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A Technical Approach to Local Government Amalgamation

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A technical approach to local government amalgamation

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Abstract:

The paper deals with an empirical attempt to apply a variant of King's model of optimal local government size. The debate on local government amalgamation has been particularly intensified by the economic crisis from 2008 that imposed dramatic pressures towards reduction of government expenditures. Despite the fact that the focal point of ongoing and future reforms are fiscal savings, there is a lack of methodology that would enable construction of a tool for better decision-making with regards to the process of local government amalgamations. In this paper, we apply a genetic algorithm as an iterative and flexible optimization procedure that enables calculating a territorial amalgamation of local governments that would save cost. This does not only allow for determination of a cost saving amalgamation scenario, but also can serve as a benchmark of tolerable costs of local government provision of local goods and services.

Key words: local government amalgamation, optimisation, King's model, cost savings, genetic algorithm

1. Introduction

The cornerstone of the fiscal federalism theory is the principle of "subsidiarity," or the so called Oates theorem (1972, 1990, 1993). This principle tells us that there are benefits of decentralizing the government to the level able to make the best spending decisions on public goods and services. This is due to the fact that, for example, local government representatives have better information about the needs of local inhabitants for local goods and services. This mechanism of better spending choices, according to the proponents of decentralisation, brings better outcomes measured by higher rates of economic growth and level of citizens' satisfaction.

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Even though this theoretical assumption looks assuring, unfortunately, there are still no empirical proofs that confirm this thesis. We do not know whether decentralisation causes or is a consequence of economic growth (Bahl-Linn, 1992). Furthermore, the development of individual federal systems was historically not subjected to economic considerations: on the contrary, the formation of administrative-territorial division across countries was rather a result of political, social, ethnic, demographic and other important factors. This led to a number of quite different and unique systems of division of public governments. This is the reason why a range of local governments' size varies among different countries from those with less than 100 local governments to those with more than 30,000. Even though, the excessiveness of the costs imposed by over-fragmented local government sector cannot be judged solely by the number of governments, in general, empirical research shows that many countries have far more local government than the economically optimal threshold would suggest. A potential explanation for such a state might be a political bias at both national and local government level towards formation of more local governments (reflecting desirable voters' preferences). Once that new a local government establishes, there is very strong political and civic resistance to its abolishment.

The latest economic and fiscal crisis that particularly hit EU countries presents an important stimulus for considerations of cost reductions that can be made by local government amalgamations. The economic and fiscal pressures of this crisis couple with underlying problems of undesirable demographic changes that impose additional burden on general government expenditures. Therefore, the governments are increasingly prone to fiscal consolidations and changes of spending structure by decreasing administrative costs and directing these savings towards growth-promoting spending.

There is a great variability of local government sizes in Europe. When this variability is compared with the growth rates, there is no correlation that would provide an answer about the optimality of the territorial setup. That means that territorial division of the national space does not have a crucial meaning in defining the level of development, or the rate of economic growth. However, one has to be careful not to demine the importance of the territorial division. This is because the issue of territorial-administrative division is a part of the wider context of the system of intergovernmental relations. The level of fragmentation will define the level of public services delivered, the level of human capital and technical expertise, financial power and other categories relevant to the quality and quantity of local government goods and services. In other words, an extremely fragmented area will lead to centralized structure of governance and national space. On the other hand, larger local government units will enable a greater dispersion of power in the public sector. Therefore, this situation presents a sort of a paradox. Even though smaller local governments give a maximum level of democracy and level of preferences of local residents, due to the loss of efficiency that comes from limited economic (and other) potential of small governments, in practice this situation leads to centralization.

So far, the research on cost savings of local government amalgamations was usually made by a rule of thumb. In some cases of amalgamation, the cost savings were not in the centre of the reform, but rather the political viability of the reform – voluntary amalgamations of governments. In the best case, the scenario of amalgamation was based on numerous criteria that cannot be quantified and do not consider economic costs and benefits in particular. This research offers an attempt of an empirical representation of the King's model (1984) of optimal government size. The results made by this empirical research provide a clear evidence of benefits of local government amalgamations from an economic perspective and a possible economic benchmark for amalgamations driven by other criteria. More importantly, the best results of the application of this model can be achieved by interaction with other criteria. Such interaction is possible by an iterative procedures that can be implemented in our proposed algorithm.

Therefore, in spite of the fact that decentralization processes in almost all countries were a result of historical processes, present economic and financial pressures give arguments for designing the system of intergovernmental relations that will be cost efficient and, at the same time, will provide the maximum level of supply of local goods and services. The methodology and algorithm elaborated in this paper present a novel approach to the issues of territorial consolidation. The results of the application present a valuable tool for decision-making on these issues and provide non-partisan arguments for amalgamation of particular local governments. After the first part, which presents an overview of local government sizes in EU-27, the second part of the paper briefly describes territorial-administrative division of the government in Moldova, which is used as a case for conducting the empirical research. Republic of Moldova is in the midst of a comprehensive reform of its decentralized system with 902 local governments that impose a significant burden on the efficiency of the public sector in general. In the fourth part of the paper, before concluding, the empirical methodology and the results of the research are presented in more detail.

2. Local government consolidation issues

Local government efficiency comes from many sources. However, we can address three pillars which should enable increasing the efficiency in sub-national public spending (Hemmings, 2006):

- opportunities to encourage greater economies of scale in service provision
- adjustment of sub-national government financing to further increase transparency and provide the right balance between autonomy for the regions and municipalities and the central-government power
- improvements in accountability – in the form of oversight and transparency in public procurement process, strengthening the benchmarking processes, and improvement of e-government particularly in the sense of better coordination between government databases

In this paper, we deal with the issue of achieving greater economies of scale in provision of local public goods and services. This is the first and fundamental step towards exploiting the advantages of other categories that improve the outcomes of local government activities. Questioning the optimal level of local government size, as was mentioned, has many layers (given as criteria in the next section). When we focus on economic efficiency, besides average (marginal) costs which decrease with the size of the local government, we have to aggregate these layers into one that is beneficial in terms of optimal size. There is a general consensus that the level of citizens' participation (which does not refer only to voting) and the level of democracy (in terms of better information and accessibility given to the citizens) negatively correlates with the government size. This comes from the fact that as the government gets larger, the more the individual preferences towards local public goods and services are blended into aggregate preferences of the whole community. At some point of the government size, there is a possibility that aggregate preferences and the distribution of individual preferences do not match closely. It is highly unlikely that a sample of numerous distributions of preferences for many local public goods and services would follow a normal distribution (which would guarantee that most of the citizens' preferences are satisfied). Therefore, local government representatives have to be more responsible towards individual voters in smaller governments simply because they are more accessible and their actions are more visible.

