autonomy before 2014. Hence, almost all the municipalities belonged to one of the 2145 EPCIs by January 2014 and this law led to the generalization of a new tier of local government: the inter-municipal level.⁴ Obviously, in such a situation, one of the cornerstones of democracy is the municipalities' representation at the group level.

By law, an EPCI is governed by its own board of municipal delegates. Typically, each municipality is represented in the inter-communal structure by one or several municipal councilors. Before 2010, the law gave

1. See for example, Canada, where the number of municipalities sharply decreased between 1996 and 2001 (Poel 2000), Finland (Saarima and Tukiainen 2014), and Japan (Weese 2015).

2. In particular, small municipalities (the 20,000 entities with less than 500 inhabitants) have difficulties in financing some public goods and services; the formation of inter-communal structures allows them to pool resources and benefit from economies of scale.

3. Note that most of the inter-communal structures are *Communautés de Communes (CC)*. More precisely, in 2015, there were 1884 CCs, 226 CAs, 9 CUs, and 11 *Métropoles*. The situation evolved rapidly as on January 2018 there were 1009 CCs, 222 CAs, 11 CUs, and 18 *Métropoles*. The differences between these forms of cooperation depend on the types of responsibilities that municipalities can transfer to the inter-municipal structures, on the size of the municipalities, and on other features.

4. Except for some municipalities which received a derogation in the Île-de-France region until January 1, 2016 to consider the creation of the *Grand Paris Métropole*. This Grand Paris Metropole gathers 131 communes located in 7 departments, with more than 7 millions of inhabitants. The high stakes associated with the dimensions of this metropole justified the delay of two years.

the inter-communal structures a lot of flexibility in the allocation of the EPCI assembly seats to municipal members. The only conditions were that: i) each municipality should have at least one delegate; ii) the population criterion should, in theory, be broadly applied, this condition being, however, freely interpreted in practice; and iii) no municipality could have a majority of inter-municipal delegates. It opened the door to very different institutional arrangements. In one inter-communal structure, we could apportion the number of delegates proportionally to the population, or use degressive proportionality, or even give the same number of delegates to any municipality, regardless of its population! Naturally, under these rules, negotiation played an important role in the way the inter-communal structures were formed; the delegates were allocated among the municipalities, and the power was divided between EPCI members.

Among the numerous objectives of the 2010 law, three points concerned the governance of inter-communal structures: 1) as said before, it obliged all municipalities to join an inter-communal structure by January 1, 2014; 2) it reduced the total number of delegates in each inter-communal structure as the flexibility afforded by the previous laws had led to an uncontrolled increase in the number of delegates; and 3) it proposed well-defined criteria in the allocation of delegates, based upon the Jefferson apportionment method. The municipal elections held on March 23 and 30, 2014 implemented all these reforms for the first time. The new inter-communal structure councils were installed a few weeks after these elections.

The purpose of this paper is to analyze the fairness of the apportionment of delegates among French municipalities before and after the 2010 law. All in all, the governance of these inter-communal structures of a federal type, where citizens are indirectly represented in the inter-communal structures' council, has been widely debated in the political economy literature (see Le Breton et al. (2017)). In fact, a central issue of democracy is to identify whether each citizen is equally represented in such a federal system regardless of her municipal location.

Since the pioneering works of Penrose (1946), Shapley-Shubik (1954), and Banzhaf (1965), the theory of power indices proposes tools to measure the voting power of individuals in a collective structure. It has made numerous contributions both on the theoretical and the empirical sides.⁵ Regarding the French inter-communal case, Bonnet and Lepelley (2001) and Bisson et al. (2004) studied the representation of the municipalities inside inter-communal structures in the *Basse-Normandie* region. The authors found that the voting power of municipalities in the inter-municipal structure is often different from their population weight,

5. For theoretical contributions, one can see Straffin (1977, 1994) and Felsenthal and Machover (1998). Over the last 70 years, empirical contributions have been numerous. Most of them deal with the analysis of power in legislative assemblies. In this line, we can suggest the recent analysis of the Greek Parliament (Koki and Leonardos, 2019) or the governance structure of the Lebanese Republic (Diss and Zouache 2015, Diss and Steffen 2017). The analysis of power in the federal union is also a widespread application of the power index tools. Without being exhaustive, see Bobay (2004), Felsenthal and Machover (2001, 2004), Laruelle and Widgren (1998) in the European Union context, Leech (2002) on the governance of the International Monetary Fund, etc.

and proposed an algorithm that computes the perfect distribution of delegates to respect power indices for the *Basse-Normandie* inter-communal structures. More recently, Kamwa and Dia (2019) replicated these analyses in two French Overseas Departments (Martinique and Guadeloupe). Using the Banzhaf power index and an inequality measure, our objective is not, as in Bisson et al. (2004), the determination of the "optimal" number of delegates for each municipality. Instead, our first aim is to compare the apportionment of delegates before vs. after the 2010 law, while our second purpose is to evaluate whether the new criteria implemented by this law improve the fairness of the representation among citizens in different municipalities.

Section 2 presents a brief description of the French institutional context, the rules set by the 2010 law, and our data set. Then, in Section 3, we present the power index that we used - the Banzhaf index - and its application in the two-tier voting mechanism. In Section 4, we analyze the fairness of the apportionment of delegates before and after the 2010 law. Concluding remarks and further research issues are presented in Section 5.

2 Institutional framework and data description

2.1 The French institutional context

As mentioned before, in the nineties, French laws left a lot of flexibility in the negotiations between municipalities required to join or create an EPCI, ranging from the total number of municipal delegates to their allocation. In order to limit this flexibility, the law of December 16, 2010 established new conditions for the allocation of delegates to each municipality in the inter-communal structure council, which is now determined according to two conditions.⁶ First, to limit the number of delegates and even before allocating them among its members, the law awards a fixed number of delegates to each inter-communal structure according to its total population (see *Table 1*).

6. We consulted the website of the *Assemblée des communautés de France* to obtain the details of the new rules. See [https://www.adcf.org/contenu-article?num_article=488&num_thematique=7].

TABLE 1 – The number of delegates assigned to the inter-communal structures by the 2010 law

Population	Number of Delegates
Less than 3,500 inhabitants	16
Between 3,500 and 4,999	18
Between 5,000 and 9,999	22
Between 10,000 and 19,999	26
Between 20,000 and 29,999	30
Between 30,000 and 39,999	34
Between 40,000 and 49,999	38
Between 50,000 and 74,999	40
Between 75,000 and 99,999	42
Between 100,000 and 149,999	48
Between 150,000 and 199,999	56
Between 200,000 and 249,999	64
Between 250,000 and 349,999	72
Between 350,000 and 499,999	80
Between 500,000 and 699,999	90
Between 700,000 and 1,000,000	100
More than 1,000,000	130

Second, the delegates must be distributed among the inter-communal structure members according to the Jefferson apportionment method:⁷

- Step 1): we determine the number of inhabitants each delegate should represent. For this, we derive the ratio between the total population N and the total number of delegates d as in *Table 1*. This fraction is known in the apportionment literature as the **Divisor** (D).

$$D = \frac{N}{d}$$

- Step 2): Next, we divide each municipality's population n_i by the divisor, to obtain its **quota** (q_i):

$$q_i = \lfloor \frac{n_i}{D} \rfloor$$

Since the law can only allocate whole delegates, the *quota* is rounded down.

- Step 3): If the total number of delegates allocated from step 2) is smaller than the number of delegates assigned to the inter-communal structure (*Table 1*), the remaining R ($R = d - \sum q_i$) delegates are allocated one by one on the basis of the highest average rule. If municipality i already has q_i delegates,

7. For more about the different apportionment methods, see Balinski and Young (2001). Note also that the 2010 law gave each EPCI the option to escape from this apportionment method provided that the alternative allocation was unanimously accepted by municipalities and that it respected some other strict conditions. See the « LOI n° 2015-264 du 9 mars 2015 autorisant l'accord local de répartition des sièges de conseiller communautaire ». However, this option was so severely regulated that it remained an infrequent occurrence.

the next delegate will be assigned to the municipality with the highest ratio:

$$\lfloor \frac{n_i}{q_i + 1} \rfloor$$

At the end of the procedure, if a municipality does not obtain a delegate, one will automatically be assigned to it.⁸

- Step 4): Moreover, if one municipality j obtains more than half the total number of delegates, the law gives fifty percent of delegates to municipality j while the remaining delegates are distributed among the other municipalities according to the method described above.

For the rarer types of inter-communal structures, namely CUs and Métropoles, delegates are apportioned on a strict population-proportional basis. Thus, a municipality with more than half of the total population of this type of inter-communal structures can account for more than 50% of the delegates allocated to the inter-communal structure. For this reason, we choose to analyze these types of inter-communal structures separately. Also, in CUs and Métropoles, delegates are not elected with a winner-take-all method as in the CCs and CAs; instead, each party represented in the municipality council can send some delegates to the upper level according to a proportional rule.

