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Inter-regional migration, commuting, and transportation tariffs

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Abstract

Transport services between the core and periphery make the two regions compete for workers and residents. When individuals freely choose their residential location and work place, the commuting policy becomes a strategic instrument being viewed differently by the competing jurisdictions. We build a theoretical model that channelises the inter-regional migration effect on commuting tariffs and subsidies in the presence of the social cost of public funds. We assume that the benevolent federal state is able to endogenise the transport induced migration and use the corresponding social optimum as a benchmark for the welfare comparison between three alternative governance structures. First, the peripheral region being fully responsible for the commuting policy aims to set a lower than socially optimal commuting tariff, attracting migrants from the urban region and stimulating the demand for transportation services. Second, when the urban region is large enough to have both wages and rents insensitive to transport induced migration it opts for suboptimally higher commuting tariffs. Third, when commuting policy is delegated to an inter-regional partnership, its share structure can be properly designed to define the decision making rule that would replicate the socially optimal tariff and determine the allocation of financial burden between the regions. Our model demonstrates that the optimal share of the peripheral region in the partnership increases with the social cost of public funds when the two regions jointly support the transport infrastructure. Our results shed light on how a properly structured organisational capacity shapes the commuting policy in a socially optimal manner.

Keywords: commuting, transportation tariffs, regional migration, inter-regional partnership

1. Introduction

Commuting has already become a part of everyday life for many people. An average person spends about 4.3 years of life on transport. This integral component of people’s lives has already attracted great attention among researchers from the related but still largely disconnected fields of study, namely transportation economics and urban economics.

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Both fields aim at an elaboration of the government policy that would help people improve their lifestyles via greater transport accessibility and thus greater social inclusion. Intuitively, any development of a transportation system due to more affordable tariffs and/or higher quality of services is viewed as an unconditional welfare improvement. In this paper, we argue that if regions in a federal state compete for residents and workers between each other, the level of transportation tariffs may be chosen strategically by the competing local authorities of the neighbouring areas.

The direct way to shape the spatial allocation of the labour force in the country is the development of its transportation system. Most studies on commuting have addressed either investment or tariff policy aspects of the transportation system. Yet, workers have been assumed to have a permanent residential address and their daily commuting has been largely driven by the inter-regional wage differentials. A new wave of research interest in this area of study emerged in the 2000s when the French state railway company SNCF started to run high-speed trains all over Europe. Longer commuting started to affect the spatial allocation of the labour force and Lyon to some extent became a satellite city to Paris. Another example is Brussels, where around 400,000 commuters travel to the city on a daily basis, not only from its less developed outskirts, but also from the regions of Flanders and Wallonia.

However, apart from the highly increased commuting as a result of the improved transportation system, one recent phenomenon deserves greater attention – a permanent change in residential location without changing the workplace. While various effects of commuting have already been comprehensively studied, inter-regional migration in the context of the transportation policy appears to be a relatively less researched topic. The assumption of the immobility of residents in the existing modelling frameworks may be too restrictive. We relax this assumption and allow for zero migration cost making the choice residence endogenous and dependent on the commuting tariff.

On the one hand, the opportunity to decrease daily transportation costs and migrate to a larger city will cause a decline in the demand for commuting. On the other hand, the ability to migrate to a city with smaller rent payments and commute to a larger one makes people choose migration and daily commuting, which increases the demand for commuting. The net effect seems ambiguous since migrants can also commute. Apparently, by means of the transportation policy, the government (being it a regional or federal one), can influence individuals’ decision to migrate and commute. In this paper, we study the migration effect on commuting and establish a channel of induced demand for transportation that may lead to a suboptimal allocation of the workforce across the regions.

We consider a federal state comprising the two regions. The urban region is assumed to have higher labour productivity and thus pays higher wages, which are fixed due to the relatively large size of the region. The wage in the peripheral region depends on the local labour market which is elastic. The federal government being a benevolent social guardian maximises the unweighted total surplus of its residents, which implicitly includes the consumer surplus of both workers and firm owners. At the same time, it accounts for the social cost of public funds, which induces a welfare loss when the transportation system is subsidised from the budget. Our idea to endogenise the inter-regional migration decision requires to model a market for rent in the peripheral region

The rest of the paper is structured as follows. The next section reviews the related literature and discusses a range of relevant modelling approaches that fit our research purposes. The general model setup is introduced in Section 3 and applied to the standard case with no migration in Section 4. Section 5 considers a pure migration story without commuting (e.g. between very remoted regions) to make the migration effect tractable and interpretable. Section 6 presents our main findings for the migration effects on commuting when transportation tariffs are set by: 1) the peripheral region, 2) the urban region, 3) the social planner, and 4) the inter-regional partnership with the share structure determined by the social planner. Section 7 discusses our contribution to the literature and concludes the paper.

2. Related literature

The current research on commuting is shaped by at least three streams of literature. Vandyck and Proost (2012) study interregional transport infrastructure investment decisions when the two cities with different labour productivities compete in taxes. Since our model features very similar modelling blocks, we discuss hereinafter their framework in more detail. The authors assume three main actors: residents, firms and the regional government. All of them are directly or indirectly connected with the changes in the commuting system. Residents account for the commuting costs in their decision-making constraint at the individual level. In this way they choose whether to incur time and money transportation costs and earn higher wages or to earn lower wages in the less productive city without commuting. Firms’ productivity directly depends on the number of employees: decreasing the marginal product of labour (MP_L) function assumes that each additional worker brings a lower increase in output than the previous one. As the labour market is perfectly competitive, wages are equal to MP_L. So, with an increase in the number of employees the decrease in wages offsets a lower growth of the final output and so firms earn zero profits.

However, such changes affect the earnings of the residents and for this reason such dynamics is non-neutral in terms of income redistribution from the firm owners to the employees with the simultaneous increase in the overall output. These effects are taken into account by the government. The authors mainly focus on the strategic investment decisions of the federal state and of the regions. The decision taken by the first agent is assumed to be optimal for the country. Based on it, the researchers investigate the strategic incentives of the regions to deviate from that choice, paying attention to the reasons which have led to such sub-optimal choices. The external prerequisites are market basics and are also constant in our framework: prices and wages are unaffected by the demand side as the market share of one agent is too low to be influential, the economy is closed, labour supply is perfectly inelastic, labour is the only input and there is an urban wage premium, no congestion externalities in the transportation paradigm are taken into account. The intrinsic assumptions refer to the residence decision-making level: the indirect utility function depends on income, the leisure time is fixed and cannot be utilised for commuting, the commuting costs are constant and the residents cannot change the place of residence.

Overall, the model of Vandyck and Proost suggests that the ‘exporting labour’ peripheral region has an incentive to decrease the number of commuting residents in order to balance the marginal benefits derived from the increased output and growth of wages of commuters with marginal costs of the decreased wages of residents. Considering the ‘importing labour’ urban region, the conclusion is the following: there is no incentive to attain an optimal level, as the burden of the invested sum lies on the residents who do not directly benefit from it. Researchers also go behind the described set-up and extend the model with the third region competition, federal tax and firm ownership redistributions, agglomeration and congestion externalities and emphasise the effects of such implications. However, the mentioned factors do not conceptually invert the underinvestment outcomes previously described. In our paper, we have challenged to implement the existing model while adjusting it to several assumptions, crucial to our research objectives. One of the most fundamental changes on the agency level decision making level is the relaxed assumption of resident immobility. Such change will require the inclusion of the rent market in the model. Besides, while the authors study the investment decisions in commuting policy we will concentrate on the tariff policy including fares and subsidies.

Out paper also fuels the debate on ‘commuting paradox’. This phenomenon was first documented in Germany and described in the research of Stutzer and Frey (2008), and also widely researched in Great Britain (Roberts, Hodgson, and Dolan, 2011) and in China (Nie and Sousa-Poza, 2018). However, in our framework, we abstract from the existence of the ‘commuting paradox’ and assume fully rational individuals.

A political economy view of these issues in the context of a simple urban general equilibrium framework is presented in Brueckner and Selod (2006). The authors compare the social optimal and politically feasible choice of the urban transport tariff. They show that commuters experience a trade-off between the money cost and time cost of commuting, meaning that residents will try to counterbalance their expenditures on transport with the partial loss of their income due to the time spent on the trip rather than work. We borrow the authors’ idea to split the user cost of transportation into an explicitly defined commuting tariff and implicit value of travel time. Since in our model in equilibrium all commuters work in the urban region with fixed wages and the inter-regional distance is fixed, the value of travel time is assumed to be constant. The idea of differentiation of the costs connected with the operating system was also outlined in De Rus (2012). The author investigated the rationale for the high-speed rail (HSR) investment and highlighted that the total social costs of HSR operating activity are separated into three types: the producer-operating and infrastructure, the user-time and access costs and the external one, which are ignored in our model.

