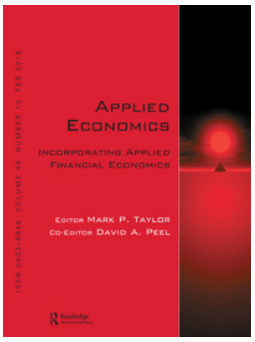

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The relevance of commuting zones for regional spending efficiency

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ABSTRACT
We use data envelopment analysis (DEA) efficiency scores to show that clustering municipalities into encompassing regional clusters improves spending efficiency of single stand-alone municipalities. We propose a new geographic aggregation based on municipalities-to-municipalities commuting flows, defined using hierarchical cluster analysis. Our example for Portugal shows that from an output-oriented perspective between 83% and 98% of municipalities would increase their efficiency scores, while from an input-oriented perspective between 86% and 98% of municipalities would also be better off in terms of efficiency. Then using a linear regression model, we find that population increases positively affects the efficient scores (via scale economies). Also, increases in the share of high-educated and poorer residents leads to higher efficiency scores.

KEYWORDS
Public spending efficiency; local government; data envelopment analysis (DEA); commuting zones

JEL CLASSIFICATION
C14; H72; R50

I. Introduction

Reducing local government spending and increasing the efficiency of regional governments has been a significant issue in public finance and regional economics for quite a long time. This is particularly relevant when governments try to reign in public spending, as it is the case, for instance, in many European Union (EU) countries.

This article contributes to the literature by showing that having a cluster of several municipalities improves the spending efficiency of once single stand-alone municipalities. We draw on the labour market concept of commuting zones and on the data envelopment analysis (DEA) framework. Our geographic unit of analysis is community zones, groups of municipalities where the majority of the inhabitants live, work or study. This geographic concept was based on municipalities-to-municipalities commuting flows of working population. To compute the DEA efficiency scores, we use a composite indicator of municipal services' provisions (outputs), as in Afonso and Fernandes (2008), and we use local government spending as the input. We test our approach for the case of Portugal, both for the mainland and for the EU Nomenclature of Territorial Units for Statistics (NUTS) regions.

In addition, we evaluate the possible relationship between the municipality characteristics and the increases in the efficiency scores in the clustered regions. This is of particular interest to policymakers. In fact, giving insights to the reasons for efficient increases might help local governments and policymakers to effectively approve measures to correct and or control local inefficiencies.

Portugal provides an excellent context in which to analyse the impact of clustering municipalities on spending efficiency. First, a municipality in Portugal spends on average 7.7 million euros, which corresponds to approximately 290 euros per inhabitant. The main expenditure items are investment and current spending such as expenditure on goods and services, compensation of employees and transfers to parishes. As local authorities have fiscal and administrative autonomy, their main sources of revenue are transfers from the central government and municipal direct taxes. Second, the municipalities are all covered by the same Portuguese rules and legislation, but local politicians have some discretionary power on how to implement their policies and to use their resources. For example, local governments are responsible for social and economic development, territorial planning and supply of public

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goods such as water and sewage, education, healthcare, social and cultural activities to local the population (see Laws 159/99 and 2/2007). Also, local authorities have to comply with budgeting rules and principles common to those binding the central government budget. Finally, the Portuguese government agreed on April 2011 with the EU and with the IMF, in the context of the Memorandum of Economic and Financial Policies, to reduce the number of parishes and municipalities and in this way reduce public spending and increase its efficiency.

Our results show that there are potential efficiency gains from clustering municipalities. This is true notably from an output-oriented perspective, given that between 83% and 98% of municipalities would be able to increase their efficiency scores. In addition, we obtain a similar result from an input-oriented perspective, with between 86% and 98% of municipalities being better off in terms of efficiency scores if one follows our commuting zone aggregation via hierarchical cluster analysis. Our conclusions hold both for an overall mainland assessment and for the NUTII regions.

In addition, we find that the increase in the population positively affects the efficiency scores, which can be seen as evidence of gains via scale economies (i.e. under commuting clustering and geographical vicinity), in providing the municipal services. Also, increases in the share of high-educated residents leads to higher efficiency scores, hitting at the hypotheses that educated residents pressure local governments to provide better and more efficient public services. On the other hand, municipalities with increases in the proportion of richer residents impinge negatively on the above-mentioned efficiency scores.

Our results are also robust considering different clustering criteria. In fact, our results are likely to extend beyond the context of this study and might be particularly relevant to reduce local and regional spending, and for countries wishing to restructure its administrative regions. Finally, our strategy and results are naturally quite relevant in a context of public spending control.

The organization of the article is as follows. Section II reviews the related literature. Section III presents the methodology. Section IV reports and discusses the empirical results. Section V is the conclusion.

II. Related literature

In the literature that assesses production efficiency, it is rather common to use frontier analysis to evaluate technical efficiency (a concept stemming from Farrell 1957). In fact, and to assess the efficiency of government spending, many studies usually estimate nonparametrically a production function frontier and derive efficiency scores based on the relative distances of inefficient observations from the frontier.

Several specific government functions such as education and health have been addressed notably by Afonso and St. Aubyn (2006, 2011). Moreover, St. Aubyn et al. (2009) studied the case of universities in the EU, and Eugène (2008) assessed the relative efficiency of Belgian general government as provider of public order and safety, in addition to healthcare and education services. On the other hand, Afonso, Schuknecht, and Tanzi (2005, 2010) studied the overall public sector efficiency, taking into account the level of general government spending. Overall, those studies show the existence of room for improvement regarding public spending efficiency.