2.2 Data description

The French local institutions are characterized by three tiers of local government recognized in the Constitution. In 2010, the lowest tier consisted of 36,681 municipalities, the middle one contained 96 counties (called departments), and the top one comprised the 22 French regions.⁹ In practice, the development of inter-communal structures, with the power to tax and with numerous responsibilities, created a fourth tier between the municipalities and the departments.

In order to analyze power inequality in these French inter-communal structures, we employ an original, extensive set of data from 377 EPCIs gathering 4526 municipalities in three French regions - *Bretagne*, *Basse-Normandie* and *Pays de la Loire* - comprising twelve departments (see *figure 1*). The data were centralized by the Interior and Local Government Ministry based upon the minutes of the inter-communal structure councils. They contain the number of delegates assigned to each municipality in the three regions as of

8. In this case, the law admits that an inter-communal structure can have a number of delegates higher than the number it must have according to the figures displayed in *Table 1*. See an example in *Table 2*.

9. In 2014, the French parliament passed a law reducing the number of metropolitan regions from 22 to 13 effective on January 1, 2016. Also, recently, changes to French law have facilitated the possibility of mergers among municipalities, and their number in France has slowly decreased since 2010, to 32,287 by 2017.

January 1, 2010.¹⁰ To analyze the possible consequences of the 2010 law, we derived the new allocation of delegates by applying the Jefferson method suggested by the 2010 law and the constraints of *Table 1* to the 2010 population data.

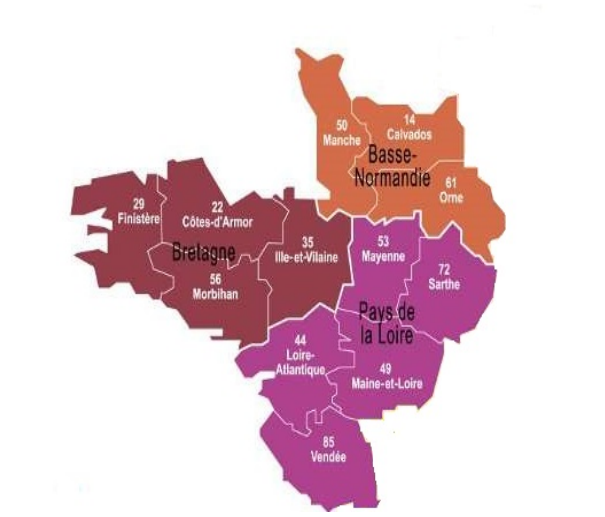


FIGURE 1 – Regions and departments in our data set

To give an example, *Table 2* presents an inter-communal structure in the *Calvados* department, the *Basse-Normandie* region named *Communauté de communes Coeur de Nacre*. The first column in *Table 2* gives the names of the member municipalities. The next column, called "*Pop10*", displays the population n_i of each member i in 2010. The column headed "*%Pop10*" derives the population of each member as a percentage of the total population of the inter-communal structure. The column headed "*Pop10/Quota*" derives the population of each municipality divided by the quota. The column named "*Nbr – del*" gives the number of delegates assigned to each municipality-member before the law of 2010, while the last column, headed "*Nbr – del – S*", gives the simulated number of delegates assigned to each municipality-member according to the new criteria. According to *Table 1*, this inter-communal structure should be represented by 26 delegates, which means that the quota to get a delegate is 18,228 divided by 26, that is 701.07. Dividing the population by the quota, we allocate 20 delegates. The remaining additional delegates go to *Douvres-la-Délivrande* (+2), *Luc-sur-Mer* (+1), *Cresserons*(+1) and *Anisy* (+1). As *Plumetot* and *Colomby-sur-Thaon* are left with no

10. Technically, we could have analyzed the apportionment of delegates for all the French regions. However, considering the time constraints that the correction of data imposes, we chose to restrict our analysis to certain regions. First, these three regions have historically a high number of municipalities belonging to inter-communal structures, a fact that makes the comparison before and after reform possible. Second, we chose these three regions because of their geographical proximity to our laboratories. This allowed us to reach out to our personal acquaintances in order to contact the EPCIs more easily when it became necessary to check the consistency of our data. Note that this data base is the last one available to analyze the allocation of delegates between municipalities, the 2014 allocation being unknown from a national point of view.

delegate, two delegates are added to the inter-communal structure council to obtain a total of 28 delegates.

TABLE 2 – Communauté de communes Cœur de Nacre (department 14 « Calvados »)

Municipalities	Pop10	%Pop10	Pop10/Quota	Nbr-del	Nbr-del-S
Plumetot	215	1.17	0.30	2	1
Colomby-sur-Thaon	415	2.27	0.59	2	1
Anisy	665	3.64	0.94	3	1
Anguerny	812	4.45	1.15	3	1
Basly	910	4.99	1.29	3	1
Cresserons	1,217	6.67	1.73	4	2
Langrune-sur-Mer	1,723	9.45	2.45	5	2
Saint-Aubin-sur-Mer	1,836	10.07	2.61	5	3
Bernières-sur-Mer	2,379	13.05	3.39	5	3
Luc-sur-Mer	3,172	17.40	4.52	7	5
Douvres-la-Délivrande	4,884	26.79	6.96	8	8
Total	18,228	100		47	28

As said before, the data reported in the "*Nbr – del*" column are derived from the analysis of the minutes of the inter-communal structure councils. More precisely, these data were obtained from the report of the inter-communal structure board. Unfortunately, they contained some obvious errors and inconsistencies, as they were extracted from the raw minutes. In fact, we noticed that the number of delegates assigned to certain municipalities was problematic (for 56 *EPCIs* of our data set) in the sense that municipalities with very few inhabitants had, according to the raw data set, more delegates than municipalities with more inhabitants, which is an a priori unexpected situation. In the absence of fixed and clear rules for the attribution of a number of delegates per municipality before January 2010, we tried to address this problem by initially classifying the problematic cases into two types.¹¹

Demographic trend: First, sometimes the number of municipal delegates was defined well before 2010, and some municipalities did not update the number of delegates according to their changing numbers of inhabitants. We can identify this source of error by checking the consistency of the delegates allocated against the 1999 census data. For instance, *Table 3* gives an example of demographic errors for the inter-communal structure Val ès Dunes.

11. Appendix I gives the classification of the 56 *EPCI* that we identified according to the different types of errors.

TABLE 3 – Communauté de communes du Val ès Dunes (department 14 « Calvados »)

Municipalities	Pop-1999	Pop-2010	Nbr-del	Correction
Poussy-la-Campagne	93	97	2	=
Conteville	82	98	2	=
Saint-Ouen-du-Mesnil-Oger	147	165	2	=
Canteloup	166	170	2	=
Ouézy*	-	238	2	=
Cesny-aux-Vignes	500	295	2	=
Billy	320	332	2	=
Cléville	272	335	2	=
Fierville-Bray	438	462	2	=
Chicheboville	463	516	2	=
Vimont	486	581	3	=
Airan	703	587	3	=
Cagny	1,597	1,483	5	=
Bellengreville	1,418	1,496	4	5
Frénouville	1,498	1,609	5	=
Moult	1,139	1,687	4	5
Argences	3,274	3,495	8	=
Total			52	54

* Note to Table 3: From January 1, 1972, to December 31, 2005, the Ouézy municipality was merged with Cesny-aux-Vignes. Then, the municipalities were separated again. This explains why the population of *Cesny-aux-Vignes* decreased.

Looking carefully at the number of delegates allocated to each municipality, we notice that despite Moult's larger population in 2010, the municipality has fewer delegates than Frénouville. This can be explained by the fact that the Frénouville municipality had a larger number of inhabitants in 1999 than Moult, and that the number of delegates had not been updated in 2010 according to the change in the municipality's population. We assume that, if the inter-communal structure had had a chance to update its number of delegates, the problem would have disappeared, and we adjust our figures accordingly.

"Gross/coarse" error in the Minutes: In this case, the population numbers do not justify the number of municipal delegates allocated to each municipality (either in 1999 or in 2010). This type of error can be divided into 3 subtypes:

- "Clear" gross error in the Minutes: This is the case when the delegate allocation problem is easy to correct according to the logic of population levels. *Table 4* gives an example of this error type. Looking at the number of delegates allocated to each municipality, we notice that the Bréhand municipality has fewer delegates than Landéhen, even though Bréhand has a larger population in both 1999 and 2010 than Landéhen. Thus, we can suspect that this is a gross error in the minutes used to build the database. To deal with this problem, we decide to add another delegate to the Bréhand municipality.

TABLE 4 – Lamballe Communauté (department 22 « Côtes D’Armor »)

Municipalities	Pop-1999	Pop-2010	Nbr-del	Correction
Quintenic	275	331	2	=
Saint-Trimoël	327	391	2	=
Saint-Rieul	335	412	2	=
La Malhoure	355	450	2	=
Saint-Glen	564	562	2	=
Penguily	427	567	2	=
Trébry	730	719	2	=
Noyal	799	801	2	=
Morieux	786	859	2	=
Meslin	723	889	2	=
Andel	928	1,024	2	=
Hénansal	954	1,031	2	=
Landéhen	1,006	1,251	2	=
Bréhand	1,293	1,404	1	2
Coëtmieux	1,289	1,515	2	=
Pommeret	1,758	1,845	2	=
Lamballe	11,187	11,261	17	=
Total	23,736	25,312	48	49

- ”Corrected” error: In the less clear cases, we contacted the *EPCI* directly and confirmed the actual number of delegates allocated to the inter-communal structures. In order to illustrate this type of error, let us take a simple example: the CC du Bocage (*Table 5*).

