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IMPACT OF POPULATION AGING ON CITY'S FINANCES

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Abstract: The local aspect of aging is often ignored. However, municipalities, in particular cities will be affected by the consequences of population aging, in particular a decrease in tax revenues and an increase of expenditures on public goods demanded by the elderly. In this paper we use a static general equilibrium model to analyse the impact of aging on city's finances. We show that an increase in the number of pensioners will raise the cost of public goods. However, an increase in the number of working elderly can alleviate the situation.

Keywords: population aging; urban economics; fiscal policy; general equilibrium model

JEL codes: J14, R13, R51

1. Introduction and motivation

The population aging is one of the most important phenomena reshaping our world. The impact of a demographic structure where elderly people are dominating is widely studied and discussed. Although we cannot reverse the trend, many forecasts are showing that we can slow it down and with right policies we can alleviate its consequences. Thus, the main question is what these consequences are and what policies we should apply.

One of the answers is to create incentives for the elderly to stay longer active. Adjusting infrastructure and daily facilities, providing cultural events available for everyone, delivering education dedicated to seniors are basic tools for keeping the older part of society active. Most of them should be delivered by the public sector at the local level together with other public goods in such a way as to stimulate the desired behaviour of the society.

Since there are often no nationwide rules on local policies towards aging, municipalities have a lot of freedom in a way in which they can answer the needs of their older inhabitants. Moreover, among all municipalities the cities, in particular big cities are growing older faster than the rest of the country. Therefore, it is a great environment for finding solutions for counteracting the consequences of population aging. From the local perspective it is easier to see real needs of senior citizens and try to satisfy them. In this paper we want to analyse interactions within the aging city, which is the first step for planning new policies of motivating elderly people to work and to remain an active part of a community.

This work fills a gap in the literature. On a country level many papers have proven significance of the problem and are analysing the impact of an increasing number of the elderly. Most of them show that increasing the number of working elderly seems to be best solution available. However, the analyses of aging at the local level, although numerous, often do not focus on general consequences of aging processes. Many existing papers focus on relatively narrow problems like housing or transportation. Clearly, a wider perspective of the effects of aging at the local level is necessary. Therefore, in this paper we bring together the population, local authorities and local market in order to show the need for increasing the labour market activity of the elderly and to prove that spending money on public goods required by elderly people in a long run is nothing else than an investment.

In order to achieve these objectives we build a simple static general equilibrium model of municipality, which focuses on the city as a separate economy. The model defines relations between households, local market and local authorities, assuming that there is one consumption good provided by the market, a public good provided by the city and labour is the only production factor. The central government is in the model as an external tax gatherer and provider of retirement benefits and subsidies for the local government. The main idea of finding an impact of increasing number of elderly can be explained by assuming that there are 3 types of households: working households, households of active/working seniors and households of inactive elderly. Of course, each household has specific demand function and the weight of these demands depends on the population structure.

Next section contains analysis of a problem It includes not only description of a population aging but also its impact on a city. Third section is a literature review of the impact of aging on local level and of the methodology used in such studies. Later part is focused on a model, its design, derivation and solution. The last chapter contains conclusions about outcomes from the model.

2. Analysis of the problem

The problem of aging is crucial and concerns everyone in developing and developed countries. Thus, it is the subject of extensive research in many disciplines. In local and regional analysis current demographic trends and populations' projections are used as a basis for very practical studies, concerning for example public transport or housing (e.g. Kanaroglou et al. 2009; Maoh et al. 2007; Fernandez-Carro 2012).

Such works are very useful for local governments in planning development of their municipality or region.