The assumption that each regulator maximises the welfare of its residents and does not include the welfare of commuters in its objective function is borrowed from the work of Proost and Sen (2006). In their work the researchers deliberately explain the reasons of the mentioned behaviour of regional government representatives.

The problem associated with the strategic choice of financing systems in regulated and interconnected markets is discussed by Bassanini and Pouyet (2005). Their paper suggests a modelling framework to study an interaction between the regional regulators and the transportation firm serving both regions. The objective function of the regulator (represented by the infrastructure manager) consists of the consumer surplus net of subsidy to the transportation firm weighted at the social cost of public fund, and the firm’s profit. The crucial element in such a set-up is the introduction of the cost of social funds $\lambda > 0$. We employ a similar approach in our model and assume efficient regulation when the transportation firm just breaks even.

Similar approach in terms of the maximisation function is used in Arnott and Yan (2000). The authors consider the objective function of the regulator as the sum of the consumer surplus of the residents and the government surplus, viewed as transportation tolls less construction costs.In the research paper of Roca and Puga (2017), the authors point out that employees in larger cities ‘obtain an immediate static premium and accumulate more valuable experience’. This observation supports our approach to modelling the labour market in the urban area. Also we rely on the findings in Zenou (2011), who outlined that the urban area differs from the peripherals in terms of the conditions on the labour market.

As it was mentioned above, in order to capture the migration effect on commuting we need to explicitly model the market for rentsBesides, the dependence of short-run housing prices on demand is also actively supported in the paper of Madsen (2012). At the same time, we make a simplifying assumption of fixed rent rates in the urban region, which is assumed to be large enough to remain unaffected by the migration flows. Such a modelling approach allows us to avoid unnecessary complications of the model and makes it possible to obtain closed form solutions. In particular, we are able to capture a stylized fact documented in Brandt and Maennig (2012) that rent payments decrease with the increase in commuting expenses.

In order to introduce the rent payments into the decision-making constraints of the individuals, we use the approach described in (Federal Reserve Bank of Richmond and Pinto, 2017). Besides, while the study captures different cases of land-ownership with the usage of the specific parameter, we only consider the extreme case with the absentee-landownership.

The significance of the subsidisation of the transportation system was outlined by Parry and Small (2009) . The researchers represent the reasons of the transit subsidies referring to the classic explanations. The most relevant for our study is the mentioned scale economies effect, which implies that the marginal social cost is much lower than the average cost. This leads to inability to set the efficient tariff without subsidies, introduced into (dedicated to) the transportation system. The main aim of research is to investigate whether the described opinion is applicable to the modern world. The authors check their hypothesis on the example of the three large cities: Washington, Los Angeles and London. The case study revealed that the necessity to maintain the transportation system with the subsidisation stays crucial nowadays.

An interesting study of Romaní, Suriñach, and Artiís (2003) is devoted to the investigation of whether is it plausible to assume that the migration and commuting happen simultaneously. The researchers outline that in Catalonia the described phenomena occur together and explain that these flows are generated by one type of people. The motivation of such decision-behaviour patterns, highlighted by the authors, comes from the fact that suburban housing is cheaper in the same area as compared to the urban residence. The ability to spend the same money for the larger area becomes especially crucial for young families and as a result lower rents per meter lead to an increase in population. In the research, the Catalonia observation is further extrapolated on Europe and it is proved that the described phenomenon can also be captured in other developed and developing countries. Their empirical study highlights the importance of joint determination of commuting and migration decisions, which we study at the theoretical level in the following section.

The large research, dedicated to the investigation of centralised and decentralised provision of local public goods, was elaborated in Besley and Coate (2003). The paper contains an insight into the choice of the management strategy with the aim of maximising the overall surplus based on the public goods redistribution between regions. The main specificity of the author’s insight is that the method through which the problem is approached is based on the political economy. It is interesting to note that while the methodology, used in our study differs, the problems arising with the described types of management, such as inefficient results and ignored spill-over effects are similar. Conformity of results allows for the assumption that our approach to the problem is not limited to theoretical usage.

The idea of partnership creation is borrowed from the study Bennett and Iossa (2010), who investigated how in an incomplete-contracting setting, the delegated contracting of public services can be achieved. A similar approach to the provision of transportation services is described in Dementiev and Loboyko (2014).For the simulation we have followed several basic approaches, used in Proost and Sen (2006). The researchers implement the model on the Brussels example and therefore also use some specific assumptions in order to receive the closest to real life estimates.

3. The model

There are two regions in the federal state. Each region has four main economic agents: individuals (being workers on the one hand and residents on the other), firms (which are managed by firm owners), the government and the transportation firm. Individuals choose their work location, so the commuting flows originates directly from the decision-making pattern of the residents. We will first investigate the case of residents' inability to change the living place and after that extend the model with the mobility of individuals. Firms' profits depend on the number of commuters: while the labour market is fully competitive, the increase in the number of employees leads to growth in the company's output; that is why profits positively depend on the number of workers.

The third actor- the state - has the power to control the commuting flows via the access price and transfer instruments. As it was already mentioned, we aim to investigate not the investment policy, but rather the choice of tariffs by the state regulators. The last agent is the transportation firm, which is the main provider of the transportation services. Hereinafter, we also refer to it as a transportation firm, which is a state-owned enterprise and operates under zero-profits through government control.

The transportation system can be regulated by the regions separately or by one single regulator, which is able to incorporate all the effects in both regions in a unified welfare function. Independently made decisions by different governments lead to distortions from the optimal tariff, as the agents do not take into account the side effects on other regions. This is exactly what generates the main interest of our study: how different regulators behave if they are granted with the right to choose the tariff-transfer system and how the state should redistribute transfer burdens in order to achieve the socially optimal level.

3.1 Individuals

First, we consider the behavioural patterns of individuals. We start with two regions denoted by $i = 1,2$. There are N_i individuals that live and work in region 1 and 2. The number of commuters or people who live in region i and work in region $i \neq j$ are denoted by N_{ij} . So, in our initial case without migration, there are 3 types of residents: N_1, N_2, N_{12}. Region 2 is assumed to be more productive than region 1, which results in higher wages and exactly this triggers commuting from region 1 to region 2. Such a set-up can be interpreted as the relationship between urban and peripheral areas.

The number of the residents in region 1, which is less productive, will be determined as $N = N_1 + N_{12}$. Under one-side commuting we imply that the wages in the urban region can not become lower than in peripherals. Both goods and labour markets are assumed to be perfectly competitive and the residents cannot influence prices and wages and perceive them as given. The economy is closed, the labour supply is fixed, all residents are homogeneous in their skills and compose the workforce of the country.

Each resident of region 1 decides whether to stay and work in region 1 or incur some transportation costs, but earn higher wages in region 2. The leisure time is fixed and individuals can travel only at the expense of their working time capacities. We assume that commuters incur two types of user costs: direct money expenses - tariffs t and indirect disutility expenses from every day commuting, measured in money equivalence and denoted as φ. As wages in each district differ, we can model the choice constraint of the commuter as the following equation: $w_2 - t - \varphi \geq w_1$. Such condition is crucial for the commuting phenomenon to exist. Otherwise, the individuals would work and live each in their own district and the transportation system would become senseless. As it was mentioned, the labour market is perfectly competitive, so the wages of residents are equal to the MP_L of firms.

3.2 Firms

Firms employ labour as the only input in the production, the capital is fixed, so issues such as the optimal input mix, or substitution possibilities are ignored in our model. While firms differ in productivity between regions, they are homogeneous inside one area. The relative advantage in labour productivity in the urban region originated from its capital stock and various agglomeration effects. All firms produce a single homogeneous good, which is consumed directly by the residents of these regions. Any issues on the heterogeneity of products and segmentation of demands are omitted as they would lead to redundant complications of the model.

The production function of the firm is denoted by $F_i(N_i + N_{ji})$. In case of restricted mobility we obtain the following notions: $F_1(N - N_{12}) = F_1(N_1)$ and $F_2(N_2 + N_{12})$. It is assumed that firms are tied to their locations. The production function of less productive region is characterised by decreasing economies of scale and from it follows that the marginal product of labour is decreasing with the number of employees. Besides, for simplicity, we assume that the MP_L function is linear. The weakness of such modelling is that it does not account for the agglomeration effect with the increase in the number of employees, so we can not observe the dynamic changes. However, as it was already mentioned, we imply the initial difference in the agglomeration set-up, which is reflected in a higher constant term in the MP_L function.

Moreover, one of the most crucial assumptions in our model is that the MP_L in region 2 - the urban region - is unaffected by the number of workers. This leads to the fact that the decrease or increase in commuters from one region is supplemented by the mass of commuters from other regions, which does not allow the change of wages paid by more productive firms.

