Commuting and Solvable Agglomeration

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Abstract

New Economic Geography models conventionally assume the consumer's workplace is also his home. However, when applied on local levels, workers can commute. We present a solvable model with NEG-type agglomeration effects, in which workers can supply labor away from their home. With high commuting cost, centrifugal forces cause labor supply and inhabitants to spread. At low commuting cost, an industrial core region develops with smaller residential satellites, and workers commute into the core. The long run residential distribution accordingly concentrates or spreads, but residentially larger regions attract proportionally more labor: the jobs per head increase in regional size. The results persist when including transport cost and a more generalized utility function.

Keywords: commuting, household and firm location, new economic geography

JEL-Classification: J61; R23; R12

1 Introduction

When models of the New Economic Geography (NEG) are applied to cities, the characterization of intranational mobility should differ from international mobility. In addition to relocating, workers may commute from their region of residence to their region of work. This possibility features in few of the theoretical models in the NEG-fashion. Yet, commuting options significantly alter the outcomes of such models, and they are empirically well-established.

Sizeable commuting between regions are no minor phenomenon. Although the mean travel distance to and from work is around 16 kilometers in the Netherlands in 2005, 7% of the respondents in the Rijkswaterstaat (2006) survey report travelling over 50 kilometers to work. This means a substantial portion of workers could

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travel distances from Amsterdam to Utrecht (22 minutes by train) or Rotterdam (40 to 60 minutes by train) - places other than their home region. In European countries, substantial shares of the workforce report crossing NUTS-2 regional borders for their daily commute. Shares around 10 % are not uncommon (Netherlands, Germany, Denmark), the UK approaches 20%, but in France 1 in 20 workers crosses borders (OECD, 2005). Likewise, in the US, around 8.3% of commuters traveled out of their own metropolitan area, moreover, the intercity commuting flows in the US grew nearly three times as fast as internal commuting flows over 1980-2004 (Pisarski, 2006). Furthermore, Pisarski documents that around half of commuting flows within metropolitan areas are not destined to a central business district, but to other employment centers. Aguilera (2005) makes similar observations for French cities. Such commuting flows also have substantial effects on the urban landscape, for instance leading to "jobs-housing imbalances" (Levine, 1998). As argued and documented by Glaeser and Kohlhase (2003) and Anas (2004), the distance deterrence that most shapes the national urban structure may not be the falling freight transport cost, but the cost of moving people.

To explain such commuting flows and their consequences, we use a geographical economics model that considers a general equilibrium of the goods, labor and land market. The general equilibrium approach seems to improve the partial equilibrium (transport market) analysis of commuting (Rouwendal and Nijkamp, 2004). In our model, both firms and households are footloose, and since locations of consumption and labor supply do not need to coincide, we can differentiate regions by a residential and an industrial function. In the long term, the consumer's location decision is interdependent: the residential choice and commuting choice are made jointly. This is consistent with recent empirical evidence of houshold's location decisions (Eliasson et al., 2003; Romaní et al., 2003; So et al., 2001). A residence's desirability depends on the local prices and employment opportunities, but nearby jobs have an option value - a labor market potential from the labor supply side. In Sweden, Swärdh (2009) even finds evidence that the average commuting time increases after a residential relocation, suggesting commuting time is compensated by other effects of relocation.

The tradeoff between agglomerating and dispersive forces, the crux of many NEG models, affects the commuting patterns. This is also noted in other commuting models[1] . With a frictionless labor market, like in our model, there is generally no commuting between symmetric regions, so agglomeration externalities are crucial in generating positive commuting flows. In our framework, all workers and firms are footloose, and we choose land as an immobile factor to prevent the economy from collapsing into a point. This means there is a housing market, in which locational features capitalize in the landprice. This is consistent with empirical research

[1] In Pierrard (2008), commuters into the region may have a job-creating ("vacancy") effect, while the job search model of Epifani and Gancia (2005) shows that NEG-type externalities lead to persistent unemployment disparities.

that shows access to labor markets translates into property value (Armstrong and Rodríguez, 2006; Debrezion et al., 2007; Fingleton, 2006; Tse and Chan, 2003). In addition, we assume some goods cannot be transported. The implications of the non-transportable good are that the agglomeration of firms and households is incomplete, and secondly, that the cost of living in the core is generally higher than in the periphery. This fits well with the empirical regularity that living in large cities is often expensive, which many NEG models fail to capture (Suedekum, 2006).