Another issue is the cost of retirement. Many studies prove that not only the higher number of pensioners is increasing spending on benefits and decreasing income from taxes but also that it changes preferences of median voter (e.g. Conde-Ruiz et al. 2005). In such case the preferences will have to adjust to the needs of increasing group of poorer seniors who require financial help from government, which has lower revenues. The easiest solution is to raise the retirement age (Bielecki et al. 2014). However, further researches showed the pension's reform should include supporting incentives for staying employed for satisfying effect (Staubli & Zweimuller 2012). In this field local governments' role is very important, since creating environment fitted to needs of elderly people is necessary for not excluding them from a community. Adapting city structure for older people is crucial for keeping them active and self-contained for a long time. The problem is that such policies can be expensive. Therefore, in our work we would like to focus on impact of aging on city's finances.

The biggest problem of aging that concerns cities is that there appears a huge group that is not active and requires special assistance. Therefore, we can easily see fiscal effects of population aging (Lee & Edwards 2002). Since retirement benefits are on average lower than wages, pensioners provide significantly lower revenues for city's budget. However, they need a lot of social services. In case when working-age people group is not big enough to cover these expenditures with taxes it creates permanent fiscal pressure. Thus, municipalities have to do whatever they can to motivate the elderly to continue working. Making city age-friendly and promoting "active aging"[1] makes it much easier for elderly to join social and professional activities. Therefore, this process can be seen as investment, which will alleviate financial pressure on local governments.

In Poland the data proves that municipalities with the highest share of elderly are biggest cities in the country, which are aging much faster than their neighbourhood. Such process can be explained in many ways. One of the reasons is historical processes with migrations to cities and baby-boom after the II world war. Another reason is the move to the suburbs of the young and middle-aged. Still another reason is prices of property and goods in big cities that in many cases make it infeasible for young people to settle down.

In Poland big cities have quite large freedom in managing their own budget. However, the problem is connected with raising revenues. Only small part of income is collected by city directly and it is usually a property/land tax which has limits established by the central government. Another part of revenue is a share in central government income taxes paid by citizens and companies which are established in the city. Next source is the subventions and grants from the central budget which depend mainly on the size of population. Moreover, rich municipalities have to transfer part of their revenues to poorer region. Such situation makes managing

[1] "Active aging" is defined as process of optimization of availability of health care, participation in society and security due to increase life quality of elderly (WHO 2002).

a city much harder but it still confirms that the city needs a lot of taxes and growing number of retirees is a risk to the city's finances.

3. Literature review

In the formal studies of cities, the key element is to properly define interactions in the city (Batty 2008). As for all models of this type, the population structure is one of the significant factors. However, in many of them aging is not a crucial aspect. Usually researchers are concentrating on population density (e.g. Abdel-Rahman & Anas 2004), migrations (e.g. Kopp 2000) or city crowdedness, like Rappaport (2006). Nevertheless, we can find models analysing demographic shocks in details (e.g. Horridge 1999). Such papers usually are focused on situation of certain country and use general equilibrium model to provide wide perspective of the problem (Jimeno et al. 2008).

In general, although not always referring to formal, theoretical models, the literature on aging and its consequences on the local level is abundant. As mentioned in the previous section there are many studies concerning practical issues, like housing or transportation in a municipality. Another type of approach consists of analyses of the determinants of local ageing and their consequences in a given city (e.g. Olberek-Żyła 2013 for Bielsko-Biała in Poland) or in all municipalities or regions of a given territory or type (e.g. Podogrodzka 2013; Gregory & Patuelli 2015). There are also some international comparisons and reports with policy advices (e.g. OECD 2015; WHO 2007). It is worth noting that some of those papers use different forms of spatial analysis, like spatial econometrics (e.g. Hiller & Lerbs 2016) or GIS (e.g. Engels & Liu 2011).

There are not many papers that combine general equilibrium model for cities and aging due to complexity of the problem. Usually general equilibrium models are used to analyse this phenomenon for whole countries, like Lin et al. (2013) for Taiwanese economy or Productivity Commission (2013) for Australia. In local studies one of important aspects that should be included in the analysis is government revenues, mostly based on taxes (Kim et al. 2014), which can be included in a model in a few ways simultaneously (Harberger 1962; Wing 2004). However, regional or municipal income includes also subsidies and/or transfers from higher levels of government (Kim et al. 2014). As far as an analysis of a city using a formal general equilibrium model is concerned, one of the most developed examples is a model for Melbourne (Horridge 1999), developed to study land use and travel demands. As in our model in this work goods are divided only into 2 categories: one provided by the city and another comprising all other goods.