Conversely, public spending efficiency studies covering services provided by local governments include, for instance, Van Den Eeckhaut, Tulkens, and Jamar (1993), De Borger et al. (1994), De Borger and Kerstens (1996, 2000), Athanassopoulos and Triantis (1998), Worthington (2000), Prieto and Zofio (2001), Balaguer-Coll, Prior-Jimenez, and Vela-Bargues (2002), Afonso and Fernandes (2006, 2008) and Afonso and Scaglioni (2007). Once again, the results of this strand of the literature point to the fact that governments can attain efficiency gains at the municipal level as well.

Still, the novel approach that we develop in this article, showing the increase in efficiency via the clustering of municipalities based on commuting flows, has not been done in the literature so far. Indeed, and from a motivation perspective, vicinity of municipality consumers makes it more cost efficient to provide certain public services such as waste disposal or water supply as it is the case of several metropolitan agglomerations. In the case at hand, several existing services on a municipality can be feasibly expanded to neighbour municipalities. There are several examples where the pooling of municipalities, notably for water supply, sewage provision, primary education, increase efficiency notably by cost reduction, in clustering. Interestingly, such pooling of resources could be dependent on the percentage of municipalities, within a clustered region, with a mayor from the same political party as the government. That is actually not the case in our results, leaving improvements via scale gains a strong explanation for the increase in both output and input efficiency.

Therefore, although commuters move for work purposes across municipalities, it is not expected that municipalities intend to compete for having a higher number of resident population *per se*. What is theoretically relevant in this case is that since commuters cross municipalities' boundaries the local public services they use are, to some extent, also 'crossing' borders, being the provision more efficiently done from a cluster perspective.

III. Methodology

Commuting zones

Portugal's administrative regions are organized into three tiers: districts and two autonomous regions of Azores and Madeira, municipalities and parishes. There are 18 districts, 308 municipalities and 4261 parishes.[1] Of the 308 municipalities, 278 of which are located in mainland Portugal and the remaining 30 are oversea municipalities. In this study, we define a new geographic unit of analysis, community zone: groups of municipalities where the majority of the inhabitants live, work or study.

To construct our new measure (geographic unit), we use the methodology defined by Tolbert and Killian (1987) and Tolbert and Size (1996). We start by constructing a matrix with the commuting flows between municipalities. To account for variations in municipality work population, we convert these absolute flows into proportional measures. The strength of commuting ties between two municipalities i and j, T_{ij}, is measured according to

$$T_{ij} = \frac{c_{ij}}{\min(r_i, r_j)} \quad (1)$$

where r_k is the number of all workers residing in municipality k, ($k = i, j$) and c_{ij} is the number of workers who reside in municipality i and work or study in municipality j or vice versa.

The statistic T_{ij} depicts the relationship between the flow of workers who commute between two municipalities, independent of the direction and the number of individuals who live in the smallest municipality. In this way, the statistic defines better the commuting tie between municipalities with large size differentials. The proportional matrix of T_{ij} is a similarity matrix. The stronger the commuting relationship between two municipalities, the higher is the value of T_{ij}.

We employ a hierarchical cluster analysis to delineate the labour market areas. This analysis starts by grouping the municipality pairs with largest value of T_{ij} and subsequently forms clusters of interrelated municipalities. As suggested by previous literature (see, for instance, Dorn 2009), we choose the average linkage between clusters as a statistical algorithm. In the average-linkage method, the distance between two clusters is obtained by taking the average distance between all subjects in the two clusters. Alternatively, we also consider other sets of algorithms (single linkage, centroid linkage and ward linkage). All of them point to similar market labour areas.

As defined in Dorn (2009), municipalities with stronger ties are the ones with an average value of T_{ij} above 0.02.

DEA efficiency analysis

The DEA methodology, which originates with Farrell's (1957) seminal work and was further used by Charnes, Cooper, and Rhodes (1978), assumes the existence of a convex production frontier. The production frontier in the DEA approach uses linear programming methods.[2] The general relationship that we consider is the following function for each municipality i:

$$Y_i = f(X_i), i = 1, \ldots, n \quad (2)$$

where Y_i is the composite output measure for municipality i and X_i is the per capita municipal expenditures registered on municipal accounts for the year

[1]For statistical purposes, the EU redefined the Portuguese territory into NUTS regions. The NUTS system subdivides the country into three levels: NUTS I (Portugal mainland and 2 autonomous regions of Azores and Madeira), NUTS II (7 regions) and NUTS III (30 subregions). These latter classifications were developed for the purpose of delivering structural funds for less favoured regions and subregions.
[2]Coelli, Rao, and Battese (2002) and Thanassoulis (2001) offer introductions to DEA.

2011 as a measure of the municipal resources used in local services' provision input in municipality i.

If $Y_i < f(X_i)$, it is said that municipality i exhibits inefficiency. For the observed input levels, the actual output is smaller than the best attainable one and inefficiency is measured by computing the distance to the theoretical efficiency frontier.

In an output-oriented framework, we provide here the description of the linear programming problem in the variable-returns to scale hypothesis. Suppose there are k inputs and m outputs for n decision management units (DMUs). For the ith DMU, x_i is the column vector of the inputs and y_i is the column vector of the outputs. We can also define X as the $(k \times n)$ input matrix and Y as the $(m \times n)$ output matrix. The following mathematical programming problem, for a given ith DMU, specifies the DEA model[3]:

$$\begin{aligned} &\text{Max}_{\delta,\lambda}\delta \\ &\text{s. to} -\delta y_i + Y\lambda \geq 0 \\ &\quad x_i - X\lambda \geq 0 \\ &\quad n1'\lambda = 1 \\ &\quad \lambda \geq 0. \end{aligned} \tag{3}$$

In Equation 3, δ is a scalar (that satisfies $1/\delta \leq 1$), and specifically is the efficiency score that measures technical efficiency, the distance between a municipality and the efficiency frontier, defined as a linear combination of the best practice observations. With $1/\delta < 1$, the municipality is inside the frontier (i.e. it is inefficient), while $\delta = 1$ implies that the municipality is on the frontier (i.e. it is efficient).