Some papers allow intracity commuting in an NEG-framework. As with the interregional commuting cost presented in this paper, high intracity commuting cost hamper the formation of agglomerations and the inability to supply labor elsewhere fosters spreading of economic activity (Murata and Thisse, 2005; Cavailhes et al., 2007). Of the models of intracity commuting, Tabuchi and Thisse (2006) are closest to our paper because they allow for two types of manufacturing goods, which allow for incomplete agglomeration in the long run. These models assume inhabitants work in their own region, so commuting is interpreted as an urban cost, while our aim is to allow traveling to work in another employment center - intercity or interregional commuting. To our knowledge, there are two models that provide such a commuting option.

Grueber (2010) proposes an NEG model that explicitly allows for interregional commuting. The model uses four goods (housing, agriculture, manufacturing and services) and three mobile factors (firms, low skilled workers and high skilled workers). Manufacturing uses land and low skilled labor as input, and services use low and high skilled labor, both with a fixed technical rate of substitution. Given this extensive production structure, the analytical solution is not straightforward, so the conclusions are drawn on the basis of simulations. When both low- and high skilled workers can migrate as well as commute, Grueber shows that (partial) agglomeration is the only stable equilibrium. In that equilibrium, high-skilled workers both concentrate residences in the core, and commute to the periphery more compared to low-skilled workers. The assumption that high skilled labor is only used in the non-traded service is decisive in the long run outcome. When high skilled workers cannot migrate, they commute from smaller to larger regions (where the wage is larger) whereas lowskilled workers with the ability to migrate locate in the large region to commute to the smaller region (in pursuit of manufacturing of service wages). One strategy that is logically impossible for workers is to migrate to a low housing price area while commuting back for higher wages - i.e. bedroom communities are not an option in this model.

Borck et al. (2009), by contrast, propose a solvable model of the commuting behavior in the NEG setting. Solvability is achieved through the "footloose capital or entrepreneur" assumption (see Baldwin et al. (2003, chapters 3 and 4), for instance). The model assumes only high skilled workers are mobile, and in addition, they do not contribute to the variable cost of production. This restricts the price level to depend on numéraire wage only, thus preventing the wage of the mobile factor from entering the equilibrium equations non-linearly. This setup yields rich insight into the commuting decision, as it allows disentangling of supply- and demand linkages and competition effects. Borck et al. vary transport and commuting cost independently. Without commuting cost, low trade cost foster agglomeration of industry but dispersion of residences. The opposite happens for higher trade cost: residences concentrate and workers commute into the small region. The home market effect only dominates the competition effect when trade freeness is sufficiently high. Without commuting cost, the model predicts symmetric equilibria are always unstable. The intuition is that with commuting, the wage effects and the cost of living and housing market effects are decoupled. In particular, with low trade freeness, the cost of living effect is larger than housing congestion, leading to full agglomeration of residences. With higher trade freeness, the housing price effects dominates the cost of living when the residential distribution is sufficiently asymmetric, so partial agglomeration of residence is the stable equilibrium. The analysis becomes complicated for positive commuting cost, so the authors present a graphical analysis. Most notably, this leads to a band of inaction where the wage differential are too small to compensate commuting cost (i.e. at very low or high levels of trade freeness).

This paper presents an alternative model of commuting and agglomeration. Compared to Borck et al. (2009) it relies on a different specification of trade cost to achieve solvability. This allows us to to drop the assumption of a division between mobile high skilled labor and immobile low skilled labor, and consequently, the assumption that high skilled labor is involved in a specific part of production or industry. In comparison with Borck et al., we allow for a non-traded good, which allows for stable symmetric residential equilibria. Due to residual demand in the periphery, firm and household agglomeration are always incomplete in our model. In our model, home market effects are larger (smaller region's nominal wages are lower), so commuting from the core into the periphery is not observed. This prediction is more restricted than Borck at al.'s (where core to periphery commuting occurs under high trade cost), but it is founded on a simpler model that still describes the evolution of residential towns next to an industrial core. Our model is certainly more stylized than the one put forward in Grueber (2010), but allows for analytical expressions of the solution.