TABLE 5 – Communauté de communes du Bocage (department 14 « Calvados »)

Municipalities	Pop-1999	Pop-2010	Nbr-del	Correction
Les Cerqueux	652	788	2	3
Somloire	806	892	3	=
La Plaine	835	936	4	3
Coron	1,333	1,477	2	3
Yzernay	1,625	1,660	2	3
Maulévrier	2,899	2,951	3	=
Total	8,150	8,704	16	18

If we look closely at the number of delegates allocated to each municipality here, we notice that Somloire has a higher number of delegates than Coron or Yzernay, even though those municipalities had more inhabitants both in 1999 and 2010 than Somloire; thus, we can probably assume that this is a gross error. Similarly, La Plaine has more delegates than Coron or Yzernay but a lower number of inhabitants. To deal with this problem, we contacted the inter-communal structure and obtained the right number of delegates for the year 2010 (3 delegates each).

- ”Deleted error”: In some problematic cases, we were unable to check the accuracy of the data and/or we could not find a logical way to correct it. For example, we can take the case of the Percy municipality (*Table 6*).

TABLE 6 – Communauté de Communes du Canton de Percy (department 50 Manche)

Municipalities	Pop-1999	Pop-10	Nbr-del
La Haye-Bellefond	70	73	2
Morigny	84	90	2
Le Guislain	129	114	2
Maupertuis	128	134	2
Margueray	132	151	2
Villebaudon	287	282	3
Montabot	273	286	2
Le Chefresne	281	300	2
Montbray	412	371	3
Beslon	506	514	3
La Colombe	569	619	3
Percy	2,219	2,216	6

We can notice that the Villebaudon and Montabot municipalities have almost the same population size in both the 1999 and 2010 censuses, but that Villebaudon has one delegate more than the Montabot municipality and even more compared to the Le Chefresne municipality. As we were unable to check the accuracy of these data, we decided to delete this EPCI from our database. For the same reason, we deleted only one other inter-communal structure: Le Leff CC in the 22 department. The classification of all the problematic cases according to the types of errors described above is given in the appendix I.¹²

Hence, of the 377 EPCIs existing in 2010 in the three French regions under scrutiny, we are able to exploit 375 EPCIs grouping more than 4500 municipalities. This allows our empirical analysis to be the first, to our knowledge, to evaluate the fairness in the allocation of delegates within a federal body with such a high number of federal institutions, granted by a real freedom to choose how to share the seats in the federal assembly. In the following section, we present our power index and the reasoning behind it to evaluate the degree of inequality between municipal members of one inter-municipal structure.

3 The measurement of voting power in inter-communal structures

Clearly, the few examples displayed above demonstrate that the inter-communal structures had a lot of flexibility in the allocation of delegates before 2010. We can easily infer that in the 2010 law, one of the aims of the legislators was to give more specific guidelines to the inter-communal structures, assuming that the proportional rule is the ideal that should be met. But is it the right thing to do in this context? Another

¹². Details of these classifications are available upon request.

criterion we can use for the allocation of delegates in an inter-communal structure is the following: each citizen should have the same a priori probability to be a swinger.¹³ That is, the probability of influencing the result of a vote should be equalized regardless of the municipality the voter resides in. This idea has been developed in the power index literature for the analysis of decisions in two-tier voting rules (Penrose 1946, Banzhaf 1965), and applied to numerous cases such as the US Electoral College (Owen 1975, Gelman et al. 2004) or the European Union (Felsenthal and Machover 2001, 2004).

3.1 The definition of the Banzhaf index

Banzhaf uses the same idea as Penrose (1946) and considers that the power of a voter i in an assembly is measured by her capacity to change the assembly decision by reversing her vote. In a game (N, v) , $N = \{1, \dots, N\}$ is a set of the N members of the voting structure, or players in the game. v is a real-valued function defined on the subsets of N to $\mathbb{R}$. A coalition S is a non-empty subset of N . The game is called a simple game if $v(S) \in \{0, 1\}$. If $v(S) = 0$, then S is a losing coalition, while if $v(S) = 1$ then, it is a winning coalition. Let us denote by $\mathcal{W}$ the set of all winning coalitions; sets not in $\mathcal{W}$ are called losing coalitions. That is to say, if members of S vote on an amendment then, the amendment passes if S in $\mathcal{W}$, and it is rejected otherwise. A member i of a voting structure is decisive if her vote may change the result of the vote; that is to say, if i votes "Yes," the decision is adopted, while if he or she votes "No", the decision is rejected ($v(S)=1$ and $v(S - \{i\})=0$). A minimal winning coalition is a winning coalition in which all players are decisive.

The non-normalized Banzhaf index of player i is equivalent to the Penrose index:

$$B_i(v) = \frac{\sum_{S \subseteq N, i \in S} [v(S) - v(S - \{i\})]}{2^{n-1}}$$

Where 2^{n-1} is the number of coalitions to which player i may belong and S is a non-empty subset of N . This index gives the probability that a player i is decisive. The formula of the normalized Banzhaf index is:¹⁴

$$BB_i(v) = \frac{B_i(v)}{\sum_{i \in N} B_i(v)}$$

A particular class of simple games is the weighted quota games. They are defined by a vector of positive

13. A *swinger* is a voter/player who casts a vote that may allow a motion to succeed and/or would change the outcome of an election. In the literature, there are two synonyms for swinger: *decisive* player and *pivotal* player.

14. We can note that the Banzhaf index can be used to compare the relative power of voters inside the same assembly and under the same decision rule. However, the Banzhaf index is not appropriate to compare the voting power of different voters (or of one voter) under different decision rules, as the Penrose index is.

weights, $\tilde{a} = (a_1, a_2, \dots, a_n) \in \mathbb{R}_+^n$ and a quota $q \in [0, \sum_{i \in n} a_i]$. a_i is the weight attached to player i , and a coalition S is winning if and only if $\sum_{i \in S} a_i > q$. Typically, any inter-communal structure council can be modeled as a weighted quota game, where a_i is the number of delegates controlled by a municipality i , and q is equal to half of the weights.

3.2 Power in two-tier voting systems

The inter-communal structure council can be viewed as a two-tier voting system. In each municipality, the citizens elect their delegates to represent them in the municipal council; then, this municipal council elects its delegates in the inter-municipal structure; that is, the council of delegates is the upper tier in a composite two-tier system. Ideally, when a decision is proposed, the citizens vote "Yes" or "No", and according to the majority will of their citizens, all the delegates are assumed to report this majority decision in bloc.

In this study, our objective is to evaluate the inequality of voting power in French inter-communal structures. In other words, we aim to analyze the fairness of the distribution of the delegates among municipalities belonging to the same inter-communal structure. We are here interested in the ex-ante distribution of municipal delegates in the inter-communal structure councils and not in the different ex-post decisions that the delegates make. Moreover, our aim is to calculate the different coalitions of delegates that may arise and not to analyze the way citizens and delegates vote. We choose to use the most simple way to consider all these combinations, that is the Banzhaf index, rather than other indices.¹⁵

According to Penrose, the probability of voter i being decisive is the product of the probability that i is decisive in her municipality times the probability that her municipality is decisive in the inter-communal structure. Hence, equity can be implemented using the law of probability. In a model where voters have to choose between two exclusive proposals A and B, where each vote is determined by independently flipping a fair coin randomly and each municipality is represented by a weight a_j at the federal level, the independence

15. Academic treatments, as far as we know, do not cover or at least do not agree on a theoretical account of the choice of the most suitable power index. For instance, in studies concerning European Union decision-making, some arguments can be found in favor of the Banzhaf index. Felsenthal and Machover (2001) analyze the distribution of power of the Council of Ministers of the European Union and argue that the Banzhaf index is the most appropriate measure of power in their case. A similar conclusion is drawn in the study of Laruelle and Widgren (1998), who analyze fairness in the allocation of votes among the EU states. They claim that the non-normalized Banzhaf index is the most appropriate to their study. Laruelle and Widgren argue that in the absence of information about the probability of coalition formation (equal or different probabilities), the Banzhaf index is the most appropriate. Also, for two tiers voting systems, there are hardly any theoretical works that studied the adjustment of other power indices to this situation, Owen (1975) being a rare exception.

of votes across voters allows Penrose to state that:

$$\begin{aligned} & \text{Probability that citizen } i \text{ in municipality } j \text{ is decisive in the assembly} = \\ & \frac{\text{Probability that citizen } i \text{ is decisive in her municipality} \times}{\text{Probability that municipality } j \text{ is decisive in the group}} \end{aligned} \quad (1)$$