The profits of the firms are equal to the revenues, computed as the output multiplied by constant price (we assume that it is equal to 1), fewer costs constituted by wage expenses. All profits are redistributed to regional shareholders and the cross-regional ownership is excluded. Such restriction makes it possible to attribute the output growth directly to the owner of the production capacities. At the moment, we have specified sufficient conditions in order to express both the production functions of the regions and the choice of commuters and in addition to demonstrate the production side of the economy graphically. Thus, the production functions are: $MP_L^2 = w_2$ and $MP_L^1 = a_1 - b_1 \cdot (N - N_{12})$, with $a_1 < w_2$.

3.3 *Residential choice*

The commuting condition (CC) can now be expressed as $MP_L^1 \leq MP_L^2 - t - \varphi$. As the MP_L^1 function is increasing in each additional commuter and the wages conducts directly by the same manner, the commuting will stop when the following condition is achieved: $MP_L^1 = MP_L^2 - t - \varphi$. The commuter which becomes indifferent to the place of work is determined as a marginal commuter and his choice of location can be expressed by the previous equality.

This condition is what determines the allocation of labour force between the two regions and can be illustrated as follows (see Fig. 1):

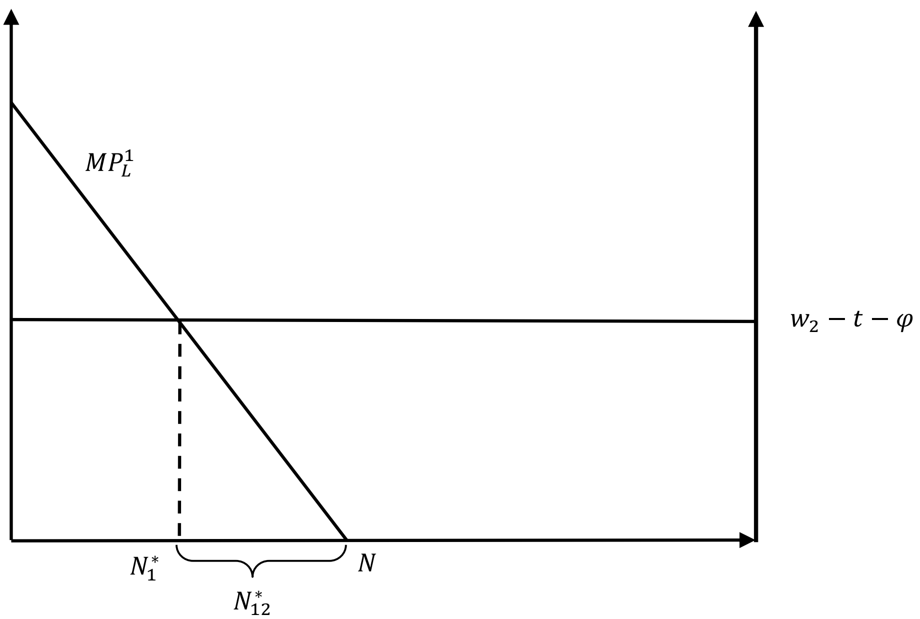

Fig. 1. The original residential choice

Before we move to the investigation of the behaviour of the policy-maker, we model the operating mechanism of the downstream firm. We assumed that the provider of transport services is in ownership of the regulating agent; that is why all fixed costs and losses from the operating activity are covered directly by the subsidies gathered from the residents. The operational profit of a transportation firm is $\pi_t = (t - c)N_{12}$, where t is the tariff or access charge, and c is the constant average costs of the infrastructure. The firm is operating under a break-even condition so that $\pi_t + Sub = 0$, which implies that the transportation subsidy becomes $(c - t)N_{12} = Sub$.

3.4 Regulator's objective function

The regional regulator maximises the total welfare of the residents in its region, while the social planner being a benevolent social guardian takes into account all the residents in both regions. As the profits of firms are redistributed directly to the residents, the objective function of the regulator maximises the total income in the corresponding jurisdiction. It comprises the consumer surplus of the residents, the profits of the firms (income of firm owners), the profit of the transportation firm and is decreased by the value of subsidies enhanced by the social cost of public funds. Taking into account the restrictions on downstream firm operating activity, the program of the regulator in region i writes as follows:

$$max_{(t)} W_i = \pi_i(N_i) + w_i N_i + \pi_t - (1+\lambda) Sub_i$$
$$s.t. (BB): (c-t) N_{12} = Sub_i$$

We module the problem in the following way: if the regulator is given a right to set up a tariff, it also implies that the region bears all the costs connected with the provision of the infrastructure services. We consider three cases. In the first case, in which the objective function of the regulator implicates the effects of commuting on both regions, the subsidies are gathered from the whole population and under such tariff the transfer policy is assumed to be socially optimal. In the second case, in the choice of infrastructure variables is made and the burden of investment is borne by region 1, and in the third case, region 2 operates under the same conditions.

We start with the investigation of the no-migration-commuting framework. Under the next step we will relax restrictions on migration, and at this point we will introduce rent market into the model. Further, we elaborate new conditions for the subsidy policy, so that the activity of the transportation firm will partially be supported by the taxes collected from users of the system. With the introduction of these extensions in our framework we will continue the modelling process through the addition in the set-up of necessary markets and conditions.

4. Commuting with no migration

Before we move to the political decision-making investigation, we determine the condition by which the marginal commuter is found. The state implements in its objective functions the behavioural patterns of residents, which the state cannot affect and that is why we start with the scrutiny of this mechanism.

The first order conditions with respect to the number of commuters N_{12} and number of workers for two regions were determined previously and the following connections can be easily derived:

$$MP_L^2 = \frac{\partial F_2}{\partial N_{12}} = w_2$$
$$MP_L^1 = \frac{\partial F_1}{\partial N_1} = a_1 - b_1 \cdot (N - N_{12})$$

A lower relation will be used only for further derivations and has no economic sense as the second term in absolute value can be interpreted only as loss in the output arisen through the decreased number of workers in region 1.

$$\frac{\partial F_1}{\partial N_1} = -\frac{\partial F_1}{\partial N_{12}}$$

The marginal commuter condition is the following: $MP_L^1 = MP_L^2 - t - \varphi$,that is equivalent to

$$\frac{\partial F_1}{\partial N_1} = w_2 - t - \varphi$$
$$a_1 - b_1 \cdot (N - N_{12}) = w_2 - t - \varphi$$
$$(CC): N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

We see that the optimal number of commuters is decreasing in line with transportation tariffs. This expression will act as the main constraint for the state agents maximising their objective functions. From the other point of view, it clearly expresses how the regulators can use tariffs in order to control commuting flows. For example, higher tariffs will result in retention of labour force in region 1, which intuitively is beneficial to the less productive area.

4.1 Peripheral region

We impose the responsibility of tariff decisions to the regulator from the less productive region 1. Besides, it has to be remarked that the loss from the operating activity of the transportation firm has to be subsidised by local funds only from region 1. Taking all this into account, the regulator from region 1 faces the following maximisation problem:

$$\max_t W_{R_1} = \pi_1(N - N_{12}) + w_1 \cdot (N - N_{12}) + (w_2 - t - \varphi)N_{12} + \pi_t + Sub_1 - (1+\lambda)Sub_1$$

$$s.t.\ (BB): (c - t)N_{12} = Sub_1$$

$$(CC):\ N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

The first-order condition with respect to t results in the following optimal tariff:

$$t_1^* = \frac{(w_2 - \varphi + c - a_1 + b_1 N)\lambda + c}{1 + 2\lambda}$$

The expression shows that the optimal tariff, set by region 1, increases with the marginal cost of the investment system and decreases with the personal disutility expenses. The relation between the social cost of public funds and the tariffs is not so straightforward:

$$\frac{dt}{d\lambda} = \frac{(1+2\lambda)(w_2 - \varphi + c - a_1 + b_1 N) - 2((w_2 - \varphi + c - a_1 + b_1 N)\lambda + c)}{(1+2\lambda)^2}$$

$$\frac{dt}{d\lambda} = \frac{(w_2 - \varphi - a_1 + b_1 N) + (2\lambda - 1)c}{(1+2\lambda)^2}$$

The effect of the social cost of public funds on tariff is positive if $\lambda \geq \frac{1}{2}$. While the parameter is high enough, the increased tariff will lead to both output growth benefits from the restrained number of commuters and lower operating firm loss coverage. When λ turns out to be lower than ½, under each level of tariffs the state faces the trade-off between the production level effect and the need to cover the operating losses of the transportation firm. It can be noticed that there may exist some positive level λ equal to $\frac{w_1+\varphi-w_2}{2c} + \frac{1}{2}$, under which the tariff becomes insensitive to the social cost of public funds. Besides, it has to be emphasised that when $\lambda = 0$, the tariff turns out to be equal to the marginal cost of the industry and the state has no need to pay subsidies.