Finally, the specific key to solvability in our model is the existence of an interregionally tradable and a non-tradable aggregate good. The aggregate goods draw their inputs from intermediate firms that face increasing return to scale. This concept is not new in urban economics (Abdel-Rahman and Fujita, 1990), but when applied to a two-region model it simplifies the price indexes considerably. The assumption of trade cost over the aggregate goods prevents the trade cost from entering the market-clearing conditions non-linearly, allowing for a solvable expression of the condition. This is an alternative to the conventional solvable models of New Economic Geography (Forslid and Ottaviano, 2003).

The next section develops a simple version of the commuting model that is analytically solvable. This boils down to deriving wage ratios for two possible states, one where the production of a transportable consumption good is perfectly concentrated and the alternative where it is incompletely concentrated. Subsequently, we extend the model by varying elasticity between traded and non-traded goods, and the introduction of transport costs on goods in addition to commuting cost.

2 Model

This section shortly lays out the structure of the economy, followed by a more detailed discussion on households and firms. Consumers and producers locate in one of the two regions in the economy. Households consume land for housing, a freely tradable good, and a non-tradable or local good. Both regions are endowed with a stock of land. Landowners are tied to their land and have the same preferences as workers. Workers live in one region but may choose to supply their labor in the other region, incurring a loss of utility by commuting. In the long run, workers can change residence. Producers of the tradable and local good acquire their inputs from local firms and assemble their good using a technology that has a constant elasticity of substitution between the inputs. Intermediate firms produce the inputs using labor under increasing returns to scale. The inputs and the local good cannot be traded across region, but the tradable good can be transported, for analytical convenience the transport cost are zero in this section. In the notation, I will not subscript variables for the region if the equation holds for both locations.

2.1 Households

The consumer's utility function comprises four items: consumption of the traded and local good c_t and c_{nt}, housing h, and potential utility losses caused by commuting, captured in θ. Consumers have Cobb-Douglas utility over their consumption of goods and housing.

$$U = c_t^{\sigma} c_{nt}^{\mu} h^{1-\sigma-\mu} (1-\theta) \tag{1}$$

The utility function yields a unit-elastic housing demand, like in Helpman (1998). The commuting cost are captured by θ, which is zero if a workers supplies labor in his residential region, but θ is positive if the worker commutes to another region. The form of the commuting cost is inspired by the time loss involved in commuting. This utility maximization problem does not predict the worker changes his supply of hours worked if his commuting time changes. Although the independence of labor supply and leisure loss is simplifying, it is not too far besides reality (Gutiérrez-i Puigarnau and van Ommeren, 2010). The functional form also allows the expenditure shares on housing and consumption goods to be unaffected by the commuting decision. There is no direct financial cost to commuting, so all wage is spent on housing and consumption goods:

$$w \leq P_t c_t + P_{nt} c_{nt} + P_h h \tag{2}$$

where P_t, P_{nt} and P_h are the prices of the traded and local good and housing rental rate. Landowners supply one unit of land so their income is p_h. Their demand functions are equal to the workers', with the wage replaced with the land rental rate. The utility function and budget constraint give rise to the demand functions:

$$\begin{aligned} h &= \tfrac{(1-\sigma-\mu)w}{P_h} \\ c_{nt} &= \tfrac{\mu w}{P_{nt}} \\ c_t &= \tfrac{\sigma w}{P_t} \end{aligned} \tag{3}$$

Given the homotheticity of the demand function and the absence of commuting cost in the budget contraint, the expenditure shares are independent of the commuting decision; commuters, non-commuters and landowners allocate the same share of their budget to a good, and their consumption decision is unaffected by commuting. Considering a two-region setup, the tradable can originate from any region. However, the tradable good is homogenous, so at a given price, consumers do not care about the good's origin. For later analysis, it is useful to describe the indirect utility function by plugging the demand function into the utility function. The indirect representation of the utility function can be written as (an affine transformation of):

$$V = \frac{w\ell}{p_h^{1-\sigma-\mu} P_{nt}^{\mu} P_t^{\sigma}} \tag{4}$$

Intuitively, the indirect utility function shows that consumers have a preference for higher wages, not commuting, and lower prices of the tradable and local good and housing.