As the probability of being decisive in municipality j with n_j inhabitants can be approximated by $\frac{\sqrt{2}}{\sqrt{\pi n_j}}$ when n_j is large, equity in terms of power between citizen i in municipality j and citizen i' in municipality j' is achieved if:

$$B_j \frac{\sqrt{2}}{\sqrt{\pi n_j}} = B_{j'} \frac{\sqrt{2}}{\sqrt{\pi n_{j'}}} \quad (2)$$

Said differently, the ratio between the Banzhaf indices of the two municipalities must be equal to the ratio of the square roots of their populations. Hence, equity in terms of power will be achieved if the normalized Banzhaf power of municipality j is as close as possible to its share of population, measured in square root terms ($\frac{\sqrt{n_j}}{\sum \sqrt{n_j}}$). We will define the *Quotient* of a municipality j as:

$$Q_j = \frac{BB_j \sum \sqrt{n_j}}{\sqrt{n_j}} \quad (3)$$

This variable should be as close as possible to 1 for each municipality; a value superior to 1 (inferior to 1) indicates that it is overweighted (underweighted). In order to evaluate inequality in terms of power as measured by the Banzhaf index, we use the *max-min* index: it indicates the number of times that the most powerful citizen is more powerful than the least powerful citizen:

$$\max - \min = \frac{Q_j^{\max}}{Q_j^{\min}}$$

Our choice is slightly different from the one proposed by Felsenthal and Machover (2001), who use instead $Max(d) = Q_j^{\max} - 1$ and $ran(d) = Q_j^{\max} - Q_j^{\min}$. We felt that our measure, max-min, had a more direct interpretation. Also, to analyze the whole distribution of power, they propose to use classic statistical indices, ρ and χ^2 , to check whether the distributions of power among the municipalities are close to the vector of the square roots of populations. However, Felsenthal and Machover do not provide any theoretical argument to justify their use of these standard indices. We computed both the *max-min* and χ^2 indices, but we will report results for the *max-min* index only, as the results are similar.¹⁶

16. Felsenthal and Machover (2001,2004) also obtained very similar results with different measures.

4 The impact of the 2010 law on the power inequality in EPCIs: empirical results

4.1 The method and the main results

In this section, we will compare the fairness of the apportionment of delegates in the French inter-communal structures of three regions in Western France before and after the 2010 law. We will derive our criterion Q_j and max-min index, which we have used to evaluate the fairness of the distribution of delegates. As a first step of our analysis, we calculate the normalized Banzhaf index for each municipality within an inter-communal structure. For this, we developed an algorithm using the "R" software. The algorithm computes, in a first step, all possible coalitions that can be formed by the municipal delegates in the inter-municipal structure. In a second step, it selects all the coalitions whose weight is greater than the quota, then calculates the number of times that a given player is a swinger. This number is then divided by the number of times the other players are swingers.¹⁷ Table 7 gives an example of the calculation of our indices.

TABLE 7 – Communauté de communes Coeur de Nacre (department 14 « Calvados »)

Municipalities	Pop10	Nbr-del	Banzhaf %	$\frac{\sqrt{popmun10}}{\sum \sqrt{popmun10}}$	Quotient	max-min
Plumetot	215	2	4.24	3.54	1.19	(1.19/0.86) = 1.45
Colomby-sur-Thaon	415	2	4.24	4.92	0.86	
Anisy	665	3	6	6.23	0.96	
Anguerny	812	3	6	6.88	0.87	
Basly	910	3	6	7.29	0.82	
Cresserons	1,217	4	9.04	8.43	1.07	
Langrune-sur-Mer	1,723	5	10.48	10.03	1.04	
Saint-Aubin-sur-Mer	1,836	5	10.48	10.35	1.01	
Bernières-sur-Mer	2,379	5	10.48	11.78	0.88	
Luc-sur-Mer	3,172	7	15.29	13.61	1.12	
Douvres-la-Délivrande	4,884	8	17.69	16.89	1.04	
Total	18,228	47	100	100		

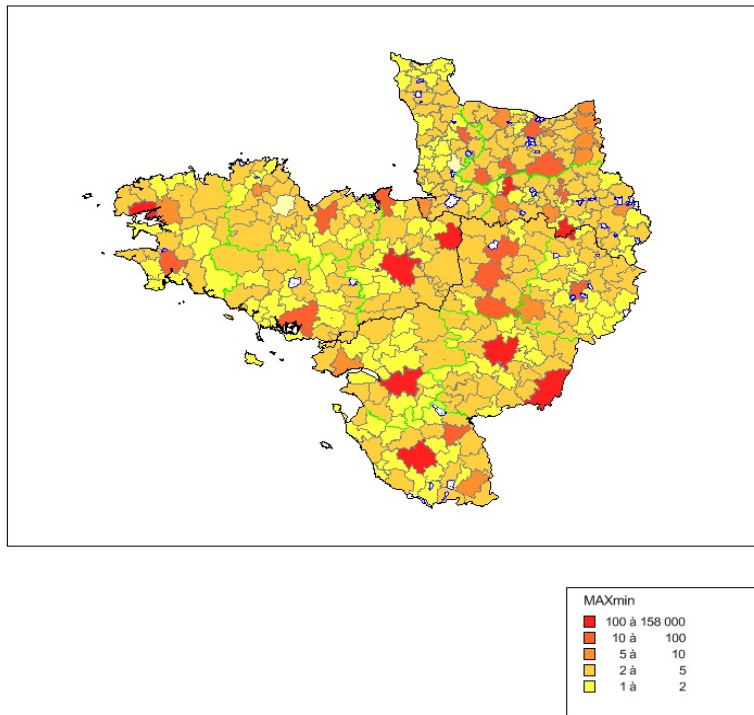
The fourth column, named "*Banzhaf %*", gives the normalized Banzhaf index as a percentage of the total number of swing situations. The quota is set as the least integer strictly greater than 50% of the total weight. The column headed "Quotient" is the division between the column "*Banzhaf %*" and the relative square root of the population (the fifth column). The column named "*max-min*" shows power inequality in the studied EPCI using the ratio of the power between the most powerful municipality and the least powerful one.

In a nutshell, Figure 2 and Figure 3 illustrate our main result: the drastic increase of the max-min ratio

17. In order to check our calculations, we also used automatic computation, via Dennis Leech's website; refer for details at [[http://homepages.warwick.ac.uk/\\$\\$\sim\\$secaae/](http://homepages.warwick.ac.uk/$$\sim$secaae/)] .

across the regions of Western France after the 2010 reform.¹⁸ This result was to be expected for the new law as, by definition, the Jefferson method is proportional to the population, while the power index theory points towards a repartition of the seats that should be proportional to the square root of the population.¹⁹ To some extent, the pre-reform repartition of power comes as a surprise as it was unexpectedly similar to the theoretical recommendation for many inter-municipal structures. We shall come back to this puzzling fact in the conclusion but let us first analyze in detail the situation before and after the 2010 law.

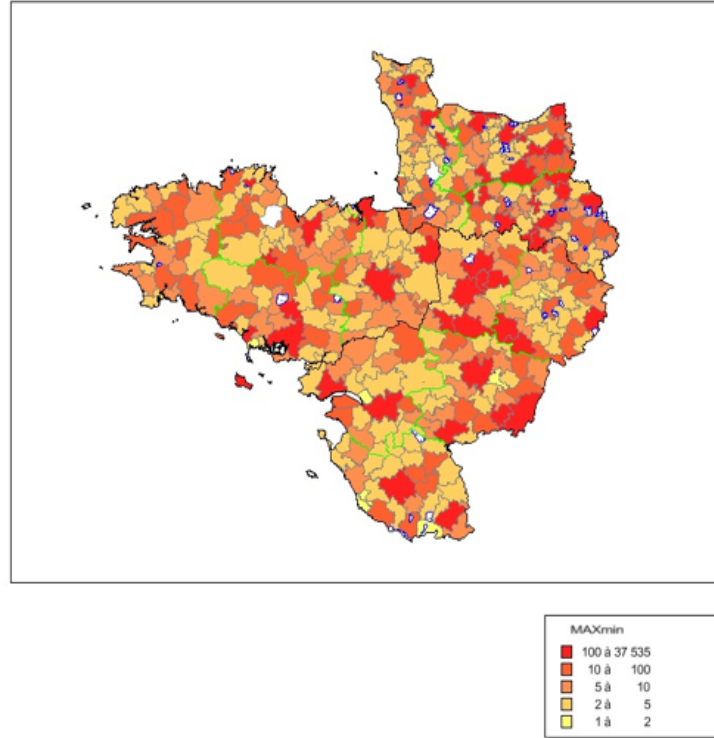
FIGURE 2 – Geographic distribution of the max-min index in EPCIs before the 2010 law



18. Note that the blank EPCIs are the EPCIs where the raw data were uncertain, as explained before.

19. Incidentally, Barthélemy and Martin (2011) pointed out that among the classic proportional apportionment rules, the Jefferson method was the worst when it comes to equalizing the Banzhaf power of the US citizens in the Electoral College.