The vector λ is a $(n \times 1)$ vector of constants that measures the weights used to compute the location of an inefficient DMU if it were to become efficient, and $n1$ is an n-dimensional vector of ones. The inefficient DMU can theoretically be on the production frontier as a linear combination of those weights, related to the peers of the inefficient DMU. The peers are other DMUs that are more efficient and used as references for the inefficient DMU. The restriction $n1'\lambda = 1$ imposes convexity of the frontier, accounting for variable returns to scale. Dropping this restriction would amount to admit that returns to scale were constant. Problem (3) is solved for each of the n DMUs in order to obtain the n efficiency scores.

IV. Empirical analysis

Portuguese commuting zones

Data on community flows and workers population per municipality are from the 2011 Census data.[4] With these commuting patterns, the clustering procedure yielded 52 commuting zones for mainland Portugal.[5]

In practice, the resulting labour market areas are geographically contiguous. Note that these set of labour market areas result from a data-driven method without requiring any subsequent *ad hoc* manipulation to exclude unusual distant commuting patterns. By using solely the commuting data, we partition the country very sensibly without manually imposing region restrictions. In Table A1, we present the entire list of municipalities included in each community zone in 2011 for mainland Portugal.

Column 1 of Table 1 presents the summary statistics for the commuting zones in Portugal mainland. On average, 188 000 workers reside in a commuting zone and the largest labour market is Lisbon with over 2 700 000 work inhabitants. Each commuting zone includes roughly six municipalities, with the number of municipalities ranging from 1 to 21. Isolated commuting zones (single municipalities) accounted for approximately 4% of the total municipalities. Table 1 also reports statistics for alternative clustering thresholds, notably based on geographic distances.

Baseline DEA efficiency scores

We use DEA efficiency scores, notably building an output composite indicator, as computed by Afonso and Fernandes (2008), for Portugal mainland and for the NUTS II regions. Municipal spending is used as an input measure and a

[3]This is the equivalent envelopment form, derived by Charnes, Cooper, and Rhodes (1978), using the duality property of the multiplier form of the original programming model.

[4]These data are available from the Portuguese Statistic Office's website under the variable names 'Commuting of the employed or student resident population by place of residence or destination and place of destination or residence' and 'Resident population by place of residence (at the date of Census), sex and by main source of livelihood'.

[5]For the purpose of our analysis, we exclude the two autonomous regions of Azores and Madeira and only consider the mainland region.

Table 1. Descriptive statistic on DMUs.

	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
	(1)	(2)	(3)
Number of municipalities	52	115	67
Panel A: resident workers			
Mean	187 867	84 948	145 807
SD	420 208	195 218	316 564
Median	77 289	27 666	49 738
Minimum	4823	1792	1792
Maximum	2 757 450	1 575 334	2 300 652
Panel B: municipalities composition			
Mean	5.35	2.42	4.15
SD	3.47	1.70	2.80
Median	5	2	3
Minimum	1	1	1
Maximum	21	41	13
Sole municipalities	4%	36%	13%

Notes: The table reports the descriptive statistics for different cluster strategies. Column 1 reports the statistics for commuting clusters and columns 2 and 3 report the statistics for clusters defined according with the geographic distance between the municipality's capitals of 20 and 30 km, respectively. Sole municipalities include the percentage of DMUs with one municipality.

composite of the Local Government Output Indicator (LGOI) is used as an output measure. This composite is a single measure of municipal performance evaluated in terms of social services, Y1 (local inhabitants above 65 years old as a percentage of resident population); basic education Y2 (school buildings per capita measured by the number of nursery and primary school buildings in per cent of the total number of corresponding school-age inhabitants, Y21, gross primary enrolment ratio, the number of enrolled students in nursery and primary education in per cent of the total number of corresponding school age inhabitants, Y22); cultural services, Y3 (number of museums, zoos, botanical gardens and aquariums); sanitation, Y4 (water supply, Y41, urban waste collection, Y42); territory organization, Y5 (building permits issued by local administration); and road infrastructures, Y6 (length of roads maintained by the municipalities per number of the total resident population and area). Except for water supply and road infrastructures, all data are from 2011. In Table A2, we present further information on the variable definitions and their data sources.

To obtain the composite output indicator, all values of each sub-indicator mentioned were normalized by setting the average equal to one. Also, we compile the performance indicator from the various sub-indicators giving equal weight to each of them.

Table 2. Baseline DEA efficiency results.

		Efficient DMUs		Average efficiency scores	
Region	No. of DMUs	No. of DMUs (municipality)	% of DMUs in the region	Input oriented	Output oriented
North	86	2 Valongo, Vila Nova de Gaia)	2.3	0.476	0.202
Centre	129	4 (Almada, Leiria, Sintra, Tomar)	3.1	0.540	0.382
South	63	6 (Alcoutim, Beja, Évora, Faro, Marvão, Olhão)	9.5	0.537	0.519
Mainland	278	3 (Tomar, Valongo, Vila Nova de Gaia)	1.1	0.455	0.203

Notes: The table reports the baseline DEA efficiency scores using 2011 data. For NUTS II regions, we report the efficient DMUs for three regions: north, centre and south. The centre includes centre and Lisbon and Tagus Valley regions and the south includes Algarve and Alentejo regions. The column 'Efficient DMUs' reports the number and name of efficient DMUs and the percentage of efficient municipalities in a region. DMUs, decision management units.

Table 2 provides a summary of the DEA results that we have obtained for 2011.

