DISTRIBUTION OF MUNICIPLAITIES´ TAX INCOMES/REVENUES MODELLING BY MEANS OF GENETIC PROGRAMMING

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Abstract: *The Goal of this contribution is to demonstrate an illustrative example of genetic programming application in the area of regional administrations financing. The principle of genetic programming is used for the establishing of the analytical function for the calculation of the share each individual municipality has in the national shared taxes revenues in the Czech Republic. This approach is confronted with the existing municipal financing principle issuing from the effective act on Tax Assignment to sub-national Government Level.*

Keywords: *Tax Assignment to sub-national Government Level, shared taxes, district/local administration, genetic programming*

1. Introduction

Tax Assignment to sub-national Government Level („RUD“ in Czech - Tax Assignment to sub-national Government Level) for municipalities is a widely discussed topic in the Czech Republic. There are two associations which strive for the change in the current system, these are the Union of Towns and Villages („SMO“ in Czech) and the Association of Local Administrations („SMS“ in Czech). The Ministry of Finance of the Czech Republic (MFCR) asked, in year 2008, a consortium of universities working under the umbrella of the Economic University (VŠE) to elaborate a study on „*Analysis of financing state administration and local administrations*“. The objective of this study was to gather information fundamental for creating proposals leading to change in relevant RUD legislation [2]. The objective of such changes should not have been to increase the municipalities´ share in the total gross tax revenues re-distributed according to the RUD, but it should be more the correction of some heavily criticized disproportions inbuilt in the current system [6, 7]. Financial crises have caused a dramatic decline in tax collection in which both the national budget and the local administrations (regions and municipalities) have a share, thus any efforts to change the construction of shared tax re-distribution to municipalities and changes in RUD legislation are currently not in the centre of attention.

However, it may be expected that the already fading financial crises impacts on national budgets and the essential consolidation of public finance will bring the question of optimal local administrations financing back into attention. This subjected article is a contribution to the discussion over this topic. The objective of this contribution is to propose and design an algorithm for re-distribution of shared taxes to municipalities by application of the genetic programming method and to compare this with the current shared taxes re-distribution system.

2. Existing valid RUD

The effective RUD legislation – Act on Tax assignment of selected taxes yields to sub-national independent administrations and to certain state funds (Act no. 243 from year 2000 on RUD), has been in effect since year 2001. This Act sets the rules for re-distribution of tax yields among the state, regions and municipalities. During the period of its validity the Act was several times up-dated, the last up-date was done in year 2008, and it was published as Act No. 377/2007 Coll. effective from January 1, 2008.

According to the valid existing legislation municipalities get the following shared taxes yields allocations [2]:

- 21,4 % of the natural person income tax from dependent activities collection;
- 21,4 % of the national legal entities tax collection (excluding taxes paid by municipalities themselves);
- 21,4% of the national natural person income tax collected by reduction tax;
- 21,4% of the national tax collection from the VAT;
- 21,4% of the national natural person income tax from independent business activities tax collection (only 60% of this national tax collection is re-distributed).

Municipalities receive only 30% of the yield from natural person's income tax according to the natural person place of residence. This portion of the tax is linked to the municipality and it works as a motivation element towards promoting business activities in municipalities. 10% of the national yield of this tax belongs to the state, and only the remaining 60% of the tax yield is assigned to be re-distributed among the national budget, regional budgets and municipal budgets.

Next to the above-mentioned shared taxes municipalities get also exclusive tax revenues – these are real estate tax and the legal entity tax paid by municipalities. Detailed diagram of the valid RUD is showed in Fig. 1.