FIGURE 3 – Geographic distribution of the max-min index in EPCIs following the 2010 law



4.2 Power inequalities in EPCIs before the 2010 law

For the general cases (all the 370 inter-communal structures when excluding the 2 undocumented EPCIs and the 5 CU inter-communal structures that deserve a special treatment), *Table 8* gives the distribution of the max-min ratios across departments and regions. Our main result is the following: before the 2010 law of inter-municipal reform, most EPCIs have power inequalities lower than 5, with inequality lower than 2 in 140 EPCIs (37.83 % of the 370 EPCIs), and between 2 and 5 in 195 EPCIs (52.7%). Thus, only 35 inter-municipal communities are characterized by relatively high inequalities, representing only 9.46% of the entire set of these federal (inter-municipal) structures existing in the 3 studied regions in 2010.

TABLE 8 – Classification of inter-communal structures according to the value of the *max-min* ratio before the 2010 law

Region	Departments	≥ 1 & ≤ 2	> 2 & ≤ 5	> 5 & ≤ 10	> 10 & ≤ 100	> 100	%prop > 5
Basse Normandie	Calvados	4	24	6	4	0	26
	Manche	19	25	1	1	0	4
	Orne	12	24	3	1	1	12
	Total	35	73	10	6	1	13
Bretagne	Côtes D’Armor	13	24	1	1	0	5
	Finistère	11	11	1	1	0	8
	Ille-Et-Vilaine	10	15	0	1	2	10
	Morbihan	14	11	0	1	0	3
	Total	48	61	2	4	2	6
Pays de la Loire	Loire Atlantique	13	7	1	0	0	4
	Maine-et-Loire	11	17	0	0	2	6
	Mayenne	2	12	1	3	0	22
	Sarthe	16	14	0	0	0	0
	Vendée	15	11	1	1	1	10
	Total	57	61	3	4	3	7
Total		140	195	15	14	6	9

More precisely, according to max-min values, our inter-communal structures can be classified as follows:

Category 1: $1 \leq \text{max-min} \leq 2$. Although the ratios remain relatively close to one, our results show that 140 inter-communal structures belong to this category. This means that the most powerful citizen in these inter-communal structures is at most twice as decisive as the least powerful one. This is the case in 35 EPCIs in Basse Normandie, 48 in Bretagne and 57 in Pays de La Loire (see *Table 8*). We find, in this class, many inter-communal structures that assign the same number of delegates to all municipalities without regard to population size. *Table 9* gives an example of this type of inter-communal structure where the population ratio between the smallest and the largest municipalities remains lower than 1/2.

TABLE 9 – CC de L’Aulne Maritime (department 29 « Finistère »)

Municipalities	popmun10	Nbr-del	Banzhaf %	Quotient	max-min
Saint-Ségal	944	5	25	1.33	(1.33/0.67)
Rosnoën	960	5	25	1.32	=
Le Faou	1,708	5	25	0.99	1.983
Pont-de-Buis-lès-Quimerch	3,715	5	25	0.67	

Also in this category 1 of EPCIs with small inequalities, we find inter-municipal structures in which the largest municipality has a share of delegates lower than its weight in the inter-communal population. To

illustrate this, we give two examples of inter-communal structures with one large municipality: The first example is the case where the inter-communal structure holds a small number of members (*Table 10*), while the second one depicts the case where the inter-communal structure holds a relatively large number of municipalities (*Table 11*). This last category is an illustration of the Penrose law: The weight of the largest municipality is not big enough for it to get most of the power.²⁰

TABLE 10 – CC de Belle Ile en Mer (department 56 « Morbihan »)

Municipalities	popmun10	popmun10 %	Nbr-del	Nbr-del %	Banzhaf %	Quotient	max-min
Locmaria	789	15.55	4	0.21	16.7	0.81	(1.37/0.76)
Sauzon	867	17.09	4	0.21	16.7	0.77	=
Bangor	894	17.62	4	0.21	16.7	0.76	1.802
Le Palais	2,522	49.72	7	0.36	50	1.37	
Total	5,072	100	19				

TABLE 11 – CC du Pays de Questembert (department 56 « Morbihan »)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del %	Banzhaf %	Quotient	max-min
Le Cours	517	2.55	2	5.26	5.08	1.06	(1.24/0.81) = 1.53
Saint-Gravé	696	3.43	2	5.26	5.08	0.92	
Rochefort-en-Terre	710	3.50	2	5.26	5.08	0.91	
Larré	737	3.63	2	5.26	5.08	0.89	
Lauzach	872	4.30	2	5.26	5.08	0.82	
Molac	1,224	6.04	3	7.89	7.60	1.03	
Limerzel	1,238	6.11	3	7.89	7.60	1.03	
Pluherlin	1,267	6.25	3	7.89	7.60	1.02	
La Vraie-Croix	1,290	6.36	3	7.89	7.60	1.01	
Berric	1,428	7.04	3	7.89	7.60	0.96	
Caden	1,558	7.69	3	7.89	7.60	0.92	
Malansac	1,999	9.86	3	7.89	7.60	0.81	
Questembert	6,720	33.17	7	18.42	21.32	1.24	
Total	20,256	100	38	100	100		

Category 2: $2 < \text{max-min} \leq 5$. The max-min index of 52.7% of inter-communal structures (195 EPCIs) lies between 2 and 5. This means that the most powerful citizen in terms of voting power could be 5 times more decisive than the least powerful one. *Tables 12 and 13* show similar cases as in the first category but with an increase in power of the largest municipalities. According to *Table 8*, we can infer that the three regions have a majority number of their inter-communal structures in this category.

20. Penrose (1946) noticed that, as long as the number of players is large and no player dominates the other outrageously in terms of weight, the Banzhaf index of player i tends to be proportional to its weight a_i in a weighted majority game.

TABLE 12 – Communauté de Communes Côte de Penthièvre (department 22 « Côtes D’Armor »)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del%	Banzhaf %	Quotient	max-min
La Bouillie	802	5.94	3	10.34	3.33	0.32	(1.24/0.32)
Plurien	1,368	10.14	4	13.79	16.67	1.24	=
Planguenoual	1,773	13.14	4	13.79	16.67	1.09	3.87
Saint-Alban	1,832	13.57	4	13.79	16.67	1.07	
Erquy	3,764	27.89	7	24.14	23.33	1.04	
Pléneuf-Val-André	3,957	29.32	7	24.14	23.33	1.02	
Total	13,496	100	29	100	100		

TABLE 13 – CC Au Pays de la Roche aux Fées (department 35 «Ille-Et-Vilaine»)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del %	Banzhaf %	Quotient	max-min
Arbrissel	256	0.88	2	3.23	3.05	1.27	
Forges-la-Forêt	272	0.93	2	3.23	3.05	1.24	
Sainte-Colombe	304	1.04	2	3.23	3.05	1.17	
Chelun	314	1.08	2	3.23	3.05	1.15	
Eancé	355	1.22	2	3.23	3.05	1.08	
Boistrudan	665	2.28	2	3.23	3.05	0.79	(1.76/0.53)
Thourie	671	2.30	2	3.23	3.05	0.79	=
Brie	774	2.65	2	3.23	3.05	0.73	
Marcillé-Robert	931	3.19	2	3.23	3.05	0.67	3.32
Essé	1,032	3.54	2	3.23	3.05	0.63	
Rannée	1,159	3.97	2	3.23	3.05	0.60	
Coësmes	1,345	4.61	2	3.23	3.05	0.56	
Le Theil-de-Bretagne	1,489	5.10	2	3.23	3.05	0.53	
Amanlis	1,567	5.37	3	4.84	4.60	0.78	
Bais	2,020	6.92	4	6.45	6.15	0.91	
Piré-sur-Seiche	2,134	7.32	4	6.45	6.15	0.89	
Martigné-Ferchaud	2,598	8.91	6	9.68	9.38	1.23	
Retiers	3,575	12.25	7	11.29	10.84	1.21	
Janzé	7,711	26.43	12	19.35	23.17	1.76	
Total	29,172	100	62	100	100		

Category 3: $5 < \text{max-min} \leq 10$. In only 15 EPCIs, the *max-min* index ranges between 5 and 10. That is to say, the most powerful citizen in these EPCIs is at least 5 times more decisive than the least powerful one. In particular, we find in this category inter-communal structures with many small municipalities and one or two large municipalities. This is the case of CC du *Pays de Bégard* in Table 14.