The purpose of an input-oriented assessment is to study by how much input quantities can be proportionally reduced without changing the output quantities produced. Alternatively, and by computing output-oriented measures, one can assess how much output quantities can be proportionally increased without changing the input quantities used. In the case of the baseline for the NUTS II regions, we can see from Table 2 that in the three main regions input efficiency scores range between 0.380 and 0.642, implying that inputs could be theoretically lower by around 36–62%, keeping the same level of output. On the other hand, output efficiency scores range between 0.397 and 0.628, which means that one might envisage and output increase of around 37–60% with the same level of inputs.

Cluster DEA efficiency scores

Afterwards, the main question of our study is to assess, using the commuting zones explained above, whether the resulting regional clusters would provide a gain in efficiency. For that purpose, and as an intermediate step, we computed the municipal spending and the composite local government output indicator (the so-called LGOI) for each commuting zone using the approach defined in the previous subsection. Then we have calculated the DEA efficiency scores, both for the mainland new aggregation of regions and also for the new aggregations inside each NUTS II region.

Therefore, using the commuting zone methodology, we are able to identify 52 clusters for Portugal (mainland) down from the number of existing 278 municipalities. On the other hand, and for the case of the NUTS II aggregation, we had to consider only three regions, north, centre (aggregating *Centre* and *Lisbon and Tagus Valley*) and south (aggregating *Alentejo* and *Algarve*). In this way, we have arrived to the following number of clusters: 19, 21 and 15, respectively, for the north, centre and south (see lines 8, 9 and 10 in Table 3). The number of municipalities in each of those aggregations is 86, 129 and 63, respectively.

Using this alternative aggregation, we have then computed the DEA input and output oriented efficiency scores, for the country and for the NUTS II regions, for the corresponding clusters. Table 3 summarizes those results. For the country case, we can compare lines 1 (baseline) and 2 (commuting zones clustering) and observe several points. The average efficiency scores are higher both for input (0.661 versus 0.455) and for output (0.614 versus 0.203) oriented approaches, when the clusters are used for the DEA calculations. Indeed, around 98% and 86% of the municipalities would theoretically increase respectively output and input efficiency (as depicted in the last two columns of Table 3).

In terms of the new aggregation for the NUTS II classification, obtained also via the commuting zones approach, we can compare the results in lines, 5, 6 and 7 (baseline) with lines 8, 9 and 10 (commuting zones clustering), respectively, for north, centre and south. Again, there is an overall increase in the average efficiency scores, both input and output oriented. In addition, the number of DMUs that are on the efficiency frontier is still rather similar.

Therefore, promoting such aggregation in terms of municipalities would be helpful in terms of increasing the overall government spending efficiency of the local authorities. Given the geographic closeness of the ensuing partition via the commuting clusters, one can expect in fact the existence of scale economies in the provision of several local public services.

Robustness analysis

We have conducted several robustness exercises. As an alternative, we used a different threshold for the commuting ties between municipalities widening a bit more the geographic incidence of those commuting flows (we used a value of T_{ij} above 0.01 instead of 0.02). As expected, the results for country case are quite similar to the ones with the previous threshold, and the same holds true for the NUTS II (results not shown for parsimony).

Table 3. DEA efficiency scores comparisons (VRS).

					Input				Output				Cluster – baseline	
			DMUs	Efficient DMUs	Average	Max	Min	SD	Average	Max	Min	SD	Output	Input
1	**Country, baseline DEA**		**278**	**3**	**0.455**	**1.000**	**0.143**	**0.205**	**0.203**	**1.000**	**0.081**	**0.121**	–	–
2	Country, cz		52	5	0.661	1.000	0.280	0.164	0.614	1.000	0.280	0.164	97.8	86.0
3	Country, nearby 20 km		115	4	0.681	1.000	0.232	0.205	0.513	1.000	0.245	0.190	96.8	94.2
4	Country, nearby 30 km		67	4	0.753	1.000	0.380	0.179	0.640	1.000	0.328	0.183	98.2	96.0
5		**N**	**86**	**2**	0.476	1.000	0.147	0.219	0.202	1.000	0.080	0.137	–	–
6	**Baseline NUTS II**	**C**	**129**	**4**	0.540	1.000	0.165	0.216	0.382	1.000	0.436	0.141	–	–
7		**S**	**63**	**6**	0.537	1.000	0.252	0.208	0.519	1.000	0.262	0.204	–	–
8		N	19	6	0.830	1.000	0.275	0.166	0.824	1.000	0.653	0.125	97.7	97.7
9	NUTS II, cz	C	21	3	0.820	1.000	0.436	0.141	0.719	1.000	0.501	0.163	95.3	89.9
10		S	15	3	0.747	1.000	0.350	0.134	0.716	1.000	0.616	0.119	82.5	85.7
11		N	31	2	0.783	1.000	0.243	0.175	0.757	1.000	0.471	0.148	97.7	97.7
12	NUTS II, nearby 20 km	C	49	3	0.757	1.000	0.311	0.182	0.661	1.000	0.352	0.198	90.7	89.9
13		S	44	6	0.687	1.000	0.367	0.190	0.638	1.000	0.329	0.190	84.1	87.3
14		N	18	3	0.879	1.000	0.457	0.148	0.906	1.000	0.690	0.095	97.7	97.7
15	NUTS II, nearby 30 km	C	26	5	0.844	1.000	0.396	0.146	0.795	1.000	0.479	0.164	94.6	93.0
16		S	25	5	0.788	1.000	0.419	0.146	0.686	1.000	0.424	0.181	85.7	90.5

Notes: The table reports the input and output DEA efficiency scores for the county, rows 1–4, and NUTS II regions, rows 5–16. Rows 1 and 5–7 report the scores for the baseline case (278 municipalities), Rows 2 and 8–10 report the scores for commuting clusters, and the remaining rows report the scores for clusters defined by geographic distance. The column 'Efficient DMUs' reports the number of efficient DMUs and the column 'Cluster – baseline' reports the percentage of cases (municipalities) where there is a gain in efficiency as a result of the clustering strategy, by comparing the initial stand-alone efficiency score of the municipalities and the efficiency score of the cluster where the municipality would be allocated.