4.2 Urban region

This section derives the optimal tariff under the choice of the regulator from region 2. The agent faces the following maximisation problem:

$$\max_t W_{R_2} = \pi_2(N_2 + N_{12}) + w_2 N_2 + \pi_t + Sub_2 - (1+\lambda)Sub_2$$

$$s.t.(BB): (c - t)N_{12} = Sub_2$$

$$(CC):\ N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

Again, through substitution, we would obtain the reduced conditions system:

$$\max_t F_2(N_2 + N_{12}) - w_2 N_{12} - (c - t)(1+\lambda)N_{12}$$

$$s.t.(CC)\ N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

The result of the maximisation is the following optimal value of tariff:

$$t_2^* = \frac{w_2 - \varphi - a_1 + b_1 N + c}{2}$$

The optimal level of transportation tariffs, set by the regulator from region 2 has the same relation with the marginal costs of the industry and disutility costs as the tariff system in region 1. Importantly, the optimal tariff in region 2 does not depend on the social cost of public funds.

4.3 Social planner

The social planner considers the effects of commuting on both regions. As the expenditures on the wages of firms are equal to the earnings of residents, they are not included into the maximisation function. The change in tariffs will affect them both, but these effects will be levelled and result only in the redistribution of surpluses of agents. More crucial shifts are captured by the production effects in both regions. With each additional commuter from region 1 to region 2, the output declines in the peripherals and increases in the urban region. While the state will search for optimal redistribution of labour force between regions, it has to consider inefficiencies arising from both expenses from everyday trips of commuters and losses from public funds usage. The maximisation problem can be expressed through the following system:

$$\max_t W_{SP} = F_1(N - N_{12}) + F_2(N_2 + N_{12}) - (t + \varphi)N_{12} + \pi_d + Sub_{SP} - (1 + \lambda)Sub_{SP}$$

$$s.t. (BB): (c - t)N_{12} = Sub_{SP}$$

$$(CC):\ N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

$$W_{SP} = F_1(N - N_{12}) + F_2(N_2 + N_{12}) - (t + \varphi)N_{12} - (1 + \lambda)(c - t)N_{12}$$

The simplification leads to:

$$\max_t W_{SP} = F_1(N - N_{12}) + F_2(N_2 + N_{12}) - (t + \varphi)N_{12} - (1 + \lambda)(c - t)N_{12}$$

$$s.t. (\text{CC}):\ N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1 N}{b_1}$$

The first-order condition with respect to t is:

$$\frac{\partial F_1}{\partial N_1}\frac{\partial N_1}{\partial N_{12}}\frac{\partial N_{12}}{\partial t} + (\frac{\partial F_2}{\partial N_{12}} - t - \varphi)\frac{\partial N_{12}}{\partial t} - (1 + \lambda)(c - t)\frac{\partial N_{12}}{\partial t} + (1 + \lambda)N_{12} - N_{12} = 0$$

As each new worker brings marginal benefit to the firm equal to the wage so that $\frac{\partial F_2}{\partial N_{12}} = w_2$, the two first terms of equation mutually exclude and the following equality is left:

$$\frac{\partial F_1}{\partial N_1}\frac{\partial N_1}{\partial N_{12}}\frac{\partial N_{12}}{\partial t} + (w_2 - t - \varphi)\frac{\partial N_{12}}{\partial t} - (1 + \lambda)(c - t)\frac{\partial N_{12}}{\partial t} + (1 + \lambda)N_{12} - N_{12} = 0$$

Overall, the maximisation problem of the social planner coincides with the one of the regulator from region 1 and as a result:

$$t_{SP}^* = t_1^* = \frac{(w_2 - \varphi + c - a_1 + b_1 N)\lambda + c}{1 + 2\lambda}$$

While the values of the tariffs coincide, the initial difference between two welfare functions generates two alternative forms of distribution of benefits and costs between two regions. In the case of social planner, the benefits from commuting are distributed among firms of two regions, while in case of region 1 gained advantages are extracted by firms from region 1 through growth in output (which is attributed to the increase in income of firm owners) and by commuters, whose income has become higher. The described discretion reflects the difference in perception of the state agents of their welfare maximisation purposes and at the same time highlights the inability of the regional regulator to incorporate the effects from the undertaken actions in the welfare function.

4.4 Commuting tariffs compared

We have so far obtained the two optimal values for tariffs:

$$t_{SP}^* = \frac{(w_2 - \varphi + c - a_1 + b_1 N)\lambda + c}{1 + 2\lambda}$$

$$t_2^* = \frac{w_2 - \varphi - a_1 + b_1 N + c}{2}$$

Now we aim to find out the conditions under which the decision of the tariff policy made by regulator from region 2 will coincide with the optimal one. For this, the following must hold:

$$\frac{(w_2 - \varphi + c - a_1 + b_1 N)\lambda + c}{1 + 2\lambda} = \frac{w_2 - \varphi - a_1 + b_1 N + c}{2}$$

$$2\lambda(w_2 - \varphi + c - a_1 + b_1 N) + 2c = (w_2 - \varphi + c - a_1 + b_1 N)(1 + 2\lambda)$$

$$c = w_2 - \varphi - a_1 + b_1 N$$

$$c + \varphi = w_2 - a_1 + b_1 N$$

The values are equal, if the sum of the marginal cost of the infrastructure and disutility from commuting, expressed in monetary terms, is equal to the initial difference in wages. Under such conditions:

$$t_{SP}^* = t_2^* = w_2 - \varphi - a_1 + b_1 N$$

and it can easily be noticed that in such case $t_{SP}^* = t_2^* = c$. The equality is attainable only when the optimal tariff coincides with the tariff, which would be set by a monopolistic transportation company.

5. Migration with no commuting

Now we proceed with the case of restricted commuting and allowed migration. However, here we have to make several extensions of the initial model set-up. First of all, we introduce the rent market into the model. We consider the absentee-landownership case, so all agents are obliged to pay rents. Under the first steps, we will assume that the rent expenditures in different areas are fixed and are denoted as r_i, where i stands for the region 1,2.

5.1 Migration with equal rents

In order for migration to exist the following condition must hold: $w_2 - r > w_1 - r$. This triggers the migration process until the emergence of the 'marginal migrant', who is indifferent to where they live and work. Recall that w_1 is dependent on the number of residents, while w_2 is constant. Overall, we obtain the following condition for the distribution of labour force between two regions.

$$w_2 - r = a_1 - b_1 N - r$$
$$N^* = \frac{a_1 - w_2}{b_1}$$

Unsurprisingly, the number of residents in region 1 positively depends on the maximal possible wage in region 1 and negatively on the wage in region 2. At this step, the only reason why people decide to migrate is based on a difference in earnings.

5.2 Migration with different fixed rents

We proceed with removing the restriction on equality of rents. So, the distribution of labour force is determined by the condition of the 'marginal migrant':

$$w_2 - r_2 = w_1 - r_1$$
$$w_2 - r_2 = a_1 - b_1 N - r_1$$
$$N^* = \frac{a_1 - w_2 + r_2 - r_1}{b_1}$$

Now the number of residents in peripherals depends not only on the difference in wages, but also on the difference in rents.

5.3 Migration with variable rents

The further development of the model takes into account that the rents in region 1 heavily depend on the demand for accommodation, which is determined directly by the number of residents in the city. We consider the rent market to be modelled as: $r_2 = \overline{r_2}$ and $r_1 = d_1 + l_1 N$, where N is the number of residents in the region. The rents in the more productive region are assumed to be fixed in our model because of the constant high demand for accommodation in the urban area. These exogenously given rents can still be affected by various external factors, but they are out of interest in terms of our research area. The condition which determines the allocation of residents takes the following form:

$$w_2 - r_2 = a_1 - b_1 N - d_1 - l_1 N$$
$$N^* = \frac{a_1 - w_2 + r_2 - d_1}{b_1 + l_1}$$

The optimal number of residents in region 1 depends on the conditions on both labour and rent markets and in comparison with the previous case, it is more sensitive to changes to the second one.

6. Migration with commuting

Previously in our framework, commuting was unavailable to our residents. Now we extend our case with pure migration allowing the residents to commute to work.

From this point, we start to separate the number of residents from the number of workers in the regions. We consider the rents depending on the number of residents, while the wages are affected by the number of employees, and so

$$w_1 = a_1 - b_1 \cdot (N - N^c)$$

where N^c stands for the number of commuters. The change in notation is required for further elaboration of the model.