TABLE 14 – CC du Pays de Bégard (department 22 « Côtes D’Armor»)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del %	Banzhaf %	Quotient	max-min
Landebeàron	207	2.40	2	7.69	4.65	0.69	
Kermoroc’h	386	4.48	2	7.69	4.65	0.50	(2.13/0.34)
Saint-Laurent	428	4.97	2	7.69	4.65	0.48	=
Trégonneau	470	5.45	2	7.69	4.65	0.45	6.26
Squiffiec	728	8.45	3	11.53	6.97	0.55	
Péder nec	1,829	21.24	4	15.38	6.97	0.34	
Bé gard	4,562	52.98	11	42.30	67.44	2.13	
Total	8,610	100	26	100	100	100	

Category 4: $10 < \text{max-min} \leq 100$. The most powerful citizen in 14 EPCIs is at least 10 times more decisive than the least powerful one. This is the case for inter-communal structures which hold a large number of small municipalities. With 48 municipalities with one delegate among its 57 members, CC *Du pays de Falaise* in *Table 15* is an example of such a category.

TABLE 15 – CC Du pays de Falaise (department 14 «Calvados»)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del%	Banzhaf %	Quotient	max-min
Rapilly	41	0.15	1	1.19	0.87	1.38	(4.68/0.40) = 11.7
Vicques	52	0.20	1	1.19	0.87	1.22	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	
Fresné-la-Mère	480	1.84	1	1.19	0.87	0.40	
Morteaux-Couliboeuf	511	1.96	2	2.38	1.70	0.76	
Ouilly-le-Tesson	527	2.02	2	2.38	1.70	0.75	
Soumont-Saint-Quentin	558	2.14	2	2.38	1.70	0.73	
La Hoguette	633	2.43	2	2.38	1.70	0.68	
Villers-Canivet	692	2.66	2	2.38	1.7	0.65	
Ussy	847	3.25	2	2.38	1.70	0.59	
1 Pont-d’Ouilly	1,038	3.99	3	3.57	2.459	0.77	
Potigny	1,734	6.67	4	4.76	3.06	0.74	
Falaise	8,456	32.54	17	20.23	42.43	4.68	
Total	25,985		84	100	100		

Note that even with only 20.23% of delegates, the Falaise municipality already captures 42% of the Banzhaf power.

Category 5: $\text{max-min} > 100$. In 6 EPCIs, the most powerful citizen is at least 100 times more decisive than the least powerful one. This is mainly the case of inter-communal structures with many small municipalities and one major municipality. CC Fougères in *Table 16* is an example. It is noticed that the case of CC *Fougères* is close to what we call an oceanic game in game theory: it is a game with a large number of small players and only one major player who dominates all others in terms of weight.

TABLE 16 – CC Fougères (department 35 « Ille-Et-Vilaine »)

Municipalities	popmun10	%popmun10	Nbr-del	Nbr-del %	Banzhaf %	Quotient	max-min
Combourtillé	531	1.3	1	3.12	0.09	0.028	(4.847/0.015) = 323.13
Le Loroux	531	1.3	1	3.12	0.09	0.028	
La Selle-en-Luitré	532	1.31	1	3.12	0.09	0.028	
Dompierre-du-Chemin	541	1.33	1	3.12	0.09	0.028	
Parcé	641	1.57	1	3.12	0.09	0.025	
Laignelet	862	2.12	1	3.12	0.09	0.022	
Billé	1,006	2.47	1	3.12	0.09	0.02	
Fleurigné	1,011	2.49	1	3.12	0.09	0.02	
Beaucé	1,161	2.86	1	3.12	0.09	0.019	
La Chapelle-Janson	1,248	3.07	1	3.12	0.09	0.018	
Landéan	1,257	3.09	1	3.12	0.09	0.018	
Parigné	1,274	3.14	1	3.12	0.09	0.018	
Luitré	1,276	3.14	1	3.12	0.09	0.018	
Saint-Sauveur-des-Landes	1,341	3.3	1	3.12	0.09	0.017	
Javené	1,814	4.47	1	3.12	0.09	0.015	
Romagné	1,953	4.81	1	3.12	0.09	0.015	
Lécousse	2,914	7.18	2	6.25	0.11	0.015	
Fougères	20,678	50.96	14	43.75	98.42	4.847	
Total	40,571	100	32	100	100		

All in all, 335 EPCIs among the 370 “communautés de communes” (CC) or communautés d’agglomération (CA), the most frequent legal status of inter-municipal structures in France and in our database, have a *max-min* ratio under 5. It is inferred that in 90% of the EPCIs in Western France, there is not a strong degree of inequality among municipalities belonging to the same inter-communal structure in terms of voting power.

As said before, we chose to analyze the CU (Communauté Urbaine) inter-communal structures separately: in our data set we have 5 CUs.²¹ As is shown in *Table 17*, the *max-min* ratio tends towards infinity in three CUs, is higher than 100 in one CU, and lower than 2 in the CU of Cherbourg. The existence of infinite ratio is due to fact that we encounter dummy players. A dummy player is a player who is never a swinger and, therefore, has a normalized Banzhaf index equal to 0. This is the case in several municipalities in three CUs where the major municipality in the inter-municipal structure has more than 50% of the municipal delegates. More precisely, the Alençon municipality in Communauté Urbaine D’Alençon had 28 out of 50 delegates, the Brest municipality in Brest Métropole Océane had 54 seats among 82, and the Le Mans municipality in Le Mans Métropole had 40 among 51.

21. Note that some of them have names that use the term “métropoles” but the legal status of these 5 EPCIs is CU.

TABLE 17 – Power inequalities in CU Inter-communal structures before the 2010 law

Region	CU	max-min
Basse Normandie	Communauté Urbaine de Cherbourg (50)	1.849
	Communauté Urbaine D’Alençon (61)	Infinity
Bretagne	Brest Métropole Océane (29)	Infinity
Pays de la Loire	Nantes Métropole, Communauté Urbaine (44)	472.296
	Le Mans Métropole Communauté Urbaine (72)	Infinity

To gain more insight into these results, we use the geographic distribution of the data to see whether equity is better achieved in some departments. This geographic breakdown is interesting since EPCIs allocate delegates among municipalities mainly on their own, but were also often advised by the central government administration headed by the “préfet” in each department. Thus, differences between regions and départements in terms of power inequalities might also reflect differences in the way the grouping between municipalities and the allocation of delegates was designed with the help of the central government in France.

We can clearly see from *Table 8* that, in every département, the vast majority of inter-communal structures have a *max-min* ratio lower than 5. Indeed, the last column, headed *prop > 5* in *Table 8*, gives the proportion per department of EPCIs with a *max-min* ratio higher than 5, and it remains at 6% in the region of Bretagne. Hence, it is inferred that the distribution of delegates among municipalities in this region was fair. It is clearly shown that only 8 EPCIs have an index greater than 5, and 3 of them are in the *Ille-Et-Vilaine* department. In particular, equity was not reached for the following three inter-communal structures: CC Fougères, Rennes Métropole and CA du Pays de Saint-Malo.

The Pays de la Loire region has a low proportion of Inter-communal structures, with a *max-min* ratio above 5, but with higher differences between departments than in the Bretagne region: the Vendée department has 10.34% of Inter-communal structures with a max-min ratio above 5, and the La Mayenne department 22.22%. Finally, in *Table 8*, it is not hard to notice that the *Basse-Normandie* region contains the highest differences between departments. In particular, the *Calvados* department has 26.32% of its inter-communal structures with a power index greater than 5. In order to explain these geographic differences exhibited by our result, we propose two hypotheses. The first is that the inequalities are caused by the geographical distribution of population: there may be many inter-communal structures with an important central municipality surrounded by many smaller ones in *Calvados*. The second is that because, prior to the law of 2010, municipalities cooperatively chose the number of delegates assigned to each municipality; large municipalities were more reluctant to accept a share of delegates lower than their proportion of population in this department compared to other large municipalities in other Western departments of France.

In the next subsection, we will see what the simulated impact of the 2010 law has on these power inequalities between municipalities in their EPCI.

4.3 Simulated power inequalities in EPCIs following the 2010 law

The aim of this subsection is to compare the apportionment of delegates in the inter-municipal council carrying out the rules of the law of December 16, 2010 with the previous apportionment using the Banzhaf index. As we have said before, these rules were fully enforced only after the 2014 local elections but the resulting allocation of delegates between municipalities was not centrally documented, the central government being reluctant to collect the EPCI minutes once again. Therefore, one is unable to fully analyze the impact of the 2010 law and control for the local use of the option allocation mentioned in note 7. This is why our empirical results in this section give simulations of the impact of the 2010 reform of inter-municipal structures.

To this end, we will first present the same example of *Communauté de communes Cœur de Nacre* with the index from the simulation data; then, we will compare our index in both sets of data. *Table 18* gives a comparison of the "Banzhaf index" between the observed allocation in 2010 and the simulated allocation induced by the 2010 law. The columns whose names end in "I" (for initial) correspond to the indices before the 2010 law, while those ending in "S" (for simulated) indicate the indices according to the simulated data under the 2010 law. As a reminder, the law of 2010 attributes a smaller number of delegates to the municipalities for this EPCI. In particular, the number of delegates of small municipalities decreases by 1 while the number of delegates of the largest municipality remains the same. Hence, the Banzhaf index decreases for the small municipalities but increases for the large ones, and the *max-min* index soars to 4.6 in the simulation data case: The gap between the most powerful and the least powerful citizens is reinforced.