N, north; C, centre and includes centre and Lisbon and Tagus Valley regions; S, south and includes Algarve and Alentejo regions; Cz, commuting clusters; and DMUs, decision management units

Another exercise that we carried out was to aggregate municipalities according to their geographic distance instead of looking at the commuting flows between municipalities. From the Portuguese Geographic Institute, we retrieved information on the geographic distance (in straight line) between the municipality capitals. On average, municipality capitals in Portugal mainland are 188 km apart. Then, we employ a hierarchical cluster analysis using the nearby algorithm to delineate the new geographic regions. In our nearby approach, we defined *ex ante* the distance between the municipalities. Therefore, we limited that distance to both 20 km and to 30 km, in order to partition the country and NUTS II regions into clusters. Summary statistics for these two geographic aggregations are presented in columns 2 and 3 of Table 1. The DEA results presented in Table 3 (for the country in lines 3 and 4 and for the NUTS analysis in lines 11–16) show higher efficiency scores, implying the existence of efficiency gains from such aggregation.

Explaining clustering increasing efficiency

Finally, we examine how the DEA efficiency scores increases in the clustered regions might be explained by factors proposed in the literature on local government efficiency, namely changes in municipality characteristics and local governments' discretion behaviour.

Changes in the municipality characteristics may influence local performance. Therefore, we evaluate the changes in education and in wealth/income. In terms of education, Hamilton (1983) and Hayes, Razzolini, and Ross (1998) argue that local efficiency depends on residents' ability to pressure local representatives. In turn, this ability depends on the education level and income of local residents. Richer local residents impose higher pressure for more efficient services.[6] It is also possible that poorer residents might also want better and more efficient local services. Nevertheless, wealth and education are expected to both increase local revenues and raise public awareness towards local government performance. Therefore, we expect the efficient scores to increase for municipalities with higher increases in education and wealth of the local residents.

Also, previous literature suggests that local governments have a tendency to pursue their self-interests and their political agenda (Niskanen 1975; Migué, Bélanger, and Niskanen 1974). We therefore expect the efficient scores to decrease for clustered regions where the mayor has more discretionary power.

According to Grossman, Mavros, and Wassmer (1999), the monitoring costs to mitigate local government's discretional behaviour increase with geographic 'scarcity of municipalities'. We thus hypothesize that there are scale economies on providing local public services and the efficient scores are expected to increase for municipalities that experience a higher increase in the number of residents.

To test these hypotheses, we compare the DEA output efficiency scores before and after clustering; in other words, we evaluate the importance of changes in municipality's characteristics using the following equation:

$$\Delta\theta_i = \beta_0 + \beta_1 \Delta Edu_i + \beta_2 \Delta \mathrm{PP}_i + \beta_3 M_i + \beta_4 \Delta Pop_i + \varepsilon_i \quad (4)$$

where i denotes inland municipality.

Our dependent variable, $\Delta\theta_i$, is the difference between the DEA output scores for the DMUs defined by commuting clusters and the baseline DEA output scores. As for the independent variables, we include the change in the education share, ΔEdu_i measured as the difference between the share of educated residents in the clustered region and the initial share of educated residents in a municipality; the change in income/wealth, ΔPP_i, measured as the change in the average purchasing power at the clustered municipality and the initial purchasing power in a municipality; local discretion behaviour, M_i, measured as the proportion of mayors, in the clustered region, belonging to the same party as the government; and the change in population, ΔPop_i, measured as the change in the logarithms of the number of residents at the clustered region and initial number of residents. The definition and sources of the explanatory variables are presented in Table A3.

[6]See Hamilton (1983), Hayes, Razzolini, and Ross (1998), De Borger et al. (1994), and De Borger and Kerstens (1996).

Table 4. Linear regression model for efficiency.

	Change on efficient scores											
	Commuting zones				Nearby municipalities 20 km				Nearby municipalities 30 km			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Change education	0.811***	1.873***	1.853***	1.523***	0.998***	2.499***	2.485***	2.072***	0.839***	1.999***	2.000***	1.613***
	(0.188)	(0.341)	(0.341)	(0.378)	(0.250)	(0.371)	(0.374)	(0.398)	(0.186)	(0.342)	(0.342)	(0.354)
Change Income		−0.394***	−0.392***	−0.449***		−0.519***	−0.516***	−0.558***		−0.424***	−0.424***	−0.487***
		(0.100)	(0.100)	(0.110)		(0.100)	(0.101)	(0.108)		(0.108)	(0.108)	(0.111)
Mayor			0.057	0.072			−0.017	−0.008			0.020	0.036
			(0.049)	(0.051)			(0.026)	(0.026)			(0.036)	(0.039)
Change population				0.041**				0.044***				0.055***
				(0.016)				(0.012)				(0.013)
Constant	0.184***	0.187***	0.162***	0.082**	0.213***	0.214***	0.221***	0.170***	0.282***	0.284***	0.275***	0.178***
	(0.013)	(0.012)	(0.023)	(0.041)	(0.009)	(0.008)	(0.015)	(0.023)	(0.010)	(0.009)	(0.018)	(0.033)
Observations	278	278	278	278	278	278	278	278	278	278	278	278
R^2	0.054	0.098	0.103	0.133	0.072	0.180	0.182	0.236	0.065	0.129	0.130	0.208

Notes: The table reports the estimated coefficients for Equation 4 using linear regression model (OLS). Columns 1–4 present the coefficients using as dependent variable the change in DEA output scores for the commuting clusters and the baseline DEA output. Columns 5–12 present the coefficients using as dependent variable the change in DEA output scores for nearby municipalities clusters and the baseline DEA output. The definition and sources of the independent variables are presented in Table A3. Robust SEs are in parentheses.
***Statistical significance at 1%; **significance at 5%; *significance at 10%.