The concrete amount from the national gross shared taxes yield is allocated to individual municipalities based on three criteria:

- Total area of the municipality – criterion weight is 3% (the share of the municipality is defined as the share of this municipality area in the total Czech Republic municipalities´ area). The usage of this area criterion gives advantage to those municipalities that have lower population density. It also compensates increased expenditures for repair and maintenance of local communications and expenditures for transportation services. This criterion is also advantageous for those small municipalities who cannot, if willing so, integrate with neighbouring municipalities due to local geographic conditions.
- Simple number of inhabitants – criterion weight is 3% (the share of the municipality is defined as the municipality simple number of inhabitants in the total number of Czech Republic inhabitants).
- Number of inhabitants adjusted by gradual transitions between municipality size categories coefficients – criterion weight is 94%. Only the part of the number of inhabitants which falls into the relevant number of inhabitant's interval (category) (see Table 1) is calculated by the given coefficient of gradual transitions. This ensures that the shares of individual municipalities create a continuous curve with any jump steps in between individual size criteria. This methodology is not used for Prague, Brno, Ostrava and Plzen)[1].

The calculation algorithm is defined in the following way. First the share of the capital city Praha, the share of city Brno, Ostrava in shared taxes are found, then the total share in shared taxes is found for municipalities in the Czech Republic. The share of a concrete municipality (it is announced each year in the MF CZ by-law) is then defined as the multiple of the number

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[1] These towns have their own re-calculation coefficients.

of inhabitants of the municipality and the relevant coefficients of gradual transitions in the sum of these multiples for all municipalities (without Prague, Brno, Plzen and Ostrava).

Table 1 Gradual transitions coefficients and multiples of gradual transitions

Municipalities with number of inhabitants from - to	**Gradual transitions coefficients**	**Gradual transitions multiple**
0 – 300	1,0000	1,0000 x number of inhabitants in municipality
301 – 5 000	1,0640	300 + 1,0640 x number of inhabitants in a municipality that are above the number 300
5001 – 30 000	1,3872	5 300,8+1,3872 x number of inhabitants in a municipality that are above the number 5 000
30 001 – a more	1,7629	39 980,8 +1,7629 x number of inhabitants in a municipality that are above the number 30 000

Source: [2]