TABLE 18 – Example of the apportionment of delegates before and after the law of 2010:
CC Cœur de Nacre (department 14 « Calvados »)

Municipalities	Pop10	Nbr-del		Banzhaf %		Quotient		max-min	
		I	S	I	S	I	S	I	S
Plumetot	215	2	1	4.24	3.26	1.19	0.92	(1.19/0.82)	(2.06/0.44)
Colomby-sur-Thaon	415	2	1	4.24	3.26	0.86	0.66		
Anisy	665	3	1	6	3.26	0.96	0.52		
Anguerny	812	3	1	6	3.26	0.87	0.47		
Basly	910	3	1	6	3.26	0.82	0.44		
Cresserons	1,217	4	2	9.04	6.63	1.07	0.78	1.45	4.6
Langrune-sur-Mer	1,723	5	2	10.48	6.63	1.04	0.66		
Saint-Aubin-sur-Mer	1,836	5	3	10.48	10.19	1.01	0.98		
Bernières-sur-Mer	2,379	5	3	10.48	10.19	0.88	0.86		
Luc-sur-Mer	3,172	7	5	15.29	15.14	1.12	1.11		
Douvres-la-Délivrande	4,884	8	8	17.69	34.85	1.04	2.06		
Total	18,228	47	28	100	100	100	100		

As previously noted, the CU inter-communal structures are special cases. *Table 19* gives the max-min ratio of these inter-communal structures. The results show a contrasted situation: we can notice that the max-min ratio of *Cherbourg* and that of *Nantes Métropole* have increased respectively from 1.849 and 472.296 to 9.9 and infinity, while the ratios of *Alençon*, *Le Mans*, and *Brest* have decreased from infinity to 36043.21, 70.96 and 39.58. Indeed, the new criterion introduced by the 2010 law eliminates dummy players in these inter-communal structures. However, the max-min ratio remains largely above 10 for 4 of the 5 CUs. Hence, it can be concluded that the 2010 law does not help to decrease the power of large municipalities in the CU structures.

TABLE 19 – CU inter-communal structures following the law of 2010

Region	CU	max-min-S
Basse Normandie	Communauté Urbaine de Cherbourg (50)	9.90
	Communauté Urbaine D’Alençon (61)	36043.21
Bretagne	Brest Metropole Oceane (29)	39.58
Pays de la Loire	Nantes Métropole, Communauté Urbaine (44)	Infinity
	Le Mans Métropole Communauté Urbaine (72)	70.96

As for the remainder of the EPCIs studied, in our simulation data (except for CU communities), the max-min ratio tends towards infinity in 13 EPCIs, something that did not occur before the 2010 law. In this sense, the new law cannot be considered as an improvement in terms of fairness. These EPCIs can be divided into two categories. The first one is where the major municipality has a normalized Banzhaf index almost equal to 1, while it is infinitesimal for the other ones. This is the case of 10 inter-communal structures represented in the lines headed *Dummies 1* in *Table 20*. The second category (lines headed *Dummies 2*) is where only some municipalities have a normalized Banzhaf index equal to 0. This is the case of CC de la Ria d’Etel displayed in *Table 21*. We can see that with the new allocation of delegates, *Etel* becomes a dummy player.²²

22. The case of Étel illustrates that for small games it is easy to obtain dummy players as shown in Barthélémy et al. (2013). Note that the mergers between EPCIs imposed by laws in 2010 and 2015 have changed the data. Later, the Etel inter-communal structure joined another inter-municipal structure (Auray Quiberon) with 24 municipalities.

TABLE 20 – EPCIs where "Dummy players" appear after the 2010 law

	dep	EPCI Name	max-min-I	max-min-S
Dummies 1	14	CA Caen La Mer	84.16	Infinity
	14	CC de Lisieux Pays D'Auge	6.04	Infinity
	22	CC de Guerlédan	3.27	Infinity
	35	CA Rennes Métropole	2729.62	Infinity
	49	CA Angers Loire Métropole	157463.96	Infinity
	53	CA de Laval	13.06	Infinity
	56	CC de Belle Ile en Mer	1.78	Infinity
	56	CC Saint Jean Brévelay communauté	2.22	Infinity
	61	CC de La Vallée du Sarthon	1.73	Infinity
	85	CC du Pays de Fontenay-Le-Comté	5.79	Infinity
Dummies 2	56	CC de la Ria d'Étel	1.29	Infinity
	22	CC du Pays Rochois	1.38	Infinity
	22	CC Rance-Frémur	1.21	Infinity

TABLE 21 – CC de la Ria d'Étel (department 56 « Morbihan »)

Municipalities	popmun10	Nbr-del		Banzhaf%		max-min	
		I	S	I	S	I	S
Étel	2,042	4	4	25	0	1.29	Infinity
Locoal-Mendon	3,033	4	7	25	33.33		
Erdeven	3,240	4	7	25	33.33		
Belz	3,440	4	8	25	33.33		
Total	11,755	16	26	100	100		

Table 22 presents the evolution of the max-min index before and after the law of 2010 for our entire set of EPCIs. The proportion of inter-communal structures with a max-min ratio below 5 significantly decreases: The number of inter-communal structures in this category decreases from 335 to 167. Also, the last column, named *% prop > 5*, displays the proportion as a percentage per department for the inter-communal structures with a ratio below 5. The numbers in brackets represent the proportion in the initial database before the 2010 law. It can be noted that this proportion increases sharply in all the regions: Slightly more than 50% of inter-communal structures in almost all departments have a max-min ratio above 5.

TABLE 22 – Classification of inter-communal structures according to the value of *max-min-S* ratio²³

Région	Départements	≥ 1 & ≤ 2	> 2 & ≤ 5	> 5 & ≤ 10	> 10 & ≤ 100	> 100	%prop > 5
Basse Normandie	Calvados	1 (4)	16 (24)	5 (6)	7 (4)	9 (0)	55(26)
	Manche	1 (19)	23 (25)	8(1)	11 (1)	3 (0)	47(4)
	Orne	0 (12)	14 (24)	10 (3)	8 (1)	9 (1)	65(12)
	Total	2 (35)	53 (73)	23 (10)	26 (6)	21 (1)	56(13)
Bretagne	Côtes D’Armor	0 (13)	17 (24)	9 (1)	9 (1)	4 (0)	56(5)
	Finistère	0 (11)	9 (11)	8 (1)	7 (1)	0 (0)	62(8)
	Ille-Et-Vilaine	0 (10)	13 (15)	6 (0)	6 (1)	3 (2)	53(10)
	Morbihan	1 (14)	10 (11)	6 (0)	5 (1)	4 (0)	57 (3)
	Total	1 (48)	49 (61)	29 (2)	27 (4)	11(2)	57(6)
Pays de la Loire	Loire Atlantique	1 (13)	11 (7)	4 (1)	4 (0)	1 (0)	42(4)
	Maine-et-Loire	1 (11)	11 (17)	8 (0)	6 (0)	4 (2)	60(6)
	Mayenne	0 (2)	5 (12)	5 (1)	1 (3)	7 (0)	72(22)
	Sarthe	1 (16)	14 (14)	8 (0)	5(0)	2 (0)	50(0)
	Vendée	3 (15)	15 (11)	4 (1)	5 (1)	2 (1)	37(10)
	Total	6 (57)	56 (61)	29 (3)	21 (4)	16 (3)	51(7)
Total		9 (140)	158 (195)	81 (15)	74 (14)	48(6)	54(9)

Our second main result is therefore the following: the max-min index for the simulation data clearly demonstrates that the law of 2010 generates a priori higher inequalities of voting power among Western municipalities of France. These inequalities have different explanations: First, the number of delegates of small municipalities very often decreases, while the number of delegates of the largest municipality remains the same or also decreases but not in the same proportion. For example, Caen (the major municipality of *CA Caen La Mer*) holds 49 % of delegates according to the new law’s criteria, while the same municipality had only 36% of delegates before the new law. Looking at *Table 23*, we can easily see that the law gives to the largest municipality higher power compared to the previous situation.²⁴

23. Max-min ratios implied by observed numbers of municipal delegates are given between brackets, and were already given by *table 8*.

24. More precisely, a citizen from Caen is 22,369,620 times more powerful than a citizen from Périers-sur-le-Dan.

TABLE 23 – CA Caen La Mer (29 municipalities)

Municipalities	popmun10	Nbr-del		% Nbr-del		Banzhaf %		Quotient		max-min	
		I	S	I	S	I	S	I	S	I	S
Périers-sur-le-Dan	488	2	1	1.68	1.23	0.22	0 ⁺	0.08	0 ⁺	(2.25/0.0267) (2.44/0 ⁺) = 84.16 Infinity	
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮		
Villons-les-Buissons	684	2	1	1.68	1.23	0.22	0 ⁺	0.06	0 ⁺		
Colombelles	5,771	3	2	2.52	2.46	0.31	0 ⁺	0.03	0 ⁺		
Mondeville	10,124	5	3	4.20	3.70	0.43	0 ⁺	0.03	0 ⁺		
Iffs	10,738	5	3	4.20	3.70	0.43	0 ⁺	0.03	0 ⁺		
Hérouville-Saint-Clair	22,590	9	8	7.56	9.87	0.49	0 ⁺	0.02	0 ⁺		
Caen	109,630	43	40	36.13	49.38	92.39	100 ⁻	2.25	2.44		
Total	217,416	119	81	100	100	100	100				

Second, with the new law, cases where municipalities with different population sizes have the same number of delegates have disappeared. For instance, *Table 24* displays the case of CC D’Orival. We can see that before the law, each municipality had 2 delegates. However, under the law’s criteria, the largest municipality has 4 times more power than before, while the smallest ones lose power.