Larger governments can improve territorial equality by combining rich and poor areas (inhabitants) and eliminating differences between available resources and expenditures per capita. The smaller the local governments are, the larger the fluctuation of individual local government expenditure standards from the average expenditure standard of local governments. Of course, such a situation intensifies the needs for central government transfers in order to preserve an acceptable level of provision of local goods and services. This is a sort of a paradox. Despite the fact that smaller local governments have a greater potential for improving the level of local democracy, they demand a greater intervention of the central government to resolve inequalities in resources necessary for satisfying citizens' needs. Usually, the central government does not provide a sufficient level of transfers, which means that a possible level of democracy expressed through the provision of requested local public goods and service is never reached. On the contrary, over-fragmented territorial formation usually creates a local government able to finance only administrative costs without any space for satisfying public needs. This particularly happens in less developed countries with a lower level of fiscal capacities.

A formal model of optimal government size was presented by King (1996). Even though this model relies on restrictive assumptions, it brings interesting considerations into the fore. King argues that the optimal size of the government changes through time, and despite the significant costs of structural reforms, the size has to be periodically revised if we want to preserve an appropriate level of allocative efficiency.

Usually, the optimal local government size concept is given by the trade-off between the economies of scale brought by decreasing costs of larger government and burden of overcrowding of local government territory. Having in mind that the high level of quality of life in large cities in Europe, we can relax the boundary related to number of inhabitants as the burden which provides incentives for smaller government. The reason for such relaxation is due to the fact that amalgamation procedures go from the local government with lowest number of inhabitants and in this way respect the government size from bottom up. The more important aspect is the level of democracy on the local level that should be on the higher level given the smaller government. However, the question is what kind of democracy is valid in case of small governments that are not able to finance any outlays other than administrative ones. This is more the truth the more country is less developed.

The advantage of having fragmented local governments is in matching local residents preferences as close as possible to provision of local public goods and services. If there is such a match, we can say that there is optimal allocative efficiency and the welfare of local inhabitants is maximized. However, there are several obstacles that prevent the occurrence of such ideal case. There are inter-jurisdictional costs of benefit externalities (or spillovers), economies of scale and administration and compliance costs of the government that make argument for more consolidated local governments. Therefore, there is an optimal size of government defined by the intersection of these two opposing principles.

In addition, there is a clear relationship between the degree of decentralization and the level of economic growth. The more the country is developed, the more it can enjoy in the benefits of decentralization. Due to the abundance of the resources and higher level of mobility of local residents, specific local preferences will more diversify among local governments. On the contrary, when the economy is poor, there is not much difference between the local governments because, and, due to the lack of resources, they can provide only minimum level of local goods and services.

The table 1 presents an overview of local government size in EU-27 countries. In 2010, the average European municipality had 5592 inhabitants over a surface area of 49 km2. However, across the countries we can observe significant disparities both in terms of population and surface area in per capita terms.

Table 1: Population, surface area and number of 1level local governments in the EU-27 Member States in 2010

	Population(thousands)	**Surface area (km²)**	**1st Level (municipalities and local authorities)**	**Population (thousands)/number of local governments**	**Surface area/number of local governments**
Countries with one subnational government level					
Bulgaria	7,547	111,002	264	28,6	420,5
Cyprus	804	5,695	378	2,1	15,1
Estonia	1,340	45,227	226	0,6	200,1
Finland	5,363	338,145	342	15,7	988,7
Ireland	4,476	69,797	114	39,3	612,3
Latvia	2,239	64,589	119	18,8	542,8
Lithuania	3,287	65,300	60	54,8	10,9
Luxembourg	507	2,586	105	4,8	24,6
Malta	414	316	68	6,1	4,6
Portugal	10,636	92,152	308	34,5	299,2
Slovenia	2,049	20,273	210	9,8	96,5

Countries with two subnational government levels					
Austria	8,370	83,871	2,357	0,4	35,6
Czech Republic	10,538	78,868	6,250	16,9	126,2
Denmark	5,546	43,098	98	56,6	439,8
Greece	11,305	131,957	325	34,8	406,0
Hungary	10,000	93,029	3,177	3,15	29,3
Netherlands	16,611	41,528	430	38,6	96,6
Romania	21,431	238,391	3180	6,7	75,0
Slovakia	5,430	49,034	2,928	185,5	16,7
Sweden	9,378	449,964	290	32,3	1551,6
Countries with three subnational government levels					
Belgium	10,883	30,528	589	18,5	51,8
France	64,812	632,834	36,682	1,8	17,3
Germany	81,744	357,027	12,104	6,8	29,5
Italy	60,468	301,336	8,094	7,5	37,2
Poland	38,191	312,685	2,479	15,4	126,1
Spain	46,073	505,997	8,116	5,7	62,3
United Kingdom	62,195	243,820	406	153,2	60,1
TOTAL EU 27	501,636	4,409,047	89,699	5,6	49,2

Source: Dexia, 2010

In the cases where maximum number of inhabitants does not reach minimum level of economic efficiency, and there is no political will to introduce amalgamation reforms, there are two possible alternatives to overcome to costs of fragmentation. First, cooperation between local governments in many activities can enable reaching the optimum economic level. This refers to voluntary creation of federations of several smaller governments or creation of intermunicipal enterprises that usually offer communal services such as public transport, energy sector, water and sewer. Second solution refers to outsourcing of part of activities to private sector companies.

Such processes can be noticed for the last several years through the reforms at the municipal level that has encouraged inter-municipal cooperation and municipalities to merge. Cooperation between municipalities for some time is in the process in many different European countries (Hungary, Finland, Austria, Estonia, Bulgaria, Portugal, etc.). In addition, several countries amalgamated their local governments in rather voluntary manner such as in Denmark in 2007 where the number of municipalities dropped from 270 to 98, Latvia in 2009 where they went from 524 to 119, and Greece in 2010 with a rather aggressive approach to reform (from 1,034 to 325). Such municipal reforms are also set in England, Northern Ireland, Finland, Netherlands, Germany, Luxembourg and France (Dexia, 2011).