However, we need to show the impact made with the introduction of commuting into the model. We aim at demonstrating how the inclusion of the commuting phenomenon influences the number of residents in a less productive city. For this purpose, the number of commuters is assumed to be an exogenous variable.

In order to compare the new model with the case without commuting we apply the same set of conditions that determined the equilibrium number of residents before:

$$w_2 - r_2 = w_1 - r_1$$
$$w_2 - r_2 = a_1 - b_1 \cdot (N - N^c) - d_1 - l_1 N$$
$$N^* = \frac{a_1 - d_1 - w_2 + r_2 + b_1 N^c}{l_1 + b_1}$$

where N^* is the equilibrium number of employees in region 1, N_c^* is the equilibrium number of commuters. The graph in Fig. 2 demonstrates that under the positive number of commuters, the number of residents in region 1 is higher than under the case when commuting is not available. This fact proves that the introduction of commuting into our framework results in the reallocation process of the population between regions.

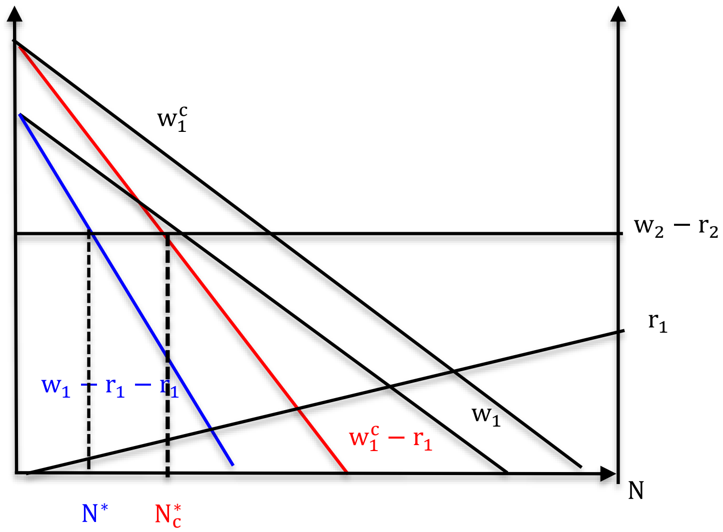

Fig. 2. Number of residents in the peripheral region with ($\boldsymbol{N_c^*}$) and without ($\boldsymbol{N^*}$) commuting

Further we proceed with the modelling of the commuting as an endogenous variable. Those who choose to work in a more productive region (in our set-up-region 2) and live in a less productive (region 1) earn a higher income w_2, but incur transportation costs and meet the budget constraint $w_2 - t - \varphi - r_1$.

Now we return to the search for the equilibrium allocation of residents. In this set-up, the residents are divided into 3 types of agents: those who live and work in region 1, those who live in region 1 and commute to work in region 2, and those who live and work in region 2.

We start with the determination of the equilibrium allocation under static residence with commuting. The following equality must hold:

$$w_1 - r_1 = w_2 - t - \varphi - r_1 = w_2 - r_2$$

For convenience we rewrite it into the system:

$$\begin{cases} w_2 - r_2 = w_2 - t - \varphi - r_1 \\ w_2 - t - \varphi - r_1 = w_1 - r_1 \end{cases}$$
$$\begin{cases} r_2 = t + \varphi + d_1 + l_1 N \\ w_2 - t - \varphi = a_1 - b_1 \cdot (N - N^c) \end{cases}$$

From the first equation, the optimal number of residents in region 1 can be found, while the second equation determines the number of those who both live and work in region 1. The system reveals the optimal numbers of both residents and commuters.

From the system, the optimal numbers of residents and commuters are:

$$N^* = \frac{r_2 - t - \varphi - d_1}{l_1}$$
$$N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$

Both the number of residents and commuters can be affected by the tariffs, which are established through the state regulation mechanism. In addition, we can see how the equilibrium allocation is reached with the graphical interpretation in Fig. 3:

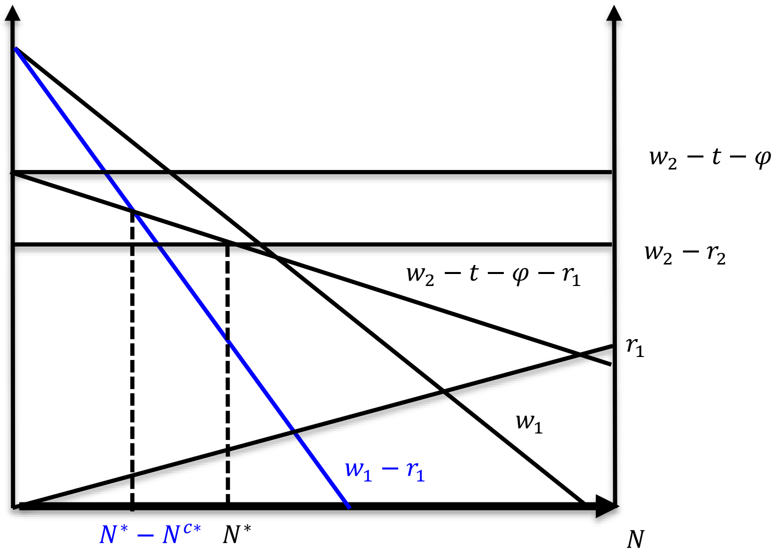

Fig. 3. Number of workers in the peripheral region ($N^* - N_c^*$)

One can notice that there is no migration phenomenon in the received result. In order to observe it, we need to include the dynamic residence into the previously stated commuting framework. In order to add dynamics into the model, we must create imbalance in the equilibrium allocation condition of residence. The regulator in the region controls the tariff variable t, and we study the effects of the tariff policy changes on the migration and commuting flows. Previously, the equilibrium was attained under some given fixed t level. Starting at this point, we consider t as an exogenous parameter, controlled by the state. First, assume the tariff is decreased. The equality turns into the system with the following inequalities:

$$\begin{cases} w_2 - r_2 < w_2 - t - \varphi - r_1 \\ w_2 - t - \varphi - r_1 > w_1 - r_1 \end{cases}$$

The conditions for the residents in region 2 are unchangeable, and that is why in the first inequality $w_2 - r_2 < w_2 - t - \varphi - r_1$ the imbalancing process happens through the changes on the right side only. The single endogenous variable is r_1 , which demostrates the situation at the rent market and is affected by the demand. The decreased tariffs make the residence and work option in peripherals more attractive and the demand on rents in less productive region increases, which pushes the rents up. Analytically, in order to attain the equilibrium, r_1 must grow, which happens directly through the increase in the number of residents. In this equilibrating process, both interpretations demonstrate the migration phenomenon emergence.

In order to learn the migration effects in the dynamic setting we need to modify our expression for rents in the less productive region, so that $r_1 = d_1 + l_1 * (N^* + N^M)$, where N^* is the initial number of residents in region 1 and N^M is the number of migrants in region 1.

While in the first expression the equilibrium is restored, the system has still not reached stability. The second inequality $w_2 - t - \varphi - r_1 > w_1 - r_1$ holds, as the increase in rents affects both sides of the expression the same way and does not allow to outweigh the tariff decline. The adjustment happens through another endogenous variable w_1. The inflow of new residents leads to a decrease in wages in the peripherals, however in order to reach the balance of the system, w_1 must grow. The process which triggers this growth is enhanced commuting. Analytically, the earlier discussed migration lowers the wage level in region 1, however this effect is overlapped with the increase in the number of commuters.

To capture the described changes by the analytical expression, we elaborate a new formula for the wages in region 1, $w_1 = a_1 - b_1 \cdot (N^* - N^c + N^M)$, where N^* is the initial exogenous number of residents in region 1 and N^M is the number of migrants to the region.

While the decreased tariffs create disequilibrium in both equations simultaneously, we can consider the beginning of the adjustment process from the second inequality. The rents in such case stay unaffected, while the change in the access price for transportation is covered with the increase in wages in region 1. The whole balancing process happens through the adjustments on the labour market by the growth in the number of commuters and does not involve the rent market at all. As it can be seen, the described case does not include the migration phenomenon in its analysis and that is why out of scope of our research. Moreover, due to a high competition level in the labour market in large cities and the tendency of the government to invest money in the development of less productive regions with intensive city building and infrastructure improvement, it is hard to predict changes in which flows: commuting or migration will be more intense.

The adjustment in the case with increased tariffs will happen in a similar manner with the inverse changes in the number of migrants and commuters. The system takes the following form:

$$\begin{cases} w_2 - r_2 > w_2 - t - \varphi - r_1 \\ w_2 - t - \varphi - r_1 < w_1 - r_1 \end{cases}$$

Higher tariffs make commuting less attractive to the residents of both regions. Starting with the first inequality, the equilibrium will be reached through a decrease in rents in region 1 as the demand for it from migrants will decline. The variable N^M becomes negative, which means that some commuters now choose to change their place of residence to region 2. Analytically, the negative value does not violate the functioning of the model. However, in order to avoid interpretation problems in further investigation, we consider N^M as a net migartion variable, which determines the changes in the number of migrants from a more to a less productive region.