The simplest models that analyse cities are assuming one central point with circular surroundings and that land is not a factor of production (Abdel-Rahman & Anas 2004). The land has rent paid to a local government and redistributed among residents what reflects a tax from land paid directly to a city budget, which is similar to our model. However, in other models land is a production factor, like in Haughwout (2004), where production of a firm depends on labour required and possessed

land, which is the approach we are following. In many papers (Rubinfield 1987), as in ours, for simplicity total income of households is allocated only among public and commercial goods.

4. The model

We build a static model of a city, in which the central government is the only outside element. Consumers are divided into three types of households: households of working adults (A), households of working pensioners (B) and households of non – working pensioners (C). Each of those households is represented by one adult. Pensioners receive their retirement benefits and working households earn wages. They buy goods on the market and supply labour for the market and the city. The city buys labour and delivers public goods. Those goods are produced using labour and other resources of the local government, or are bought from outside the city, meaning that the payment for them disappears from local economy. This purchase may be necessary when the demand for public goods is high and/or the municipal resources, mainly labour, are not sufficient to produce enough public goods to satisfy this demand. Thus, apart from wages, there is a certain cost of producing public goods, which must be covered by the city. Both households and firms pay income taxes to the central government, which in turn pays out pensions, and delivers to the city its share of income taxes and a subsidy. Households and firms pay also local tax, i.e. a tax on land to the local government. The structure of a model is presented in Figure 1 and the list of variables used in the model is presented in Table 1.

For deriving this model we have to make the following assumptions:

1. A perfectly competitive market of producers is restricted to the producers from a city which are identical and treated as a unit.
2. The factors of production are labour and land. There is no capital. Each household owns one unit of land. Each firm disposes of a constant endowment of land.
3. There are no migrations[2].
4. The city's budget is always balanced.
5. There is one commercial good provided by the market and one public good, a generalization of all services and facilities that the city can provide.
6. All working households provide one unit of labour in exchange for wage, which is the same for all ages. Wages are set by the market and a city is the wage-taker.
7. Price of public good for consumers is equal 1[3].
8. Pensions have value established by central government and it is constant.

In order to solve the model and to find the cost of the public good we have to define and solve two problems: households' utility maximization and firms' profit

[2] Obviously migrations are crucial when we analyse aging. An inflow of migrants, who are usually in working age, to a city can improve the demographic situation of this municipality and as a consequence its financial condition. With emigration the situation deteriorates. However, since our model is static we are ignoring this phenomenon, because the effects of migrations are more likely to be felt in the long-run.

[3] This assumption is necessary to close our model.