One of the consequences of sub-national government territorial fragmentation was the fact that there were substantial differences between municipalities and cities in terms of territorial size, number of inhabitants, and technical, economical and financial capabilities of these governments to deliver standard level of local goods and services. The problem is that, at the beginning, the functions and responsibilities given to the same layer of government were equal besides these obvious differences. Later, these differences had to be overcome by formation of new entities and levels of government which introduced different levels of responsibilities depending on the real possibilities of sub-national governments (this refers to “independent competencies” and “delegate powers” in Czech system or “large” cities in Croatia, for example). Despite of such attempts to overcome the problems of lack of economies of scale, research on the optimal size of local governments determine that the costs and quality of delivery of local goods and services are severely compromised in case of local governments with less that 500 inhabitants (Ladner and Steiner, 2003, acc. to Hemmings, 2006).

Surprisingly, the research on the impact of mergers provides evidence for improved quality of local government service but does not find evidence on significant cost savings (Hemmings, 2006). This might be explained by the fact that measures that stimulate mergers usually come with increased level of resources given to the local government which decreases incentives to reduce costs. It is also possible that large governments take over additional responsibilities that have to be financed.

3. Moldovan case

There is at least couple of reasons why there is a need for territorial-administrative amalgamation of local governments in Moldova. One of the most pronounced issues that make a case for amalgamation are issues related to fiscal sustainability. The impact of economic crisis had its negative effects on the economy and general government budget of Moldova. In such circumstances, it becomes expensive to finance such a large number of local governments that accrue substantial level of administrative and operational costs. Secondly, there is an underlying dynamics of negative demographic trends caused particularly by the lower birth rate and emigration of young individuals.

This dynamics produces increase in the cost of providing of social services from the central government level that causes pressure towards the local governments in form of reduced transfers from the center. Third, there is a problem of tax collection and enforcement caused by weak institutional setup. This situation reduces not only the fiscal potential of the central government, and, therefore potential for vertical and horizontal financial equalization but local governments are even less capable of capturing local revenue sources. This problem does not only come through weakening of financial possibilities of local governments but also negatively affects their autonomy.

Another issue related to the need for consolidation belongs to the administrative capacities of local governments. Intergovernmental system up till now did not support significant development of local government technical and administrative potential and local human capital. The system enabled negligible local autonomy and almost all of the public functions are just delegated either from the Raional (regional) or central government level. Therefore, this presents another case for supporting higher level of consolidation. In addition, certain specific features of the Moldovan economic and social circumstances have to be acknowledged. Majority of population resides in rural areas and therefore agriculture sector provides employment for a great number of inhabitants. Related to that, the level of education in these areas is not satisfactory enough to ensure appropriate quality and quantity of provision of local goods and services. This is an important aspect in relevance to consolidation issues that leaves two choices – provides argument for larger local governments or defines the level of services provided by such governments.

Third area of great importance is related to the development potentials of local governments. Under present state, local governments as a mere representatives of central government do not have any potential in undertaking local development programs. In addition to that, goals of EU accession put an additional pressure towards developing local government capacities in administering EU projects. Under present territorial-administrative organization only small number of larger cities is capable for limited development activities.

Long periods of centralized governance lead to substantial inequalities between larger (cities) and smaller local governments (mainly rural municipalities and villages). These inequalities refer to number of economic and social issues. The lack of infrastructure in majority of local governments strikingly differs from those in the cities. Apart from the natural reasons for that state, centralized spending intensified such inequalities. This aspect builds an argument for consolidation particularly of those governments that do not have infrastructure necessary for providing basic public services –

schools, hospitals, roads and other communal infrastructure. However, that situation creates also additional problem that some local governments due to lack of infrastructure (i.e. connectivity by roads) cannot be amalgamated despite the efficiency reasons. Therefore the geographical aspects have to be carefully analyzed in order not to make amalgamation too costly and hard to implement.

Due to the large differences in capacities between local governments the territorial-administrative consolidation has limited potential related for convergence of such differences. Therefore, the potential of ascribing the different levels of provision of local public goods and services has to be defined under the scope of functional and financial decentralization. Consolidation can only provide decrease of such inequalities and provide base for increased decentralization potential in future.

The data on the number of inhabitants per local government is given in the table 2. It can be observed that most of the local governments fall below threshold of 3000 inhabitants. For the country with one of the lowest level of development among European countries this presents too large number of local governments that are potentially below the economically reasonable level. Some studies, mostly by rule of thumb propose 5000 inhabitants as a minimum threshold for enabling local government efficiency (Swianiewicz, 2002). This threshold equals the EU27 average number of inhabitants per local government as well. Therefore, there are obvious potential gains from substantial consolidation.

Table 2: The number of inhabitants per local governments in Moldova (2008)

Number of inhabitants	**Number of municipalities**		
	urban/ towns	**rural**	**total**
<1,500	1	236	237
1,501-3,000	3	358	361
3,001-5,000	6	182	194
5,001-10,000	11	62	73
10,001-20,000	22	4	26
20,001-50,000	9	-	9
50,001-100,000	-	-	-
100,001-200,000	1	-	1
>200,001	1	-	1
total	**54**	**842**	**902**

*Note: *- excluding municipalities from Transnistria;*

Source: The Expert group (2010)

The territorial-administrative reform in Moldova has to be carefully designed in the overall framework of the fiscal decentralization process. There is a very close connection between the fragmentation of local governments and the level of decentralization (centralization). Even though smaller local governments provide basis for increased level of citizens' participation in decision-making on local goods and services, at the same time lack of economy of scale and scope lead to very limited provision of public goods. Therefore, there is an optimal size of governments that is specific for every country depending on numerous factors such as level of development, size of public sector, geographical and demographical features. Therefore, the principles that define a model of territorial-administrative consolidation have to respect these notions. The principles of implementation of the model are as follows:

- territorial-administrative organization has to be efficiently integrated into the overall framework of intergovernmental system;
- the reform has to be in accordance to the Constitution and other relevant legal documents that define intergovernmental system;
- division of territory has to enable optimal level of efficiency in providing the local public goods and services – optimum of local governments size defined between the sufficient economy of scale and number of inhabitants has to be attained;
- amalgamation of local governments has to be made on the basis of social cost-benefit analysis and the model that provides highest level of efficiency under set of constraints will be implemented;
- the proposition of the optimal model of consolidation has to be derived by the intense and broad participation of wider community, media, local government representatives and all other relevant stakeholders;
- the whole process of proposing, accepting and implementing the consolidation model has to be transparent.