Continuing with the system equilibrating process, we turn to the second inequality. The number of commuters decreases as the transportation costs are not covered with the wage difference anymore. From this follows that more people become willing to work and live in region 1 rather than commute, so the number of employees in the first region increases and this growth outweighs the outflow of potential workers due to negative net migration. This leads to the fall in w_1 until the value under which equality is established. As in the previous case, the described adjustment mechanism clearly demonstrates the migration phenomenon.

The dynamic residence with the commuting framework has revealed crucial facts, which further create the basis for our further research. Firstly, we have followed the way through which the migration arises. Secondly, we can establish a direct relationship between the absolute value of net migration and the transportation tariff.

Proposition 1: The number of migrants from urban to peripheral regions negatively depends on the commuting tariff.

Now we proceed our investigation with the research on the decision-making behaviour of regulators from different regions. We apply the same algorithm, which was used in the case with unavailability of migration: first investigate the behaviour of regulators from two regions separately, then study the choice made by the social planner who addresses the effects from the changes in policy in both regions in the welfare function. The tariffs set up by the social planner are assumed to be optimal. The aim of our research is to identify the deviations from this value when decisions are taken by the regions independently and to investigate the reasons of these discrepancies.

The welfare function of the regulator has to be modified in order to take into account the effects of migration on both wage earnings and the rent expenditures of residents. The introduction of the rent market into our model results in the following changes: for residents, rents become additional expenditures, for firms rents are neglected in the framework of our study (companies are immobile and cannot change their locations based on rents), for government rental payments appear in welfare function only as expenses of residents. This implies that when the residents change their place of living, they become a part of another region and the regulator takes into account the welfare of migrants too. Overall, the welfare function of the regulator takes the following form:

$$max_{(t)}W_i = \pi_i(N_i) + w_iN_i - r_iN_i + \pi_t + Sub_i - (1+\lambda)Sub_i$$
$$s.t.(BB): (c-t)N^c = Sub_i$$

where N_i is the general notation of residents in the region. The system demonstrates the general approach of the regulator to the maximisation problem. However, as there are different types of residents - commuters, migrants, original residents - all state agents perceive these groups in their own way. That is why both regulators and social planner face different welfare maximisation problems, and we analyse each of them separately and in detail.

In order to proceed with the investigation of regulators' behavioural patterns, we must step back to the determination of marginal commuter and marginal migrant conditions under the dynamic residence with the commuting framework. These conditions will coincide with those outlined for the search of the equilibrium allocation of residents, namely

$$w_1 - r_1 = w_2 - t - \varphi - r_1 = w_2 - r_2$$

The only difference with the values of N^{c*} and N^* found from the system is that we have to adjust it to the new functional forms of rents and wages in region 1, which now also depends on the number of migrants.

Overall, the equilibrium distribution of residents among 3 groups depends on the exogenous parameters in the following way:

$$N^* + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$
$$N^* + N^{M*} - N^{c*} = \frac{a_1 - w_2 + t + \varphi}{b_1}$$
$$N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$

Both regulators have to take into account these constraints as they represent the direct link between the transportation tariffs and the number of residents in the specific group.

One crucial element cannot be omitted in our analysis. If we refer to the case with immobility of residents (Section 4), the number of commuters was determined by the following formula: $N_{12}^* = \frac{w_2 - t - \varphi - a_1 + b_1N}{b_1}$ It can be easily noticed that under the dynamic residence the derivative of the number of commuters on the variable t increases in its absolute value.

Proposition 2: Inter-regional migration makes the demand for commuting more sensitive to transportation tariff.

6.1 Peripheral region

The welfare function of the regulator from the less productive region consists of the income of firm owners, expressed in profits, the income of employees, which comprises both the labour income of workers of region 1 and the net income of commuters (who live in region 1 but work in region 2), operational profit of the transportation firm net of subsidies weighted at the social cost of public funds and is decreased by rent expenses. We assume that the rent payments of the residents constitute at the same time income from the public utility company, which provides the accommodation and all related services. This is assumed to be a state-owned company that works under the break-even condition. However, as it was mentioned earlier rents are demand-driven, which implies that the increase in the number of people leads to a growth in rent expenses. This dependence supports the idea that with the increase in the number of residents, the state has to increase its expenditures for the maintenance of the city infrastructure. The redistribution of funds from residents to the public utility company is then neutralised in the objective function, and the element $r_1 \cdot (N^* + N^M)$ represents the expenses of the state-owned public utility company.

The maximisation problem which is faced by the regulator from the region 1 is:

$$\max_t W_{R_1} = \pi_1(N^* + N^M - N^c) + w_1 \cdot (N^* + N^M - N^c) + (w_2 - t - \varphi) \cdot N^c$$
$$-r_1 \cdot (N^* + N^M) + \pi_t + Sub_1 - (1+\lambda)Sub_1$$
$$s.t.\ (BB): (c-t) * N^c = Sub_1$$

$$s.t.\ (CC): N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$

$$s.t.\ (MC): N^{*} + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$

where MC restricts migration and CC – commuting flows.

The peripheral regulator's aim is to maximise the welfare function of the region by adjustment of the transportation policy. As the only expenditures of the firms are labour costs, changes in wages in region 1 do not affect the welfare and merely redistribute it between the agents. Thereby the welfare can be simplified:

$$W_{R_1} = F_1(N^* + N^M - N^c) + (w_2 - t - \varphi)N^c - r_1 \cdot (N^* + N^M) - (1+\lambda)(c-t)N^c$$

The first-order condition leads us to the following result:

$$t_1^* = \frac{(-b_1 + l_1\lambda)w_2 - (b_1(\lambda+1) + l_1\lambda)\varphi + (\lambda+1)(l_1+b_1)c + (\lambda+2)b_1r_2 - (\lambda+1)b_1d_1 - a_1l_1\lambda}{(1+2\lambda)(b_1+l_1) + b_1}$$

6.2 Urban region

The welfare function of the regulator from the urban area consists of the income of firm owners, expressed in profits, the income of residents, profit of the transportation firm together with subsidies and is decreased by rent expenses and subsidies gathered from the residents and enlarged by the social cost of public funds. The regulator from region 2 faces a similar situation with the rent payments. Due to the redistribution mechanism we drop out the expenditures of the residents and the income of the infrastructure firm and are left with the maintenance costs.

The maximisation problem which is faced by the regulator from region 2 is:

$$\max_t W_{R_2} = \pi_2(N_2 - N^M + N^c) + w_2 \cdot (N_2 - N^M) - r_2 \cdot (N_2 - N^M) + \pi_t + Sub_2 - (1+\lambda)Sub_2$$

$$s.t.\ (BB): (c-t)N^c = Sub_2$$

$$s.t.\ (CC): N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$

$$s.t.\ (MC): N^{*} + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$

At this point, an important element of our model must be outlined: the large city is assumed to incur fixed costs associated with the provision of utility services. That is why rents in this region are not only relatively high and unchangeable, but are also not affected by the number of migrants.

As a result, the welfare function can once more be simplified to

$$W_{R_2} = F_2(N_2 - N^M + N^c) - w_2N^c - r_2N_2 - (1+\lambda)Sub_2$$

Proceeding with the maximisation problem the first-order derivative with respect to t shows that:

$$t_2^* = \frac{(b_1 + l_1\lambda)w_2 + (\lambda+1)(l_1+b_1)c - (l_1+b_1)\varphi\lambda + r_2\lambda b_1 - b_1d_1\lambda - a_1l_1\lambda}{(b_1+l_1)(1+2\lambda)}$$

6.3 Social planner

The objective function of the social planner consists of the sum of outputs in both regions and the profit of the transportation firm together with the subsidies is decreased by transportation costs of the commuters, rent expenses and subsidies gathered from the residents and enlarged by the social cost of public funds. The social planner's main aim is to maximise the welfare of the whole population through the optimal redistribution of the population among regions. This allows this agent to capture the difference in the expenses of migrants and for this reason it has to be reflected in the objective function.