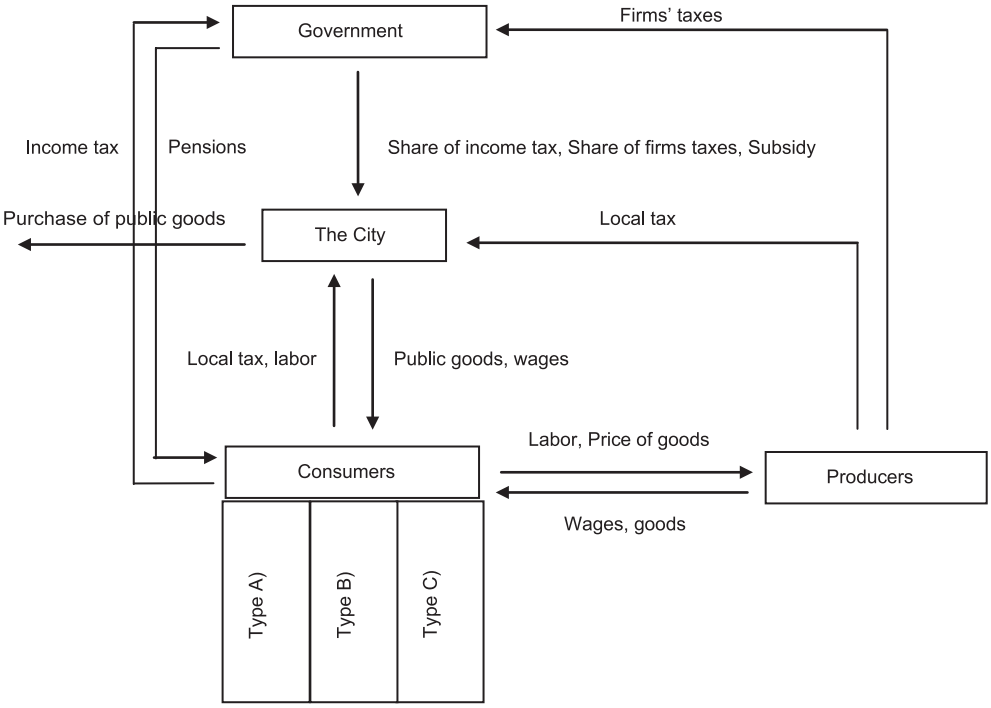

Fig. 1. Structure of the model
Source: Own study.

maximization. The first yields demand for public and commercial goods, while the second yields the firms' demand for labour. From these demands we can derive equilibrium price of the commercial good and wage, which allows to calculate the cost of public good. First, we have to define functions describing utilities, profits and budget constraints. Starting with the latter, household budget constraints have following forms:

$$H_A = w(1 - t_H) - T - px_A - PG_A \tag{1}$$

$$H_B = (w + p)\ (1 - t_H) - T - px_b - PG_B \tag{2}$$

$$H_C = P(1 - t_H) - T - px_C - PG_C \tag{3}$$

Households earn net wage and/or net pension, pay land tax, and pay for its consumption of public and commercial goods. Each function is for a particular type of household, which differ by the source of income. Households A are representing working people who are earning wages. Households B include families of working pensioners which are earning money both from work and pension. Households C are representing only pensioners. Since the model is stationary, the number of households of each type is constant.

Table 1. List of labels

No.	Shortcut	Description
1.	H_i	Income of a household from certain category
2.	w	Wages level
3.	t_H	Income tax of a household
4.	t_F	Income tax of firms
5.	π	Profits of firms
6.	p	Price of commercial good
7.	PG_i	Demand for public goods of a household from certain category
8.	x_i	Demand for commercial goods of a household from certain category
9.	x	Total production of commercial good
10.	L_i	The amount of labour required in certain sector
11.	R	The amount of land possessed by firms
12.	T	Land tax
13.	n_i	The amount of households from certain category
14.	U_i	Utility function of household from certain sector
15.	S	Subsidy
16.	y	Cost of public good
17.	α	Elasticity of demand for households of workers
18.	β	Elasticity of demand for households of working pensioners
19.	γ	Elasticity of demand for households of non-working pensioners
20.	μ	Elasticity of production of a firm

Source: Own study.

The profit equation of a firm:

$$\pi = (1 - t_F)\,(px - wL_F - TR) \tag{4}$$

City budget constraint:

$$B = n_A st_H w + n_B st_H\ (w + P) + n_C st_H P + st_F \pi + T(n_A + n_B + n_C + R) + S - wL_C - yPG \tag{5}$$

The utility functions of households:

$$U^A = PG_A^{\alpha} x_A^{(1-\alpha)} \tag{6}$$

$$U^B = PG_B^{\beta} x_B^{(1-\beta)} \tag{7}$$

$$U^C = PG_C^{\gamma} x_C^{(1-\gamma)} \tag{8}$$

We assume that utilities are defined by Cobb-Douglas functions and households differ only by their preferences given by elasticities.