Based on the previously mentioned specific issues that define possibilities for territorial-administrative reform and objectives and principles that are guided with the general framework of the decentralization process it is important to address several important groups of criteria: fiscal, demographic, geographic, economic and administrative. The main drivers of the reform are fiscal and economic aspects. Therefore, the model used for the proposition of the consolidation will treat fiscal and economic efficiency as a goal and all other factors, in this perspective, present constraints. By devising an appropriate territorial-administrative structure which is integrated within the overall framework of intergovernmental system, there are numerous positive outcomes. These are increased level of citizens participation in public spending choices, growth of development potentials, allocative efficiency gains, reduction of various inequalities and other benefits.

Of course, the possibilities to use criteria for amalgamation are severally limited by the data resources. However, from the theoretical indicators the most approximate ones have to be selected in order to get close to the optimal level of efficiency of public goods and services delivery as much as possible. It is useful to elaborate numerated criteria more extensively:

- Fiscal criteria (absolute, relative and per capita terms): Own revenues of local government / share of transfers from the center, fiscal potential of local government, share of current expenditures in the total budget expenditures (administration and material costs), costs of minimum provision of local goods and services
- Economic criteria: development indices, number of enterprises, number of facilities that support business activities (banks, development agencies etc.), local public infrastructure (schools, roads, communal infrastructure), local government economy (unemployment)
- Demographic criteria: number of inhabitants, level of education, ethnical homogeneity (heterogeneity), demographic trends (depopulation – migration, birth rate), population density
- Administrative criteria: anticipated level of decentralized public services, level of education of local government administration, number of local governments employees
- Geographic criteria: territorial size of local government, distance between the municipal centers, number and size of settlements within the local government, connectivity of settlements (local governments), geographical features of local governments (that define the level of accessibility)

Having in minded all of the above listed criteria, the analysis of models of amalgamation has to devote attention on dataset collection that can be provided by relevant government agencies. An empirical model of consolidation based on such data has to serve as a tool for clarifying number of consolidation alternatives.

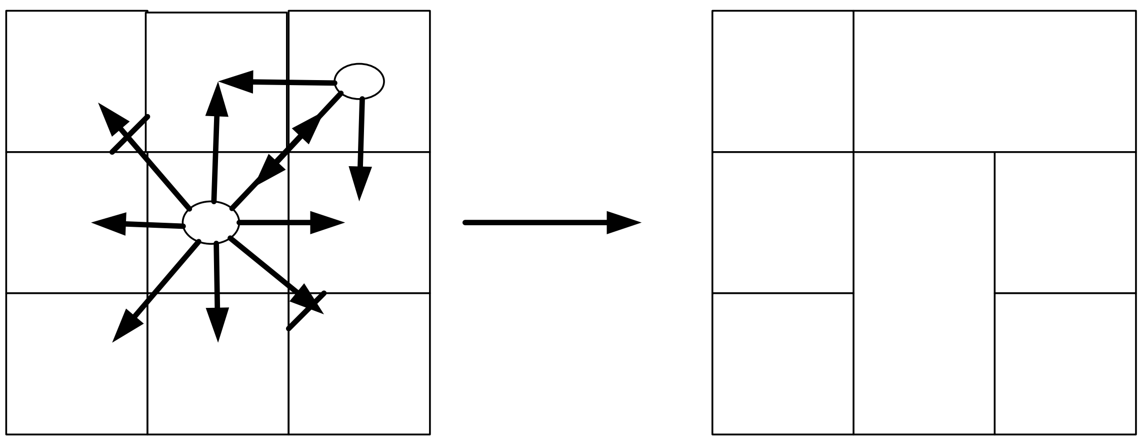
4. The Empirical methodology and the results

Prior to the application of the consolidation algorithm it is important to define appropriate criteria that would lead to increased efficiency of the local governments. The problem is that, in practice, it is highly unlikely to be able to obtain data on that would enable criteria that come from theoretical reasoning. And that is particularly valid for emerging economies. Therefore, the criteria used as empirical base have to be as much closer to the real category of efficiency. One of such criteria might be the costs of administration services, either in percentage of total costs or in per capita terms. In this paper, we will use the costs of administration services per capita.

There are several steps that have to be done in the consolidation algorithm:

1. Geographical (spatial) mapping of national space i.e. determination of local governments in national space, neighbouring communities (creation of the adjacency matrix), territorial features that define possibility for amalgamation of neighbouring communities or other relevant factors such as ethnicity, infrastructure, transport connections, education and health facilities. All this latter features actually present constraints to the optimization routine. In this part the spatial matrix of the national space has to address all of the above mentioned factors that define potential efficiency of amalgamation. This can be depicted by the following picture:

Picture 1: An example of amalgamation problem



The picture shows simple example of the amalgamation problem on the case of 9 local governments. Every square presents a local government. If we do not have any constraints, even in this small example we have a substantial number of possible solutions (5-digit solution). However, for example, if we determine that only 2 out of 9 units do not satisfy the threshold of criteria that we selected (and have to be merged to the neighbouring government), we dramatically reduce the number of possible solutions (10). In addition, if we add the constraint that for certain reasons some units cannot be amalgamated, we further reduce the number of solutions (8). Picture shows that some units cannot be consolidated due to certain constraints (geographical, ethnical, etc…) – A1 and B2, B2 and C3. Second part of the picture presents an ex-post situation with the optimal consolidation solution.