Columns 1–4 of Table 4 present the results using linear regression model (OLS) using Equation 4 for mainland Portugal. SEs for the regression are robust.

The results indicate that spending efficiency in the clustered regions increases when the percentage of highly educated residents increases and population increases, which can be seen as evidence of gains via scale economies (i.e. under commuting clustering and geographical vicinity), in providing the municipal services.

The variables that are not in line with the initial expected sign are the change in income of the local residents and mayor's discretionary behaviour. The efficiency scores increase for regions experiencing an average decrease on residents' purchasing power, which might suggest that poorer residents pressure local governments for better and more efficient local services. In addition, municipalities with a higher percentage of mayors belonging to the same political party as the national government experience an increase in the efficiency scores. Nevertheless, the the coefficient associated with this variable is not statistically significant.

As a robustness check, we also estimate Equation 4 using an alternative dependent variable, the difference between the DEA output scores for the DMUs defined by geographic distance between the municipality's capitals and the baseline DEA output scores. The estimated coefficients are presented in columns 5–12 of Table 4. Except for the discretionary behaviour of the mayor, the remaining variables have similar signs as presented for DMUs defined by commuting clusters.

V. Conclusion

This study shows that clustering municipalities improves local government spending. Using hierarchical clustering methods to define new encompassing geographic units and DEA framework to define the efficiency scores, we find that from an output-oriented perspective 83–98% of municipalities are able to increase their efficiency scores. Whereas from an input-oriented perspective, 86–98% of municipalities are better off in terms of efficiency scores. Our results hold both for Portugal mainland and for its NUTII regions.

In addition, we find that the increase in the population positively affects the efficiency scores, which can be seen as evidence of gains via scale economies (i.e. under commuting clustering and geographical vicinity), in providing the municipal services. Also, increases in the share of high-educated residents lead to higher efficiency scores, hitting at the hypotheses that educated residents pressure local governments to provide better and more efficient public services. Finally, municipalities with increases in the proportion of richer residents impinge negatively on the above-mentioned efficiency scores.

This conclusion comes with some caveats. We did not consider possible economies of scales that might occur when we cluster municipalities together. For example, costs with electricity, personnel and other inputs might decrease. Therefore, the conservative nature of our approach could bias our previous efficiency estimates downward.

This study is motivated by the growing need to reduce government spending and increase its efficiency given the global economic and financial context. In fact, our novel approach is particularly relevant for countries like Portugal that have signed international financial support programmes, and to meet the terms of the agreement, the respective governments have to cut public expenditure among other policies. Moreover, our approach to efficiency gains via commuting zones clustering has obvious policy implications for decision makers.

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Appendix 1. Conversion table

Table A1. List of municipalities included in each cluster in mainland Portugal.

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
101	Águeda	9	1	1
102	Albergaria-a-Velha	9	2	2
103	Anadia	3	1	1
104	Arouca	2	3	3
105	Aveiro	9	4	1
106	Castelo de Paiva	48	3	3
107	Espinho	2	5	4
108	Estarreja	9	2	2
109	Santa Maria da Feira	2	2	2
110	Ílhavo	9	4	1
111	Mealhada	3	1	1
112	Murtosa	9	2	2
113	Oliveira de Azeméis	2	2	2
114	Oliveira do Bairro	9	1	1
115	Ovar	2	2	2
116	São João da Madeira	2	2	2
117	Sever do Vouga	23	2	2
118	Vagos	9	4	1
119	Vale de Cambra	2	2	2
201	Aljustrel	31	6	5
202	Almodôvar	31	7	6
203	Alvito	15	8	7
204	Barrancos	45	9	8
205	Beja	15	10	9

(*Continued*)

Table A1. (Continued).

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
206	Castro Verde	31	11	6
207	Cuba	15	12	7
208	Ferreira do Alentejo	15	13	5
209	Mértola	51	14	10
210	Moura	45	15	11
211	Odemira	6	16	12
212	Ourique	31	11	6
213	Serpa	45	17	9
214	Vidigueira	15	12	7
301	Amares	11	18	13
302	Barcelos	36	19	14
303	Braga	11	18	13
304	Cabeceiras de Basto	50	20	15
305	Celorico de Basto	38	20	15
306	Esposende	36	19	14
307	Fafe	20	21	16
308	Guimarães	20	21	16
309	Póvoa de Lanhoso	11	18	13
310	Terras de Bouro	11	18	13
311	Vieira do Minho	11	18	13
312	Vila Nova de Famalicão	20	22	14
313	Vila Verde	11	18	13
314	Vizela	20	21	16
401	Alfândega da Fé	28	23	17

(*Continued*)

Table A1. (Continued).