Firms' production function is also a Cobb-Douglas with labour and land as production factors:

$$x = L_F^{\mu} R^{1-\mu} \tag{9}$$

where labour demanded by firms is a part of the total labour endowment:

$$\bar{L} = L_F + L_C = n_A + n_B \tag{10}$$

In our economy there is no unemployment and the endowment of labour is divided between firms and the local government.

In the next step we have to solve optimization problems and derive demands. First, we maximize utilities of households. For type A households we have the following Lagrangian:

$$L(PG_A, x_A) = PG_A^{\alpha} x_A^{(1-\alpha)} + \lambda_A(w(1-t_H) - T - px_A - PG_A) \tag{11}$$

The first order conditions are:

$$\frac{\partial L}{\partial PG_A} = 0 \qquad \alpha PG_A^{\alpha-1}\ x_A^{(1-\alpha)} - \lambda_A = 0$$

$$\frac{\partial L}{\partial x_A} = 0 \qquad (1-\alpha)PG_A^{\alpha} x_A^{-\alpha} - \lambda_A p = 0$$

$$\frac{\partial L}{\partial \lambda_A} = 0 \qquad w(1-t_H) - T - px_A - PG_A = 0$$

Solving this set of three equations yields:

$$\begin{cases} \alpha PG_A^{\alpha-1} x_A^{(1-\alpha)} \dfrac{x_A}{PG_A} = \lambda_A \\ x_A = \dfrac{1-\alpha}{\alpha} \dfrac{PG_A}{p} \\ PG_A = \alpha[w(1-t_H) - T] \end{cases} \Leftrightarrow \begin{cases} \lambda_A = \alpha^{\alpha}(1-\alpha)^{1-\alpha} p^{\alpha-1} \\ x_A = \dfrac{1-\alpha}{p}\,[w(1-t_H) - T] \\ PG_A = \alpha[w(1-t_H) - T] \end{cases} \tag{12}$$

In the same way we solve utility maximization for two other types of households.

After obtaining demands for each type of households, the total demands for public and commercial goods are the sum of all individual demands. Thus:

$$PG = n_A\alpha[w(1-t_H) - T] + n_B\beta[(w+P)(1-t_H) - T] + n_C\gamma[P(1-t_H) - T] \tag{13}$$

$$x = n_A \frac{1-\alpha}{p}\,[w(1-t_H) - T] + n_B \frac{1-\beta}{p}\,[(w+P)(1-t_H) - T] + n_C \frac{1-\gamma}{p}\,[P(1-t_H) - T] \tag{14}$$

Next problem is solving the firm's profit maximization problem subject to labour required for production. In this case the maximization is only subject to the labour because in the static model amount of land is constant:

$$\frac{\partial \pi}{\partial L_F} = (1 - t_F)\,\frac{\partial\,(pL_F^{\mu}R^{1-\mu} - wL_F - TR)}{\partial L_F}$$
$$= (1 - t_F)\,(p\mu L_F^{\mu-1}R^{1-\mu} - wL_F - TR) = 0$$

$$\Leftrightarrow \quad L_F = \left(\frac{w}{p\mu R^{1-\mu}}\right)^{\frac{1}{\mu-1}} \tag{15}$$

Therefore, the labour demand of firms is the function of the level of wages, price, stock of land and elasticity of production. When substituting to the firm production function (9) it results in:

$$x = L_F^{\mu}R^{1-\mu} = \left(\frac{w}{p\mu R^{1-\mu}}\right)^{\frac{\mu}{\mu-1}} R^{1-\mu} \tag{16}$$

For finding equilibrium price of commercial good it is required to find equilibrium on the commercial good's market. For this purpose it has to be calculated how much firms should produce for fulfilling the demand (14):

$$\left(\frac{w}{p\mu R^{1-\mu}}\right)R^{1-\mu} = n_A\,\tfrac{1-\alpha}{p}\,[w(1-t_H) - T] + n_B\,\tfrac{1-\beta}{p}\,[(w+P)(1-t_H) - T] + n_C\,\tfrac{1-\gamma}{p}\,[P(1-t_H) - T] \tag{17}$$