2. The selection of the objective function that has to be minimized (maximized)

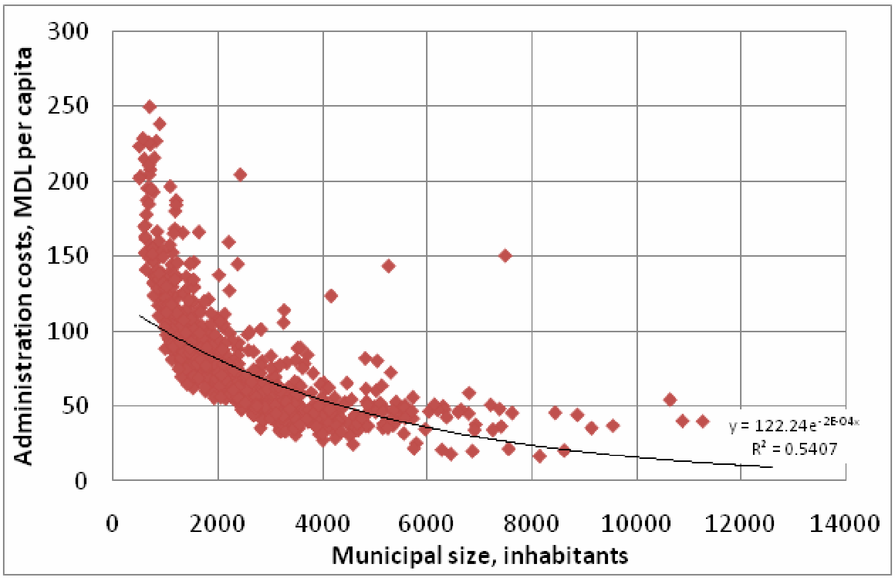
There are numerous possible objective functions that come from the theory and practice of public finances. Due to the fact that the latest consolidation pressures are primarily driven by the burden of fiscal costs, possible criteria can be as follows:

- the share of administration costs in total budget costs,
- administration costs per capita,
- share of local revenues in total revenues,
- share of local taxes in total revenues,
- share of transfers in total revenues,
- costs of basic local services per capita (communal services)

However, above state indicators denote a narrow budgetary perspective. It is not the case that local government with the high level of administration costs necessarily denotes bad governance. It is possible that government is engaged in certain activities that raise the local economic potential in medium and long term but demand high costs in the short term. This might happen in the process of EU accession and preparation for utilization of EU funds. Therefore, even though that in general indicators show the efficiency of governance, caution has to be exercised. This problem can be resolved by introducing performance indicators that show relations between output and input of governments or by dynamic representation of above mentioned indicators[5]. Figure 1 shows empirical relationship between administration costs and municipal size. We can notice obvious negative exponential relation between administration costs and the municipal size.

Figure 1: Correlation between the population of the administrative territorial unit and administrative costs

[5] For example, if local government budget and other policies lead to local development, this will increase local budget revenues.



Source: Osoian et al., 2010

The goal of the consolidation in this paper will be to minimize the function of costs that is presented by the graph. The total costs of the administration presented can be derived by integrating the exponential function. Therefore, the objective of the optimization is to minimize this empirical function.

There are two components that have to be considered. Firstly, we have to accept the assumption that by consolidating two units the costs of administration decrease precisely by the slope given by the empirical function. There are short-term costs of the reform, but this is a reasonable assumption in the medium and long-run period. Secondly, certain threshold that distinct local governments and determines necessity of amalgamation for particular government has to be selected. Even though there are economic arguments for the threshold such as the minimum funds for provision of local public goods and services, in practice, it is very hard to determine that level for particular unit. Therefore, at the end, this presents a political decision. However, the optimization that comes from that decision is driven by the optimal economic-fiscal outcome. In addition, by setting up the certain threshold we can immediately see how many of the local governments will be consolidated.

In the part that follows we present the application of genetic algorithm on the before mentioned economic problem.

4.1. Genetic algorithm

Amalgamation of local governments is a computationally intensive task, since can be mapped to an NP hard *graph partitioning problem*. In particular, the amalgamation of local governments can be represented as a graph, where local governments are modeled as nodes and their geographic adjacency is modeled by an edge between the corresponding nodes. Finding an optimal solution for the graph partitioning problem is not feasible even for very small graph, in our application, local governments of a small country. Hence, a typical approach to graph partitioning problems involves approximate solutions, also called *heuristics*, which are not guaranteed to produce the optimal result. However, properly implemented heuristic algorithms carefully tuned to an application at hand can reach very efficient solutions that are satisfactory for the given purpose.

In this paper we performed amalgamation of the local governments using a variant of a *genetic algorithm* (detailed in section 2 below), which is a search heuristic routinely used to generate solutions to optimization and search problems that mimics the processes of evolution. Results of the computation are compared to a manual country partition performed by a human expert. Although computers can easily outperform humans in these problems, a human expert is likely to take a larger spectrum of parameters into consideration, which cannot be trivially implemented in software. However, a human cannot cope with the combinatorial complexity on large data sets, so computers are necessary to help solve these problems. Hence, the best usable results should come from the interaction of the human expert and properly implemented software. In our experiments, we simplified the amalgamation problem in a way which disregards natural obstacles (e.g., mountains, rivers) and road systems between local governments, as well as different sociological and political issues. The goal of the algorithm is to perform the amalgamation that minimizes the overall costs so that the distance of every local government to its administration centre is within a given distance by air.

4.2. Genetic algorithm definition

Genetic algorithms are adaptive heuristic search algorithms modeled loosely on the principles of evolution via natural selection. They start with a random population and the fitness function applied to assess the fit of the population, then they generate a new population (generation) whose fit is assessed and used to replace the old population if their fit is better. In this way, the survival of the fittest premise of the natural selection is modeled. The new generations are usually obtained in three steps: 1) selection of parents, 2) recombination (crossover) of parents resulting in a child, and 3) mutation of the child. We simplify the steps for obtaining new generations for performing local government amalgamation: the parent crossover step is skipped, so the main mechanism for the evolution of possible amalgamations is mutation. Entire amalgamation results are used and mutations are performed millions of times in order to achieve as cost effective solutions as possible.

Mutation based steady-state genetic algorithm for local government merge is given in table 4. Data and functions used by the algorithm are defined in table 3.