TABLE 24 – CC D’Orival (department 14 « Calvados »)

Municipalities	popmun10	Nbr-del		Banzhaf %		Quotient		max-min	
		I	S	I	S	I	S	I	S
Rucqueville	128	2	1	6.66	3.82	1.78	1.02	(1.78/0.515) (1.91/0.527) = 3.45 3.62	
Colombiers-sur-Seulles	162	2	1	6.66	3.82	1.58	0.90		
Tierceville	162	2	1	6.66	3.82	1.53	0.90		
Cully	173	2	1	6.66	3.82	1.53	0.87		
Amblie	264	2	1	6.66	3.82	1.24	0.71		
Villiers-le-Sec	280	2	1	6.66	3.82	1.20	0.69		
Coulombs	293	2	1	6.66	3.82	1.17	0.67		
Saint-Gabriel-Brécy	300	2	1	6.66	3.82	1.16	0.66		
Bény-sur-Mer	331	2	1	6.66	3.82	1.10	0.63		
Martragny	333	2	1	6.66	3.82	1.10	0.63		
Fontaine-Henry	480	2	1	6.66	3.82	0.91	0.52		
Reviers	558	2	2	6.66	7.98	0.85	1.02		
Lantheuil	656	2	2	6.66	7.98	0.78	0.94		
Thaon	1,470	2	5	6.66	17.32	0.52	1.36		
Creully	1,524	2	6	6.66	24.67	0.51	1.91		
Total		30	26	100	100				

When it comes to the geographic analysis, we can observe that the increase in the max-min ratio is general, erasing to some extent any regional trend. From *Table 22*, we notice that in *Bretagne* and *Pays de la Loire* we now also have a high proportion of communities with an index power above 5, the highest proportion being observed in the Finistère (department 29) and the Mayenne (department 53). In the Basse-Normandie

region, the L’Orne département has the highest proportion of inter-communal structures with a max-min ratio above 5. As a consequence, we are now able to answer the question of the origin of disparities in voting power among municipalities before the law of 2010. It has nothing to do with the fact that, in some regions, we have a more unequal distribution of the population among the members of an inter-communal structure. The real reason of the disparities is that before the 2010 law, in some territories, the major municipalities accepted a lower share of delegates than what they could have claimed on a population basis.

To conclude, the intuition that stems from this result is the following: when the inter-communal structures were allowed before 2010 to freely decide the allocation of delegates, the largest municipality frequently accepted to reduce its number of delegates so that small municipalities, which were often reluctant to join the EPCI, would accept to become members. Central municipalities thus accepted to be underrepresented to favor a higher number of municipal members in the club, which was viewed as a sort of success in the cooperation process, including by the central government headed by its ”préfet” in each department. Furthermore, a recent paper by Macé and Treibich (2019) gave theoretical grounds for such a story. They model the formation of a federal union as a game where the first stage is to decide whether or not to join the union. Hence, as their power might be diluted in the union, the small players (in terms of population) will only cooperate if the voting rule is a weighted majority game which will award them a minimal number of delegates, superior to their proportional share. The criteria they use is not based on the concept of power, but on the classical utility concept. But as being small means a lower probability to be decisive and to be on the winning side, small players will not join the union if their stand-alone utility is higher than the one they can get in the union. To meet this participation constraint, the only solution is to adjust their number of delegates above a certain threshold.

5 Conclusion

In this work, our intention was to analyze and compare the fairness of the apportionment of delegates among French municipalities in their inter-municipal assembly before and after the law of December 16, 2010, which is based on the application of Jefferson’s apportionment method. This 2010 law had three purposes. The first was to rationalize the map of municipal cooperation, by asking each municipality to join an inter-municipal structure in 2014. The second was to reduce the total number of delegates for each inter-municipal structure. And the third one was to implement stricter rules in the apportionment of delegates, thereby reducing flexibility in the representation of municipalities within an inter-communal structure.

The main objective of our study is the exploration of the fairness of the apportionment of delegates

before and after the law of 2010. The most surprising results are that the distribution of delegates before the 2010 law was quite fair, with only less than 10% of our 370 EPCIs with a max-min ratio superior to five. In contrast, theory suggested that the systematic application of the Jeffersons apportionment method could only deteriorate the situation, and this is exactly what we observed in our simulations.

This result can mainly be explained by the fact that the new law simultaneously increases the power of large municipalities and decreases the number of delegates of small municipalities. Another reason is that some EPCI councils tended (before the law of 2010) to assign equal numbers of delegates among municipalities that did not necessarily have the same population size. These cases have disappeared. Moreover, the new criteria introduced by the 2010 law even created a handful of cases where a municipality has no power at all. We thus conclude that the law should have been checked more carefully to prevent it from creating dummy municipalities. The story behind these facts is in line with the theoretical explanation suggested by Macé and Treibich (2019): when municipalities were free to join an inter-communal structure or to remain isolated, small ones had to be compensated.

One may also raise questions about the limits of the power indices used in evaluating the fairness of the apportionment of delegates. In fact, assuming that the municipality does not know the decisions or the opinions of other municipalities, the Banzhaf index considers equally all the coalitions that a municipality may form in order to pass a decision (while being decisive). But in fact, a municipal mayor may be informed of the opinions of other mayors and delegates. We have to remind the reader here that the Banzhaf index can only be used as an a priori measure and that it says nothing about the real behavior of the delegates in the inter-communal council. Also, the independence assumption has been criticized by Gelman et al. (2004). One of the limitations of our analysis is that we have assumed that delegates of each municipality vote in bloc. However, in the law of 2010, this assumption does not hold. With the new law, the delegates that represent a municipality in the inter-municipal council may no longer belong to the same political party. For some decisions, party affiliation might become more important than defending the position of the municipality. Hence, one possible extension of our work is to analyze a case in which delegates of each municipality vote along party lines.

Finally, the situation prior to the 2010 law was fairer than expected, with many large municipalities agreeing to control fewer delegates than they could have done. This raises another fundamental question as to the way the communities handled their budgetary policies. Do the major municipalities also agree to pool their resources with the small ones? Or, on the contrary, do they trade control of resources against a lower number of delegates in the EPCI council? We plan to open the black box of the allocation of fiscal resources

inside inter-communal structures and check whether the distribution of delegates could explain some of the related phenomena, in the same vein as Kauppi and Widgren did for the European Union (see Kauppi and Widgren 2004, 2007) .

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Appendix I

Table 25 gives the classification of the problematic cases according to the type of errors described above.

TABLE 25 – Inter-communal structure classified according to type of errors

Demographic error	Gross error
CC de Trevieres	CC Du Cingal
CC Du Val ès Dunes	CC Bocage
CC Blangy -Pont L'Evêque Intercom	Lamballe Communauté
CC Campagne et Baie De L'Orne	CC Cideral
CC Copadoz	CC du Pays Bigouden Sud
CC Plaine Sud De Caen	CC du Pays Fouesnantais
CC Pays de Condé et de la Druance	CA Vitré Communauté
CC Du Pays De Falaise	CC du Pays de Béchère
CC de Morlais-Communauté	CA Rennes Métropole
CC Pays de Lesneven et Cote Des Légendes	CC Coglais communauté
CC de la région de Nozay	CC du Saosnois
CC de la Région de Montebourg	CC Loire Aubance
CC de Ste Mere Eglise	CA Angers Loire Métropole
CC de la Région de Daye	CC de la région de Chemillé
CC du Val de Saire	CC du Pays Granvillais
CC de la Selune	CC Terres de Montaigu
CA de Laval	CC du Canton de Villedieu Les Poeles
CA de la presqu'île de Guérande Atlantique	CC de l'elle
CC des Pays de Loué	CC de la Hague
CC du Pays de Sillé	CC de l'Ernée
CC du Pays Mareuillais	CC du pays de la Gacilly
CC Pays de Mayenne	CC du Val d'Oust et de Lanvaux
	CC de la Côte des Mégalithes
	CC du Pays de Redon
	CC du Pays de Muzillac
	CC du Pays Mélois
	CC du Bocage d'Athis-de-l'Orne
	CC du Pays Fléchois
	CC de Sablé-sur-Sarthe
	CC de Vendée Sèvre Autise
	CC du Pays des Achards
	CC du Pays de Saint Gilles Croix de Vie

We delete two EPCIs from our database: *CC LE LEFF* and *CC du canton de Percy*.