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
402	Bragança	28	24	18
403	Carrazeda de Ansiães	28	25	19
404	Freixo de Espada à Cinta	47	26	20
405	Macedo de Cavaleiros	28	27	21
406	Miranda do Douro	49	28	22
407	Mirandela	28	29	21
408	Mogadouro	49	30	20
409	Torre de Moncorvo	47	31	17
410	Vila Flor	28	23	17
411	Vimioso	28	32	22
412	Vinhais	28	24	18
501	Belmonte	16	33	23
502	Castelo Branco	8	34	24
503	Covilhã	16	33	23
504	Fundão	16	35	23
505	Idanha-a-Nova	8	36	24
506	Oleiros	8	37	25
507	Penamacor	8	38	26
508	Proença-a-Nova	8	39	27
509	Sertã	39	40	27
510	Vila de Rei	1	41	27
511	Vila Velha de Ródão	8	42	28
601	Arganil	34	43	29
602	Cantanhede	3	44	1
603	Coimbra	3	45	29
604	Condeixa-a-Nova	3	46	30
605	Figueira da Foz	3	47	30
606	Góis	34	43	29
607	Lousã	3	48	29
608	Mira	3	44	1
609	Miranda do Corvo	3	48	29
610	Montemor-o-Velho	3	47	30
611	Oliveira do Hospital	34	49	31
612	Pampilhosa da Serra	16	37	25
613	Penacova	3	45	29
614	Penela	39	48	29
615	Soure	3	46	30
616	Tábua	34	50	31
617	Vila Nova de Poiares	3	45	29
701	Alandroal	27	51	32
702	Arraiolos	17	52	33
703	Borba	27	51	32
704	Estremoz	27	51	32
705	Évora	17	52	33
706	Montemor-o-Novo	44	53	34
707	Mora	52	54	35
708	Mourão	17	55	36
709	Portel	17	12	7
710	Redondo	17	51	32
711	Reguengos de Monsaraz	17	55	36
712	Vendas Novas	44	56	34
713	Viana do Alentejo	17	8	7
714	Vila Viçosa	27	51	32
801	Albufeira	13	57	37
802	Alcoutim	7	58	10
803	Aljezur	14	59	38

(*Continued*)

Table A1. (Continued).

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
804	Castro Marim	7	60	39
805	Faro	7	61	40
806	Lagoa	13	62	37
807	Lagos	14	62	37
808	Loulé	7	61	40
809	Monchique	13	63	38
810	Olhão	7	61	40
811	Portimão	13	62	37
812	São Brás de Alportel	7	61	40
813	Silves	13	62	37
814	Tavira	7	64	39
815	Vila do Bispo	14	65	41
816	Vila Real de Santo António	7	60	39
901	Aguiar da Beira	40	66	42
902	Almeida	30	67	43
903	Celorico da Beira	30	68	44
904	Figueira de Castelo Rodrigo	30	67	43
905	Fornos de Algodres	37	68	44
906	Gouveia	37	69	23
907	Guarda	30	70	44
908	Manteigas	16	69	23
909	Meda	46	71	42
910	Pinhel	30	67	43
911	Sabugal	30	72	26
912	Seia	37	69	23
913	Trancoso	46	68	44
914	Vila Nova de Foz Côa	46	31	17
1001	Alcobaça	10	73	45
1002	Alvaiázere	39	74	46
1003	Ansião	39	74	46
1004	Batalha	10	75	45
1005	Bombarral	5	76	47
1006	Caldas da Rainha	5	76	47
1007	Castanheira de Pêra	39	48	29
1008	Figueiró dos Vinhos	39	40	27
1009	Leiria	10	75	45
1010	Marinha Grande	10	75	45
1011	Nazaré	10	73	45
1012	Óbidos	5	76	47
1013	Pedrógão Grande	39	40	27
1014	Peniche	5	77	47
1015	Pombal	3	74	46
1016	Porto de Mós	10	75	45
1101	Alenquer	4	78	48
1102	Arruda dos Vinhos	4	78	48
1103	Azambuja	4	79	49
1104	Cadaval	5	76	47
1105	Cascais	4	80	50
1106	Lisboa	4	81	50
1107	Loures	4	81	50
1108	Lourinhã	29	77	47
1109	Mafra	29	82	48
1110	Oeiras	4	80	50
1111	Sintra	4	80	50
1112	Sobral de Monte Agraço	29	78	48
1113	Torres Vedras	29	82	48
1114	Vila Franca de Xira	4	78	48

(*Continued*)

Table A1. (Continued).

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
1115	Amadora	4	81	50
1116	Odivelas	4	81	50
1201	Alter do Chão	42	83	51
1202	Arronches	18	84	52
1203	Avis	42	85	53
1204	Campo Maior	43	86	52
1205	Castelo de Vide	18	87	51
1206	Crato	18	83	51
1207	Elvas	43	86	52
1208	Fronteira	42	88	53
1209	Gavião	42	89	54
1210	Marvão	18	87	51
1211	Monforte	18	84	52
1212	Nisa	18	42	28
1213	Ponte de Sor	42	90	55
1214	Portalegre	18	87	51
1215	Sousel	27	88	53
1301	Amarante	38	91	56
1302	Baião	33	91	56
1303	Felgueiras	38	21	16
1304	Gondomar	12	5	4
1305	Lousada	12	92	16
1306	Maia	12	5	4
1307	Marco de Canaveses	48	91	56
1308	Matosinhos	12	5	4
1309	Paços de Ferreira	12	92	16
1310	Paredes	12	92	16
1311	Penafiel	12	92	16
1312	Porto	12	5	4
1313	Póvoa de Varzim	12	19	14
1314	Santo Tirso	20	22	14
1315	Valongo	12	5	4
1316	Vila do Conde	12	19	14
1317	Vila Nova de Gaia	12	5	4
1318	Trofa	20	22	14
1401	Abrantes	1	89	54
1402	Alcanena	1	93	57
1403	Almeirim	26	94	49
1404	Alpiarça	26	94	49
1405	Benavente	35	79	49
1406	Cartaxo	4	79	49
1407	Chamusca	26	93	57
1408	Constância	1	93	57
1409	Coruche	35	95	58
1410	Entroncamento	1	93	57
1411	Ferreira do Zêzere	1	41	27
1412	Golegã	1	93	57
1413	Mação	1	89	54
1414	Rio Maior	26	76	47
1415	Salvaterra de Magos	35	79	49
1416	Santarém	26	94	49
1417	Sardoal	1	89	54
1418	Tomar	1	96	57
1419	Torres Novas	1	93	57
1420	Vila Nova da Barquinha	1	93	57
1421	Ourém	10	96	57
1501	Alcácer do Sal	6	97	59
1502	Alcochete	4	81	50
1503	Almada	4	81	50
1504	Barreiro	4	81	50
1505	Grândola	6	98	59
1506	Moita	4	81	50

(Continued)

Table A1. (Continued).