Table 3: Data and functions used by the algorithm

`Country`	set of local governments
`TimeLimit`	time limit that implicitly limits duration of evolution. If no new better solutions are found within TimeLimit time evolution is completed.
`population`	set of different amalgamation solutions used in evolution
`BestSolution(solutionSet)`	function returning solution with minimal cost from the set of solutions
`WorstSolution(solutionSet)`	function returning solution with greatest cost from the set of solutions
`Cost(solution)`	function returning cost of the solution
`RandomNumber(a,b)`	returns random number from interval [a,b]
`Mutation(solution)`	randomly moves one or more units from one territory into another within solution. It ensures that this move results in a valid solution by conforming to given distance/neighbours constraints
`GenerateRandomSolution`	creates random amalgamation solutions that are further evolved using *Genetic algorithm*
`Random(Set)`	returns random element from the set *Set*
`Acceptable (territory, localUnit)`	returns *true* if *localUnit* can be added to *territory* conforming to the given distance limit and neighbor relations

The algorithm starts by generating a set of 50 random solutions to the problem (line 22-24). Random solutions are generated using `GenerateRandomSolution` function (lines 1-18). The production of random solutions is done by generating random territories containing local governments that are merged. Calculation of random territory (lines 5-15) starts by finding a local government that is not yet used in any random territory in the current solution (line 7). The maximum allowed size of a random territory is also a random number (line 6). A territory is allowed to grow until its allowed size is reached, or until there are no more local governments that can be added to it (line 8). A local government is added to the territory from the set of available neighbors (lines 9-11). Upon this addition, the set of available neighbors is recomputed, since a new unit in a territory can allow for more or for fewer other local governments to join the same territory (lines 12-13). When a territory size limit is reached, or there are no more neighbors available to join, a territory is added a as a part of the random solution that is being constructed. When all local governments are used up, the generation of territories is finalized and the solution is completed.

The set of 50 random solutions is refined by the genetic algorithm and new solutions are generated until the time passed from the generation of the best fitting solution reaches `TimeLimit` deadline (lines 27-37). The best fitting solution is initially picked to be the best fitting one from the 50 initially generated random solutions (line 25). Each evolutionary step starts by finding three random candidate parents (line 28). The worst (most expensive) out of the three parents is used as a basis for generation of a new child (line 29). Hence, this process guarantees that the two best found solutions always remain in the population. The central step of the evolution is mutation that is performed on a child (line 30). The mutation involves moving a random local government from the current territory into a new randomly picked territory. This is performed carefully in order to maintain geographic integrity (distances and neighbour relations) of both source and destination territory. The probability of any local government to move from one territory to another is set to 0.4%.

After a mutation is performed on a child, the mutated child fitting cost is compared to the fitting cost of its parent (line 31). If the new child introduces a reduction in the overall cost, it replaces its parent in the population. In 2% of cases, we allow a worse fitting child to replace its parent (lines 31-32). This is done to get out of local minima, i.e., because the search from a lower fitting solutions to the best fitting solution must sometimes go through a generation of costlier interim solutions.

Each new mutated child is compared to the best currently seen solution and the best solution is updated accordingly (lines 33-36). If no new best solution is found in a predefined amount of time, the algorithm terminates and the best found solution is returned (line 28).

Table 4: Genetic algorithm

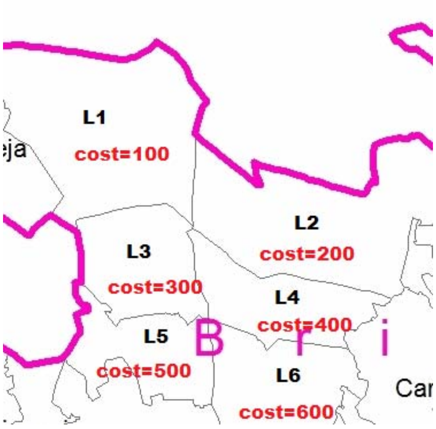
```
GenerateRandomSolution(Country){
  solution=∅;
  visited=∅;
  while(|visited|<|Country|){
    territory=∅;
    territoryLimit=RandomNumber(1,20);
    availableNeighbours=territory + Random(Country\visited);
    while((|territory|<territoryLimit) and (availableNeighbours ≠ ∅)){
      unitToVisit=Random(availableNeighbours);
      territory=territory ∪ unitToVisit;
      visited=visited ∪ unitToVisit;
      availableNeighbours = {localUnit|localUnit∉visited ∧
                                      Acceptable(territory,localUnit)};
    }
    solution=solution U territory;
  }
  return solution;
}

GeneticAlgorithm(Country,TimeLimit){
  population=∅;
  while(|population|<50){
    population=population ∪ GenerateRandomSolution(Country);
  };
  topSolution=BestSolution(population);
  lastSolutionTime=Now();
  While(currentTime-lastSolutionTime<TimeLimit){
    potentialParents=GetRandomSolutions(population,3);
    parent=WorstSolution(potentialParents);
    child=Mutation(parent);
    if((Cost(child) < Cost(parent)) or (RandomNumber(0,100)<2))
      population=(population\{parent}) ∪ child;
    if(Cost(child) < Cost(topSolution)){
      topSolution=child;
      lastSolutionTime=Now();
    }
  }
  return topSolution;
}
```

4.3. An illustration of the genetic algorithm run

To illustrate the running of our genetic algorithm, both the country and the set of rules must be chosen. We use a part of Moldova. The layout of the part of Moldova is presented in figure 2. In this example, there are no distance limitations imposed on the local government merging. The cost of the amalgamation is the sum of the costs of all territories (i.e., merged local governments). The cost of a merger (territory) is equal to the average cost of the participating local governments. Clearly, an optimal solution is the one in which all local governments are merged together. However, such a solution is not economically or politically practical.