Using this condition we can derive the equilibrium price of the commercial good:

$$p = \left(\frac{w}{\mu}\right)^{\mu} R^{\mu-1}\{n_A(1-\alpha)\,[w(1-t_H)-T] + n_B(1-\beta)\,[(w+P)(1-t_H)-T] + n_C(1-\gamma)\,[P(1-t_H)-T]\}^{1-\mu} \tag{18}$$

Since we know firms' demand for labour (15), we can calculate equilibrium wage. According to the assumption of perfect competitive market the firms' profit in the equilibrium is equal to zero. In addition the city is wage-taker and accepts the wage set on the market. Therefore by substituting firms' supply of x (16), demand for labour (15), and the equilibrium price (18) into firms profit equation (4) we can derive wages:

$$0 = (1 - t_F)\left(\left(\frac{w}{\mu}\right)^{\mu} R^{\mu-1} D^{1-\mu}\left(\frac{w}{p\mu R^{1-\mu}}\right)^{\frac{\mu}{\mu-1}} R^{1-\mu} - w\left(\frac{w}{p\mu R^{1-\mu}}\right)^{\frac{\mu}{\mu-1}} - TR\right) \tag{19}$$

where D is defined as:

$$D = n_A(1-\alpha)\,[w(1-t_H)-T] + n_B(1-\beta)\,[(w+P)(1-t_H)-T] + n_C(1-\gamma)\,[P(1-t_H)-T] \tag{20}$$

After simplification the result is as follows:

$$w = TR\,\frac{\mu}{1-\mu} \tag{21}$$

Thus, the equilibrium wage depends on the level of land tax, the amount of land owned by the firms and the elasticity of production of a firm. With (21) we can calculate the optimal level of the public good's production. Thus, after computing the equilibrium wage it is possible to find the equilibrium demand for the public good, by substituting (21) into (13):

$$PG = n_A\alpha[TR\frac{\mu}{1-\mu}(1-t_H)-T]+n_B\beta[(TR\frac{\mu}{1-\mu}+P)(1-t_H)-T]+n_C\gamma[P(1-t_H)-T] \tag{22}$$

The question is what the cost is of producing such an amount of the public good. Since in the equilibrium with perfect competitive market income of firms is equal 0, the city has no revenues from corporate income tax. Substituting (22) into the budget constraint (5), using the balanced budget assumption and knowing how much labour the city is employing from equations (10), (15) and (21), we can derive y, i.e. the cost of public good for the city:

$$y = \frac{\begin{array}{c} n_A[TR\frac{\mu}{1-\mu}(st_H-1+\mu-\mu t_H)-T(1-\mu)]+ \\ +\,n_B[(TR\frac{\mu}{1-\mu}+P)(st_H+\mu-\mu t_H)-TR\frac{\mu}{1-\mu}+T(1-\mu)]+ \\ +\,n_C[P(st_H+\mu-\mu t_H)+T(1-\mu)]\} \end{array}}{n_A\alpha[TR\frac{\mu}{1-\mu}(1-t_H)-T]+n_B\beta[(TR\frac{\mu}{1-\mu}+P)(1-t_H)-T]+n_C\gamma[P(1-t_H)-T]} - \mu \tag{23}$$

We have to assess the impact of changes in the number of households in each category on the cost of the public good. Since variables for each type are both in the numerator and the denominator it is enough to compare those expressions to check which one is bigger.

We would expect that an increase in the number of non-working pensioners' households (type C) will increase cost of public good. If this is true, then:

$$\frac{P(st_H+\mu-\mu t_H)+T(1-\mu)}{\gamma[P(1-t_H)-T]} > 1 \Leftrightarrow \mu + \frac{Pst_H+T}{P(1-t_H)-T} > \gamma \tag{24}$$

The truth of this inequality depends on the values of elasticity of production of firm, and the elasticity of demand of type C households. The second element on the left hand side of the inequality is positive although smaller than one. Assuming that the elasticity of production with respect to labour is close to one, due to fact that amount of land owned by firms is given, the inequality is true and the increase of non-working pensioners will increase cost of producing public goods significantly.