ID	Municipality name	Commuting zones	Nearby municipalities 20 km	Nearby municipalities 30 km
1507	Montijo	4	81	50
1508	Palmela	4	99	60
1509	Santiago do Cacém	6	100	61
1510	Seixal	4	81	50
1511	Sesimbra	4	101	60
1512	Setúbal	4	99	60
1513	Sines	6	100	61
1601	Arcos de Valdevez	22	102	13
1602	Caminha	19	103	62
1603	Melgaço	19	104	63
1604	Monção	19	105	62
1605	Paredes de Coura	19	105	62
1606	Ponte da Barca	22	102	13
1607	Ponte de Lima	19	102	13
1608	Valença	19	105	62
1609	Viana do Castelo	19	106	64
1610	Vila Nova de Cerveira	19	103	62
1701	Alijó	21	107	19
1702	Boticas	32	108	65
1703	Chaves	32	108	65
1704	Mesão Frio	33	91	56
1705	Mondim de Basto	38	20	15
1706	Montalegre	32	109	65
1707	Murça	21	107	19
1708	Peso da Régua	21	110	56
1709	Ribeira de Pena	50	111	15
1710	Sabrosa	21	107	19
1711	Santa Marta de Penaguião	21	110	56
1712	Valpaços	32	29	21
1713	Vila Pouca de Aguiar	50	111	15
1714	Vila Real	21	110	56
1801	Armamar	25	110	56
1802	Carregal do Sal	24	50	31
1803	Castro Daire	24	112	66
1804	Cinfães	48	91	56
1805	Lamego	25	110	56
1806	Mangualde	24	113	67
1807	Moimenta da Beira	40	66	42
1808	Mortágua	41	50	31
1809	Nelas	24	113	67
1810	Oliveira de Frades	23	114	66
1811	Penalva do Castelo	24	115	67
1812	Penedono	46	71	42
1813	Resende	33	91	56
1814	Santa Comba Dão	41	50	31
1815	São João da Pesqueira	46	25	19
1816	São Pedro do Sul	23	114	66
1817	Sátão	24	115	67
1818	Sernancelhe	40	66	42
1819	Tabuaço	40	110	56
1820	Tarouca	25	110	56
1821	Tondela	41	50	31
1822	Vila Nova de Paiva	24	115	67
1823	Viseu	24	113	67
1824	Vouzela	23	114	66

Appendix 2. Data sources

Table A2. Definition of the input (X) and output variables (Y) and respective sources.

Variable	Input measure	Source
X	Total municipal expenditures per inhabitant, 2011	Direcção-Geral das Autarquias Locais 2011, Despesas municipais do ano de 2011 com trimestres e anual (http://www.dados.gov.pt); INE 2011, Recenseamento da População e Habitação, 2011

Variable	Municipal services	Municipal results indicators	Source
Y_1	Social services	Local inhabitants with ≥65 years old, in percentage of the total resident population, 2011	INE 2011, Recenseamento da População e Habitação, 2011
Y_2	Basic education	School buildings per capita measured by the number of nursery and primary school buildings in per cent of the total number of corresponding school-age inhabitants (Y_{21}), 2011 Gross primary enrolment ratio, the number of enrolled students in nursery and primary education in per cent of the total number of corresponding school-age inhabitants (Y_{22}), 2001	INE 2012, Statistical Yearbook of Alentejo, Algarve, Centro, Lisboa and Norte Regions 2011; INE 2011, Recenseamento da População e Habitação, 2011
Y_3	Cultural services	Number of museums, zoos, botanical gardens and aquariums, 2011	INE 2012, Statistical Yearbook of Alentejo, Algarve, Centro, Lisboa and Norte Regions 2011; INE 2011, Recenseamento da População e Habitação, 2011
Y_4	Sanitation	Water supply (Y_{41}), 2009 Urban waste collection (Y_{42}), 2011	INE 2012, Statistical Yearbook of Alentejo, Algarve, Centro, Lisboa and Norte Regions 2011
Y_5	Territory organization	Building permits issued by local administration, 2011	INE 2012, Statistical Yearbook of Alentejo, Algarve, Centro, Lisboa and Norte Regions 2011
Y_6	Roads infrastructures	The length of roads maintained by the municipalities per number of the total resident population and area, 1998	National Association of Portuguese Municipalities (ANMP) (http://www.anmp.pt)

Table A3. Definition of the variables and respective sources.

Variable	Definition	Source
Change in education	Difference between share of educated residents in the clustered region and the initial share of educated residents (Edu_i): $\Delta Edu_i = \frac{Edu_c}{Pop_c} - \frac{Edu_i}{Pop_i}$ Educated residents are individuals with high school diploma, bachelor, master's or doctoral degrees	INE 2011, Recenseamento da População e Habitação, 2011
Change in income	Difference between the average of the purchasing power in the clustered region weighted by initial population and the initial purchasing power (PP_i). $\Delta PP_i = \left(\sum_c \frac{Pop_i \times PP_i}{Pop_c}\right) - PP_i$ Purchasing power is an index constructed by the Portuguese National Institute of Statistics to evaluate the income and wealth of local residents.	INE, Estudo sobre o Poder de Compra Concelho 2011; INE 2011, Recenseamento da População e Habitação, 2011
Mayor	Percentage of municipalities, within a clustered region, with a mayor from the same political party as the government.	Results of municipal elections 11 October 2009 (http://eleicoes.cne.pt/)
Change in population	Difference between the logarithm of the population in the clustered region (Pop_c) and the logarithm of the initial population (Pop_i): $\Delta Pop_i = \ln(Pop_c) - \ln(Pop_i)$	INE 2011, Recenseamento da População e Habitação, 2011

Note: i denotes municipality and c denotes clustered municipalities.