Figure 2: Map layout



The computation starts with predefining a random population (only four random solutions are used for simplicity):

```
Population=
[p1= {L1,L2,L3} {L4,L6} {L5} c=1200] [p2= {L1} {L2} {L3} {L4} {L6} {L5} c=2100]
[p3= {L1,L2} {L3,L4,L6} {L5} c=1083] [p4= {L1,L2,L3} {L4,L6,L5} c=700]
Top solution=p4
```

Step1:

```
Random generation of potential parents
  PotentialParents={p1,p4,p3}
Choosing worst parent of Potential parents
  Parent=p1 //worst of p1,p4,p3
Mutation of worst parent by moving L5 to territory containing L1,L2,L3
  Child=Mutation(p1,0.4%)=[p5 {L1,L2,L3,L5} {L4,L6} c=775]
New child is better than its parent p1 so it replaces it in population
  Population=
    [p5 {L1,L2,L3,L5} {L4,L6} c=775] [p2= {L1} {L2} {L3} {L4} {L6} {L5} c=2100]
    [p3= {L1,L2} {L3,L4,L6} {L5} c=1083] [p4= {L1,L2,L3} {L4,L6,L5} c=700]
```

Step2:

```
Random generation of potential parents
```

```
  PotentialParents={p5,p4,p3}
Choosing worst parent of Potential parents
  Parent=p3 //worst of p5,p4,p3
Mutation of worst parent by moving L2 to territory containing L3,L4,L6
  Child=Mutation(p3,0.4%)=[p6 {L1} {L2,L3,L4,L6} {L5} c=975]
New child is better than its parent p3 so it replaces it in population
  Population=
    [p5 {L1,L2,L3,L5} {L4,L6} c=775] [p2= {L1} {L2} {L3} {L4} {L6} {L5} c=2100]
    [p6 {L1} {L2,L3,L4,L6} {L5} c=975] [p4= {L1,L2,L3} {L4,L6,L5} c=700]
```

The computation in the above two steps is analogous. In these two steps, it can be observed that the population has achieved an overall improvement in the average cost, but the optimal solution is yet to be reached.

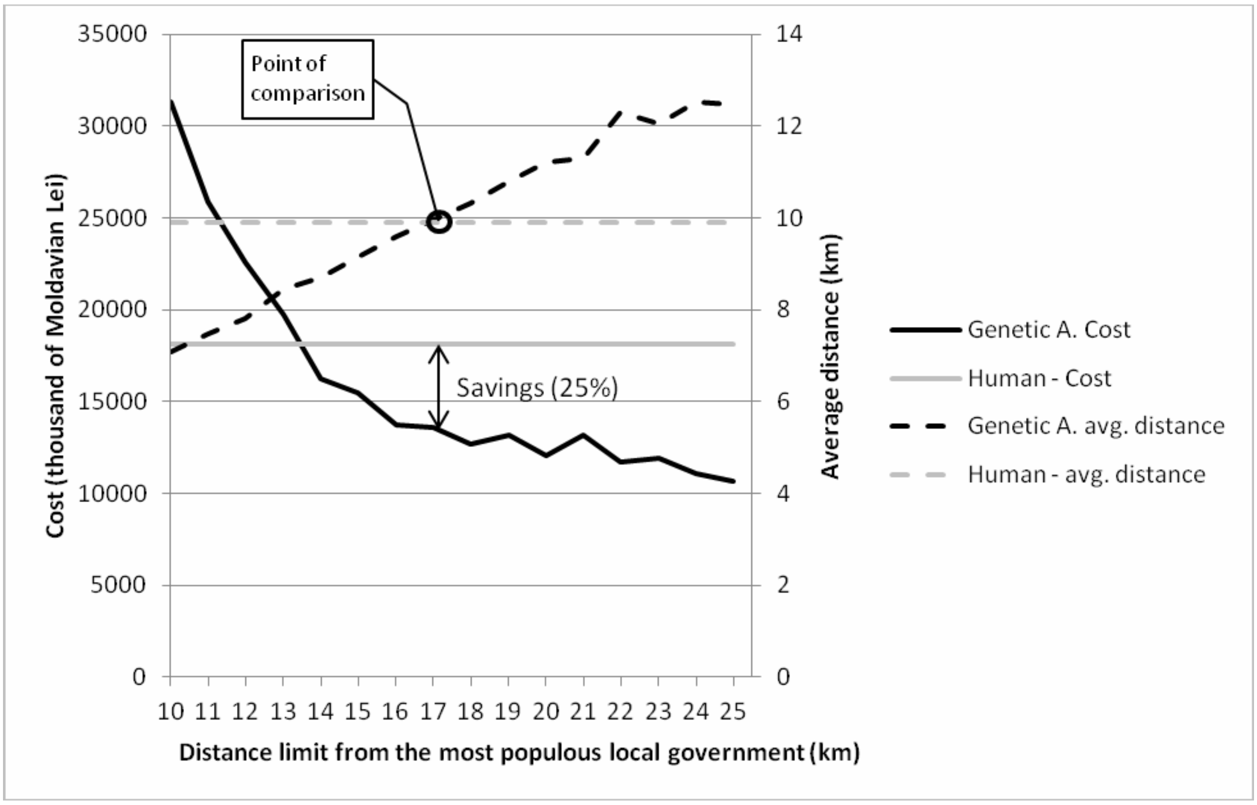
4.4. The results

The genetic algorithm is employed for amalgamation of 315 local governments in northern Moldova, which constitutes about a third of the country. Limits are imposed on distances for each local government merger: the distance from the center of the merger (most populous local government) to each of the participants must be within a given parameter. We have varied the distance in order to see the impact of the merger size on the overall amalgamation cost and to be able to compare our results to the human expert generated solution.

Distances from the most populous local government where limited to the range of 10-25 kilometers and the solution costs range from 31.2 million MLD to 11 million MLD. The human expert generated a solution with the cost of 18.1 million MLD, but that solution did not strictly conform to the specified distance limit; this resulted, in rare cases, in distances between the merged units end the merger center to be more than 30kms.

In order to make a fair savings estimate, we compared our solution with an average distance between local governments and centers as similar to the average distance computed by the human expert solution. This is marked by “Point of comparison” on figure 3. From this point of comparison, we can see that the savings achieved by our method are about 25%. Note that the human expert took different aspects of local governments into account, while we concentrated on geographical data and bare costs. On the other hand, the human expert imposed no hard limit on distances between the local centre and the gravitating local governments and our algorithm is designed to strictly conform to this limit.