The social planner faces the following maximisation problem:

$$\max_t W_{SP} = F_2(N_2 - N^M + N^c) + F_1(N^* + N^M - N^c) - (t+\varphi)N^c$$
$$-r_1 \cdot (N^* + N^M) - r_2 \cdot (N_2 - N^M) + \pi_t - (1+\lambda)Sub_{SP}$$

$$s.t.\ (BB): (c-t)N^c = Sub_{SP}$$

$$s.t.\ (CC): N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$

$$s.t.\ (MC): N^* + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$

The first-order condition with respect to t is:

$$\frac{\partial F_2}{\partial(N_2 - N^M + N^c)}\frac{\partial(N_2 - N^M + N^c)}{\partial t} + \frac{\partial F_1}{\partial(N^* + N^M - N^c)}\frac{\partial(N^* + N^M - N^c)}{\partial t} - (t+\varphi)\frac{\partial N^c}{\partial t} - N^c - \frac{\partial r_1}{\partial(N^* + N^M)}\frac{\partial(N^* + N^M)}{\partial t}(N^* + N^M) - r_2\frac{\partial(N_2 - N^M)}{\partial t}(N_2 - N^M) - (1+\lambda)(c-t)\frac{\partial N^c}{\partial t} + (1+\lambda)N^c = 0$$

The first-order condition provides us with the following result:

$$t_{SP}^* = \frac{w_2 l_1 \lambda - (b_1(\lambda+1) + l_1\lambda)\varphi + (\lambda+1)(l_1+b_1)c + (\lambda+1)r_2 b_1 - (\lambda+1)b_1 d_1 - a_1 l_1 \lambda}{(1+2\lambda)(b_1+l_1) + b_1}$$

The tariff set by the social planner does not coincide with those values chosen by either region. This leads us to the conclusion that in order to attain the maximised welfare value the state cannot impose the duty of transportation system control on either state and has to resort to more sophisticated methods for the control of the tariff system.

6.4 *Commuting tariffs compared*

First of all, we need to compare the obtained values set by regions separately with the optimal value and try to understand the reasons of the deviations.

We start with the comparison of the t_{SP}^* and t_1^* values. The denominators are equal, so we focus on numerators. If w_2-$r_2 > 0$, we receive that $t_{SP}^* > t_1^*$(While we do not exclude the possibility that $r_2 > w_2$, it is much less common case than inverse relation and we will not focus on it). From this follows that a less productive region aims to create a more accessible transportation system and as a result to attract more migrants and simultaneously to increase the number of commuters. More migrants trigger rent rates to grow, besides there is also an increase in commuting which pushes wages in region 1 up. The final result is vague, that is why we refer to the dependence of $N^* + N^{M*} - N^{c*}$ value, which stands for the number of people who live and work in region 1, from the tariff policy. The derivative is of positive sign and the fact that the tariff, set by the regulator from region 1 is lower than that of the social planner leads us to the conclusion that the number of employees in region 1 is less than optimal.

Proposition 3: Peripheral region opts for a lower than socially optimal commuting tariff $t_1 < t_{sp}$ causing a significantly low number of workers and attracting a significantly high number of migrants from the urban region.

In fact, region 1 employs transportation policy instruments to increase the number of its residents, but at the same time it decreases the number of employees in the region. This result implies that the less productive region would naturally support commuting services in order to convert the periphery into residential area rather than a business centre. It has to be taken into account by the federal government that invests in the development of the peripherals. With a mobile labour force, the development of an urban-rural transportation system may deter the receipt of a full return on investment aimed at the improvement of the business sphere.

Besides, it should be noted that the commuting flows become even larger than they were without migration as they now include not only the migrants from region 2 but also those who previously lived and worked in region 1. The outflow of the working force turns into enhanced commuting, and it confirms our supposition that the region will invest more actively in the transportation system through larger subsidies and construction projects rather than in the development of the production sphere.

The comparison of the t_2^* and t_{SP}^* under the supposition that $w_2 + d_1 + \varphi - r_2 > 0$ leads to the fact $t_{SP}^* < t_2^*$. (As it was previously noted, we do not exclude the possibility that the $w_2 + d_1 + \varphi - r_2 < 0$ case may present, however we aim to investigate the common case). A higher value than the optimal tariff set by the regulator from region 2 demonstrates that the number of both migrants and commuters is sub-optimally small. The received result leads us to proposition 4:

Proposition 4: Urban region opts for a higher than socially optimal commuting tariff preventing migration outflows.

Proposition 3 and Proposition 4 allow to conclude that the social planner cannot transfer the whole responsibility over the transportation system to either region. However, it can delegate the control over the system to the partnership which would consist of the representatives from both regions with specific weights. The aim becomes to determine these weights in such way that while both regions continue to maximise their surpluses, the power redistribution in the company guarantees that the implemented tariff is equal to the optimal one. Besides, the transportation system will be subsidised with the resources of the regions where the weights of the required funds are also determined by the shares of participation in the partnership.

6.5 Inter-regional partnership

In order to obtain a better understanding of the partnership formation we need to study the structure of welfare functions of both regions. We focus on the 'subsidy-free' welfare functions of the two regions, assuming that there is only one transportation firm to be subsidised by the regions – separately or via a share based compensation. At this step we look at the regions' cost and benefits from migration and commuting. The subsidies required to cover the operating losses of such infrastructure company are examined separately.

$$W_{R_1} = F_1(N^* + N^M - N^c) + (w_2 - t - \varphi)N^c - r_1 \cdot (N^* + N^M)$$

$$W_{R_2} = F_2(N_2 - N^M + N^c) - w_2 N^c - r_2 \cdot (N_2 - N^M)$$

$$W_{SP} = F_2(N_2 - N^M + N^c) + F_1(N^* + N^M - N^c) - (t + \varphi)N^c - r_1 \cdot (N^* + N^M) - r_2 \cdot (N_2 - N^M)$$

$$(c - t)N^c = Sub$$

Hereinafter we illustrate our findings graphically with the Fig. 4.

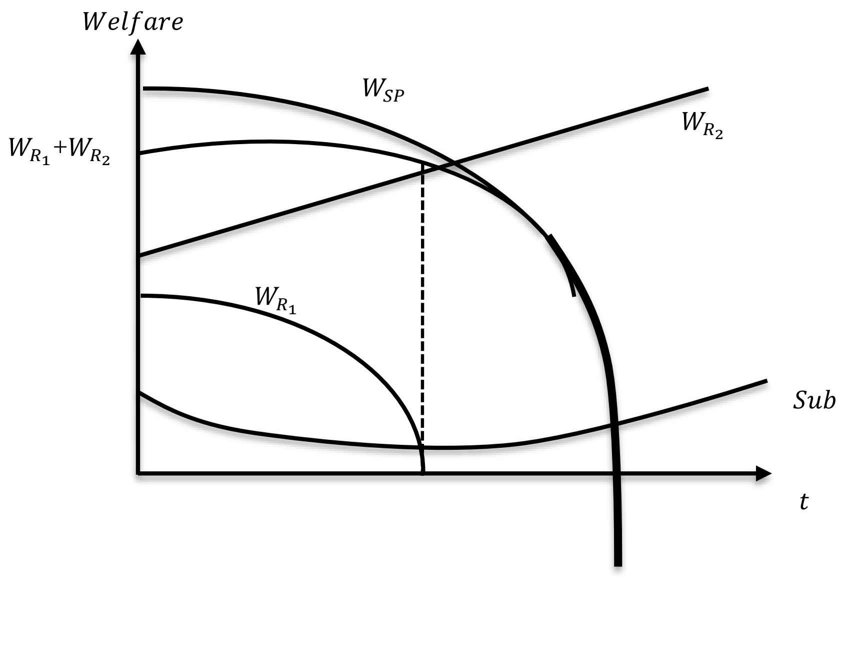

Fig. 4. Welfare values for the two regions and the social planner

Both the social planner and region 1 benefit from migration and commuting, thus they would prefer to set the tariff at a zero level. At the same time, region 2 suffers from migration (as we have proved already that commuting separately does not affect region 2 and it behaves as a separate monopolistic transportation company). The lower the migration outflow – the higher the welfare of region 2. Overall, the sum of the two welfare functions results in the gradually decreasing function. Under each level of tariff, the sum of two welfares is lower than the welfare of the social planner. The two functions have an intersection point at the level of tariff that completely prevents migration, and coincide with a further increase in the level of tariffs.

The difference in welfare values given by the W_{R_1}+W_{R_2} and W_{R_1}+W_{R_2} functions arises as a result of the inability of two separate states to incorporate the effect of additional savings in the rent payments received by the migrants through static one-period maximisation. The only agent who can catch the difference in rents is the social planner:

while maximisation also happens in the one-period model, the inclusion of all population in the welfare function makes it possible to take into account these benefits from the decreased rental payments of migrants.