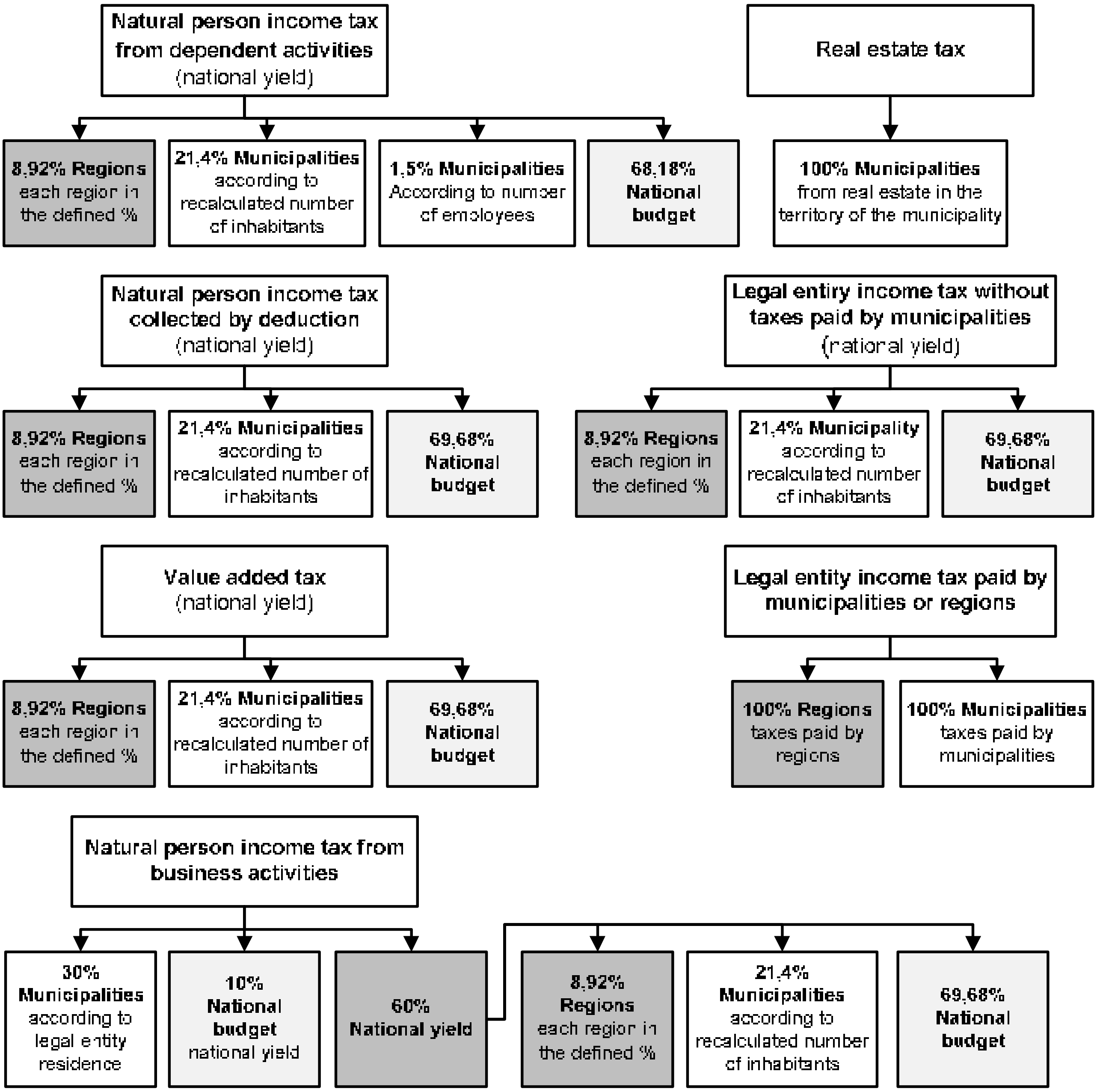

Fig. 1 RUD valid as of year 2008 (without National Transportation Infrastructure Fund, fees and fines) [12]

3. Genetic Programming

The genetic algorithm (GA) transforms a population of individual objects, each with an associated value of fitness, into a new generation of the population. The Darwinian principle of survival and reproduction of the fittest and analogue of naturally occurring genetic operation such as crossover (sexual recombination) and mutation is using for the GA.

A special group that evolve separately, but which draw from GA is genetic programming (GP), where GP is an extension of the GA in which the genetic population contains computer programs. GP makes use of the same techniques as a GA, but it implements over acceptable data structure (N–ary tree). The node of the tree contains entity from two sets (the set of primitive function and the set of terminals) [3, 4, 8].

A functions can be arithmetic (+, -, *, /, etc.), algebraic (sin, cos, exp, log, etc.), logical classical or fuzzy (not, and, or, etc.), conditional operator (If - Then - Else, etc.). A terminal symbol (A, B, C, etc.) can be input variable of program, integer, real, logical, …, constant, function without arguments having secondary effect.

In case of GP are definitions next basic operations: crossover, selection and mutation [3, 5]. Advantage GP in comparison with GA is, that GP is obtained not only common model for solving problems, but also description how is problems solution (particular analyst representation). The basic flowchart for GP is in [13].

3.1. The design of models for calculation of GP share

For the process of searching for a formula for calculation of the percentage share of a municipality in shared taxes with using GP the following attributes have been utilized:

- Common number of inhabitants of a given municipality (O),
- The total number of the Czech Republic inhabitants (CO),
- Total area of municipality (U),
- Total area of the Czech Republic (CU),
- Percentage share of municipality in shared taxes (P).

Design of model for the P calculation is described in Fig. 2.

The result of the GP is the following function that replaces the standard method of calculation of percentage share of CZ individual municipalities in shared taxes:

$genG_P$ = ((((O+O)+(((O+(-4212+(O+O)))+(O+((((O+O)+O)+O)+O)))+(O+O)))+((O+O)+(O+ O))))/(((U+CO)-(((((O+(-3880-(-9978*((-4212+(((O+(O+O))+(-4212+(O+O)))+U))+4212))))+ (((U+(-4212+((((((((6568+(-9978+(-5704*(O-(-8872*(O+O))))))-O)+((-8872-(-1560*((((((((2084+((6568-((O+(-4212+(O+O)))*((((O+(O+(2084*CO)))--3880)+((O-(-1560*((CU-((O+(-4212+(O+O)))*(((((-3880*(-9978*(3340+(O+O))))+CO)-(-1560*((((CO+(CO+((-3880* CO)+(-3870*(-9978+CO)))))-O)+(-8872*CO)))/(O)))+CO))/(O))))/(O)))+O)))/(O)))+((-8872*((-3880+(O+O))+O))*((O+(((((O+O)+(((-2218+-3880)+O)+(O+(((O+(-3880+(O+(((O+(-4212+(O+ (((O+O)+(((-1868+-3880)+O)+(O+(O+O))))+O))))+O)+O))))+O)+O))))+O)+O)+O))+(O+O)))))+ (O+(-8872*(-9978*(3340+((4756+(O+3016))-(O+O)))))))-O)+((O-((-4212+(O+O))*(((O+(4756+(-9978*CO)))+(O*(CO+(CO-(-9978*((O+(O+O))+O))))))))/((O+U))))+O))+(-5860+(-4212*(-9978* ((4756+(O+3016))-(O+O))))))--3880)+(O+CO))--4212))/(O)))+(-4212*(O-(-8872*(O+O))))))+-4212)-O)+-8872)-O))/(O)))+O)+3016))+(((-5704-(-9978*((-212+((O+(O+O))+O))+(O+O))))+O)+-5704)))/(O)+(CU+(((((4756+(O+3340))+O)+O)+((3016+(O+3340))+O))+O))))) (1)

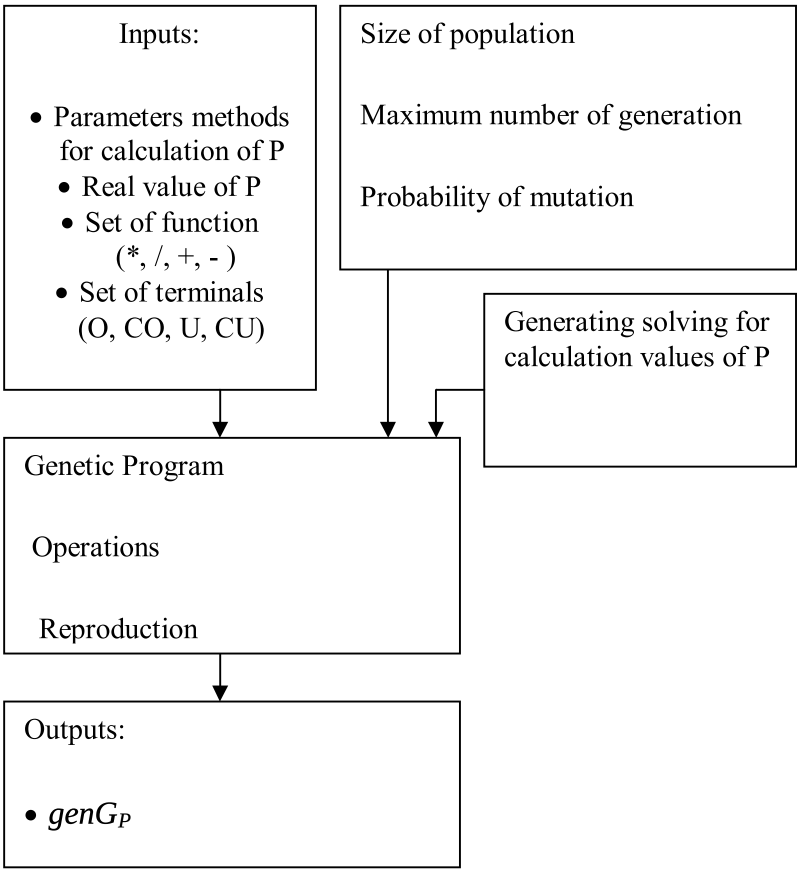

Fig. 2. Flowchart for design of models for calculation P [Source: elaborated with using 11]

This function contains 4 input attributes (O, CO, U, CU) and 11 various constants generated by programme (for example 4212, 3880, 9978, 5704 etc.).