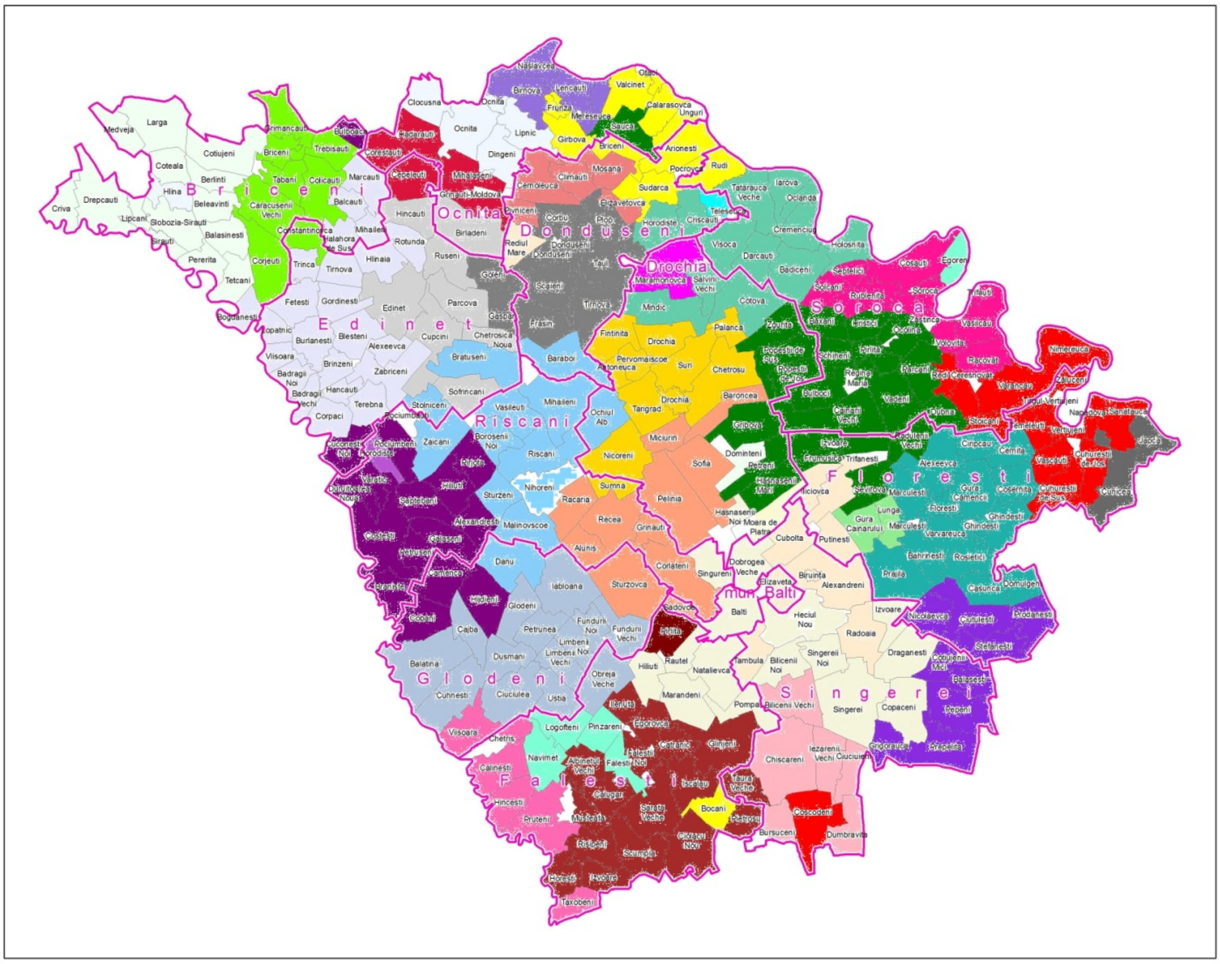
Figure 3: Fiscal savings of local government amalgamation



We put a limit on running time of our genetic algorithm to be several hours in order to obtain the presented results quickly. An increase in the algorithm's runtime and tuning of the algorithm parameters can be expected to lead to even greater savings.

The amalgamation result for distance limit of 17km is shown in figure 3. The results of the simulation are graphically presented by figure 4. It can be observed that some local governments are not merged to any of the territories. This can happen because algorithm didn't run long enough to fix these anomalies or addition of standalone local government to any nearby territory would cause this territory to split in parts (which would result in less cost effective solution). The procedure consolidated 315 local governments in northern Moldova to 40 (after consolidation, in the benchmark study, there are 32 local governments). This procedure shows that minimum savings are on the level of 25% of total expenditures. In case that such amount of resources was directed to local public investments that would be significant boost for local economic development. It can be seen from figure 3 that additional relaxation of distance limit might lead to even much higher savings. However, the level of savings remains in the domain of political choice.

Figure 4: The map of simulation results



5. Conclusion

In spite of different mechanisms of overcoming the problems of over-fragmentation of territorial division across the European countries, the best strategy would be to amalgamate local governments in each country according to the specific needs of each of them. This would lead to decreased costs of delivery of local goods and services or increased quality by changing the spending structure – decreased costs of general administration and increased local government investments. In case that this is not possible, appropriate differentiation of extent of responsibilities among tiers of local government is crucial. Differences in capacities of local government of different size have to be taken in consideration.

As a paradox, in many of the European countries the administrative-territorial division provides possibilities for extreme level of fiscal decentralisation, but due to economic, financial and technical incapacity of small local governments actually leads to centralisation. In terms of efficiency this is suboptimal. Different mechanisms of resolving this problem in form of setting up cities and municipalities with different functions and forms of inter-municipal cooperation are beneficial but do not solve the cause of problem.

It can be concluded that the optimization model presented in this research provides useful tool for analyzing the possibilities for local government amalgamation. There are many advantages that come from utilization of presented procedure: there are millions of possible solutions and only with computational power best solutions can be observed; savings that come from utilization of this model are not negligible – the presented solution gave 25% better outcome than manual consolidation which served as a benchmark; the model will give much better and more precise results if all of the principles and criteria necessary for appropriate local government amalgamation are included through the comprehensive dataset; this data, after collection, are easy to apply within the code of general model; at last, this optimization model is very flexible due to the fact that adjacency matrix which determines connectivity of local governments can be easily modified in case of occurrence of certain “on field” issues; if there is no possibility to amalgamate certain local governments due to social, political, ethnical or any other valid reason the model can be reiterated and give optimal solution under new circumstances; this flexibility is one of the main advantages of the model application.

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