The graph clearly demonstrates the main obstacle, under which the simple union between two regions with weights, corresponding to the relative proportions of the number of residents to the overall population, results in a sub-optimal transportation policy. However, the partnership can become a means by which the optimal tariff police can be set without the control of the social planner. However, the stakes of regions in this enterprise have to be determined in such way that under the maximisation process, the interests of participants are balanced and through this balance lead to an optimal tariff setting. Under the interest we consider the welfares of regions which the representatives of these states aim to maximise. Let's assume that the optimal weight of region 1 is ω. As only two agents are assumed to take part in this enterprise, the stake of region 2 is $1-\omega$. The objective function of the partnership takes the following form:

$$\max_t W_p = \omega \cdot (W_{R_1} - (1+\lambda)Sub_{SP}) + (1-\omega) \cdot (W_{R_2} - (1+\lambda)Sub_{SP})$$
$$s.t.\ (BB): (c-t)N^c = Sub_{SP}$$
$$(CC): N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$
$$(MC): N^* + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$

After the simplification the maximisation function is:

$$\max_t W_p = \omega \cdot (F_1(N^* + N^M - N^c) + (w_2 - t - \varphi)N^c - r_1 \cdot (N^* + N^M)) + (1-\omega) \cdot (F_2(N_2 - N^M + N^c) - w_2 N^c - r_2 \cdot (N_2 - N^M)) - (1+\lambda)(c-t)N^c$$
$$(CC): N^{c*} = \frac{r_2 - t - \varphi - d_1}{l_1} - \frac{a_1 - w_2 + t + \varphi}{b_1}$$
$$(MC): N^* + N^{M*} = \frac{r_2 - t - \varphi - d_1}{l_1}$$

The optimal weights will be determined in such way that the resulted maximisation tariff is equal to the optimal value of the social planner. The optimal share of region 1 in the partnership is then: $\omega^* = argmaxW_P$.

The value of the stake ω^* is fully dependent on the exogenously given parameters in a fairly complicated manner and is consequently hardly predictable in terms of the model. However, we can use the simulation method in order to follow how the participation share of the first region is dependent on another unstable parameter, namely the social cost of public funds. For this purpose we have taken the average data on wages, rents and disutility monetary compensation in Moscow and the Moscow Region and have acquired the relation, depicted in the Fig. 5.

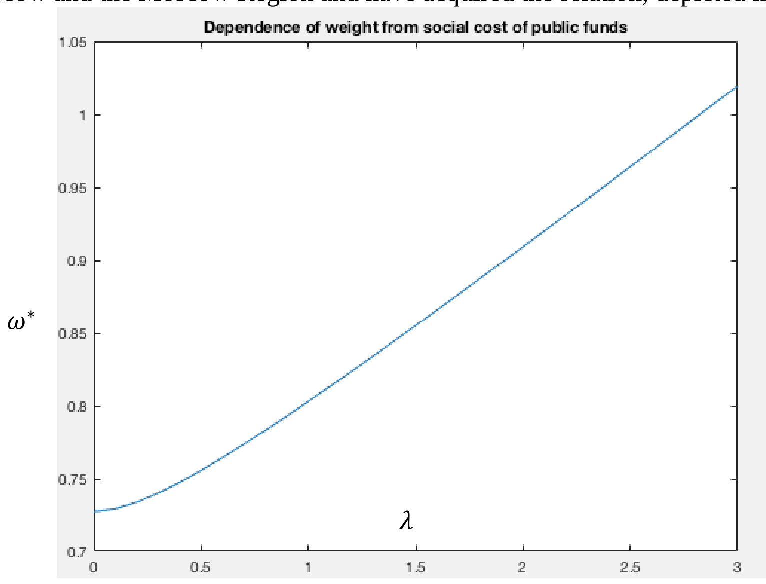

Fig. 5. The dependence of weight in the partnership of the less productive region from the social cost of public funds.

The demonstrated dependence leads us directly to proposition 5.

Proposition 5: There exists the share of peripheral region ω^* *in the inter-regional partnership* $(\omega^*, 1-\omega^*)$ *such that* $t_p = t_{sp}$ *with* ω^* *being an increasing function of the local cost of public funds.*

The growth of the social cost of the public funds parameter leads to the simultaneous increase in the burden of subsidies on both regions. From it follows that for the partnership, keeping all constant becomes beneficial to increase the tariffs, which would result in deviation from the socially optimal level. In order to maintain the main aim of the partnership- to choose the optimal tariff under the maximisation process, the state allocates the larger share of it to the region which receives more benefits from migration and commuting and gains from a decrease in tariffs. As the peripherals take advantages from the lower tariff, compared to the urban regions, which lose from it, the state has the incentive to increase the participation share of the less productive region. As a result, we can trace the positive dependence between the social cost of public funds and the weight of the peripheral region in the partnership share-structure.

7. Discussion and concluding remarks

We have developed an urban-peripheral model where individuals commute from the less to the more productive region. In a federation with two regions each agent inelastically supplies one unit of labour and consumes one unit of land. The distance between the urban and peripheral regions is fixed as well as the commuting time cost, while the direct money cost (tariff) is set by the regulator. We compare four cases when the regulator is: 1) a peripheral region, 2) an urban region, 3) a social planner, and 4) an inter-regional partnership. An individual's indirect utility of an initial workplace-residence pair is compared with the utility derived through a workplace relocation alone, a residence relocation alone, and a simultaneous relocation to obtain the optimum. We explicitly model the land and labour markets in the peripheral region while the urban region is assumed to be sufficiently large to remain insensitive to changes in commuting and migration flows. By assuming fixed (and comparatively large) wages and rents in the urban region we make our model tractable and obtain closed-form solutions, which is crucial for welfare comparison. This set-up also allows us to focus our analysis on a tariff policy when commuting can be subsidised via lump-sum budget transfers to the transportation service provider Borck and Wrede (2009) for the comparison of the US and European subsidisation practices and Dementiev (2016) for the Russian experience).

The presence of the local cost of public funds makes the first best allocation unattainable. Following the modelling approach developed in Vandyck and Proost (2012) we consider a strategic behaviour of urban and peripheral governments in a context of limited fiscal capacities. The regional budget should cover the losses of the transportation firm caused by tariffs being set at the level below the average cost. Though at the first stages the regions do not compete in taxes, their strategic approach to tariff regulation indirectly influences the attractiveness for individuals to choose their workplace and place of residence. By normalising the fixed migration cost to zero we allow for perfect labour market flexibility to confront our results with Bloze and Skak (2016). They argue that reduced labour market flexibility could be at least partially mitigated by an increase in their mobility through more commuting, while in our model greater migration induces greater demand for commuting.

Our contribution to the literature on the optimal commuting policy is to endogenise the choice of residence and make it dependent on the transportation tariff. Thus, the commuting tariff affects the demand for transportation services in two ways. First, there is a direct effect that depends upon the availability and affordability of alternative transportation modes with 'no commuting' and working at the place of residence being an outside option. Second, there is an indirect effect that induces greater worker migration to the peripheral region causing additional demand for commuting. These changes in residential locations and corresponding choices of workplace are viewed differently by the two regions.

To benchmark a welfare comparison we consider as socially optimal a policy chosen by a benevolent federal government that is able to endogenise the effects from migration. The total number of residents in the two regions is assumed to be constant and sufficiently large, so they behave as price (wage) takers. Thus the optimal choice of residence may improve the total welfare. Accordingly, the social planner would set the commuting tariff to ensure that the labour force is allocated optimally across the regions. On the contrary, the regional perspective is different.

We address the problem of the regionalisation of the tariff policy in light of sizable local costs of public funds. The peripheral region with lower wages is unable to permanently attract workers unless rental prices are dramatically lower than in the urban region. Thus it can set relatively low tariffs to make commuting more attractive not only for its 'old' residents, but also for potential migrants from the urban region. The urban region suffers losses from outflow of residents and is aimed to set sub-optimally high tariffs in order to restrict migration and commuting phenomena.

Finally, we study a possibility to internalise migration effects via a balanced regulatory approach pursued by a joint regulator established as a partnership between the urban and peripheral region. The common objective function of this regulator is shaped by the weights of the regions in the partnership. Thus the social planner is able to design its share structure in order to replicate the socially optimal tariff by delegating regulatory decision to a partnership. The burden of corresponding commuting subsidy to a transportation firm is then shared by the regions according to their interests in the partnership.

In this paper we aimed to extend and further analyse the findings of Vandyck and Proost (2012) through the introduction of the residential migration into the model. Besides, we proposed the inter-regional partnership as one of the methods, through which the federal state can correct incentives of the regulators from different regions. The method has its benefits, compared to the full federal government control over the transportation system, however, it is not flexible enough to the changing conditions on the external markets. That is why we leave the improvement of the proposed methodology or other approaches to the problem for the further research. Besides, the firm mobility was assumed limited in this paper, while potentially it may become an important element, the introduction of which would influence the transportation system activity.

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