Additionally, due to fact that pensions are not big on average, increase in the city budget will be lower than increase in cost of public good.

In case of working households (type A), our initial hypothesis was that an increase in their number will decrease the cost of public good. Consequently, it was expected that:

$$\frac{TR\frac{\mu}{1-\mu}(st_H-1+\mu-\mu t_H)-T(1-\mu)}{\alpha[TR\frac{\mu}{1-\mu}(1-t_H)-T]}<1 \Leftrightarrow \mu-\frac{R\frac{\mu}{1-\mu}(1-st_H)-1}{R\frac{\mu}{1-\mu}(1-t_H)-1}<\alpha \tag{25}$$

The second expression on the left side of the equation is bigger than one: since is bigger than , the numerator is bigger than denominator. Therefore assuming that 0 < < 1 the expectation is true. Thus, an increase of the number of working adults decreases final cost of public goods and increases city budget due to bigger income tax.

The crucial issue is the impact of increasing number of working pensioners, i.e. type B households, on the cost of public good. Those households pay high taxes, both on wages and pensions, but they are also likely to have higher demand for public goods. We would expect an increase in their number to decrease the cost of public good. Thus, it should be true that:

$$\begin{gathered}\frac{(TR\frac{\mu}{1-\mu}+P)(st_H+\mu-\mu t_H)-TR\frac{\mu}{1-\mu}+T(1-\mu)]}{\beta[(TR\frac{\mu}{1-\mu}+P)(1-t_H)-T]}<1 \Leftrightarrow \\ \Leftrightarrow \mu+\frac{(TR\frac{\mu}{1-\mu}+P)st_H-T(R\frac{\mu}{1-\mu}-1)}{(TR\frac{\mu}{1-\mu}+P)(1-t_H)-T}<\beta\end{gathered} \tag{26}$$

Without knowing values of and the only thing that can be said is that the second element on the left hand side of the second inequality is lower than one. The final outcome depends on relation between and. However, it can be explained in a theoretical way. One possibility is an analysis of the value of pensions. As all forecasts show future pensions will be lower[4], an increase in the number of working pensioners will decrease cost of public good irrespectively to the values of parameters. Moreover, with a value of pension falling to zero the numerator in the second expression on the left hand side will become negative, making it even more likely that inequality (27) is true.

[4] With increasing number of the elderly and decreasing labour force this outcome seems inevitable (see e.g. European Union 2015, pp. 92–94)

5. Summary

The main goal of this paper was to analyse the consequences of aging on a local level. Using a simple general equilibrium model of a city we were able to analyse the impact of aging on city's finances. The outcome of a model is in accordance with theoretical expectations. An increase in the number of non-working pensioners will increase the cost of public goods. On the other hand, an increase in number of working people, independently if they are pensioners or not, will decrease these costs. Such results are proving that problem of aging is significant in case of the city. The most interesting outcome concerns the working pensioners. The solution showed that decreasing value of pensions should be followed by an increase in the number of working pensioners, since they will try to improve their income level. This will lead to higher tax revenues and possibly lower demand for public goods, which can actually reduce their costs for the city allowing it to provide sufficient supply.

This result gives evidence to the fact that cities should prepare wise policies, which will convince the elderly to stay active longer. For deriving more information from a model it should be solved numerically on the basis of actual data. However, the analytical solution proved the hypothesis that the population aging has crucial effect on city budget.

The work can be extended by conducting simulations with current data or by development of a model. The most interesting method for making model more complex is adding dynamism. It would allow for inclusion of the accumulation of public goods, capital and migrations. Such development will definitely prove that officials should counteract the effects of population aging with longer time perspective.

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