Another possible output form is the generated tree (Fig. 3), which provides information on the resulting shape structure in the shape of n-ary tree.

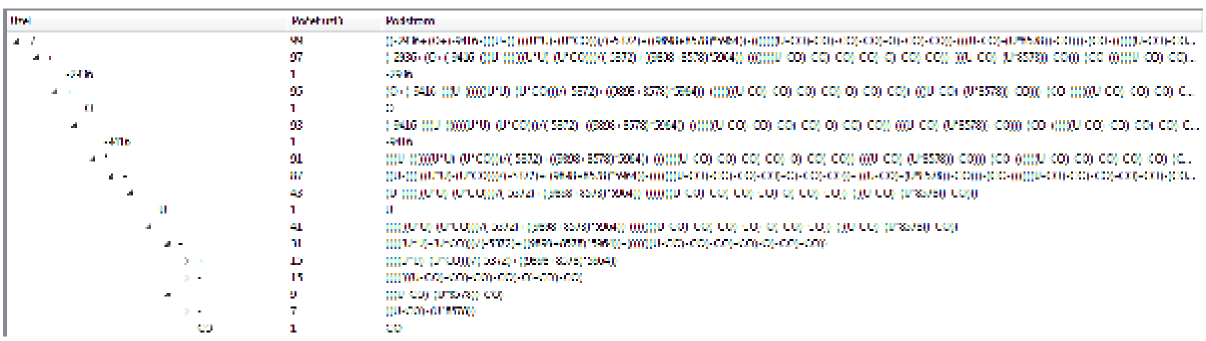

Fig. 3. The graphical representation of the tree solutions (part of the solution tree) [Source: own proceeding]

3.2. Comparison of Results

The resulting function for the calculation of P (1) was applied to the input values (values O, CO, U, CU) and results were compared with values P listed for year 2008 in [10].

The accuracy of calculation AP of the resulting function was evaluated according to the following relation:

$A_P=(P-genG_P)/P$. (2)

The results of comparing accuracy of the resulting analytical function for data from year 2008 according to the size of individual municipalities are stated in Table 2.

Table 2 Evaluation of the Calculation Accuracy

Number of Inhabitants	Number of Municipalities	Standard deviation A_P [%]
110 000 to 50 000	17	-0,073
49 999 to 40 000	5	-0,107
39 999 to 30 000	10	0,005
29 999 to 20 000	27	0,005
19 999 to 10 000	70	0,009
9 999 to 5 000	141	0,073
4 999 to 1 000	1072	-0,052
999 to 500	1311	-0,326
less than 500	3587	-1,439

[Source: own proceeding]

From Tab. 2 issues that function created by means of GP provides results with sufficient accuracy in comparison with the standard way of calculation. Higher deviation (-1,439%) appears only with municipalities with less than 500 inhabitants. With these municipalities the created function assumes higher share in the P value. Another advantage of this function is the possibility to guess P for the following year without using procedures stated in Act [1]. Upon verification of the forecast possibility for year 2009 we used data of individual municipalities in Pardubice region [9]. The accuracy was again evaluated with using relation (2). Average deviation for Pardubice region municipalities was 0,75% which is a sufficient level of accuracy for the forecast of municipal revenues for the following year.

4. Conclusion

This contribution is focused only on a partial part of the system of municipal financing – tax yield allocation to municipalities. The objective however is also to show the utilization of state-of-the-art modelling methods in this area. The entire system of the RUD and municipal financial management must be seen and analyzed as a complex system [6, 7]. New method for municipal financing proposal must be based on deep analyses of municipal financial management on both the income and expenditures sides and in view of municipalities changing needs issuing from the impacts on financing in some services sectors.

The proposal of the design for re-distribution of shared taxes collections on some standards bases that would provide for the financing of the basic needs of inhabitants in municipalities, or for the financing of needs the municipality needs for its catchment area remains to be a question. In this area we see a major space for the utilization of multi-dimensional modelling methods.

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