2.2 Firms

There are three types of firms; the intermediate firms that produce inputs, and producers of the tradable and local (non-tradable accross locations) good that assemble their product using inputs and labor. The producers of the tradable and local good use labor and intermediate inputs with different intensity. Typically, tradable goods, such as manufactures or durable consumption goods are intensive in intermediate products whereas the local goods may be thought of as services that require local personnel. The difference in transportability ensures that some production is carried out in every region. The cost of shipping inputs are prohibitive in this model.

The existence of tradable and local good assemblers that acquire local inputs is the key to solvability in the model. Transport cost are incurred on the final good, so the trade cost are split over the harmonized price index of the inputs, instead of the situation where every individual input producer incurs transport cost. Given an elasticity of subsitution between the inputs, the current setup avoids transport cost within the harmonized price index, which avoids transport cost entering the solutions non-linearly. The assumption that trade cost are only paid by the assemblers of a final good is a strong simplification. In particular, the average trade cost indirectly imposed on input producers declines in the scale of input production in the region. However, the assumption competes in realism with the alternative assumption that would solve the model analytically - the "footloose entrepreneur" assumption. Using footloose entrepreneurs removes the need for assemblers, but introduces the prediction that the mobile factor does not affect the price of the final good. This section solves the model for zero trade cost, as that yields an insightful version of the model. The transport cost are re-introduced toward the end of this paper.

The tradable (subscript t) and local good producer (subscript nt) assemble inputs $y(i)$ to produce final good C, using a CES technology:

$$Y_{\{t,nt\}} = l^{1-\delta_{t,nt}} \left[\int_0^n y\left(i\right)^{\frac{\varepsilon-1}{\varepsilon}} \, di \right]^{\frac{\varepsilon}{\varepsilon-1}\delta_{t,nt}} \tag{5}$$

where i denotes a variety from the continuum of intermediate firms. The inputs used in the traded and non-traded sector are the same, but they are used with different intensity δ. Usually, the input intensity of the traded good (δ_t) is assumed higher than the input intensity of the local good (δ_{nt}). The price of intermediates is $p(i)$. The final good producers operate under perfect competition and take the prices as given to optimize quantity. Given the constant returns to scale assumption, we view the final goods producer as a very large set of small firms, so there is no monopolistic power in the final goods market. The profit function of the final goods producer is the aggregate revenue minus the expenditure on inputs:

$$\Pi = PC - \int_0^n p\left(i\right) y\left(i\right) di - wl \tag{6}$$

The first order condition with respect to $y(i)$ yields the demand for intermediate good i:

$$y\left(i\right) = \left(\frac{p\left(i\right)}{P}\right)^{-\varepsilon} \delta C \tag{7}$$

which shows that demand for inputs is a fraction of the aggregate production and the fraction depends inversely on the ratio of the input price to the price of the final good. This demand function holds for the producers of tradable goods as well as the producers of non-tradable goods, albeit that their input intensity $\delta_{t,nt}$ is different.

Filling out the demand function in the final goods' zero profit condition gives an expression for the aggregate or harmonized input price index, which both local and tradable goods producers face.

$$P = \left[\int_0^n p\left(i\right)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \tag{8}$$

The price index is equal to the harmonized price index in a standard Dixit-Stiglitz setup. The price index shows that when there are more firms in the region, the consumer price is lower. The fall in the price index is caused by a higher efficiency of assembling the final good when there is more variety. Thus, there is a positive scale externality.

The intermediate firms only employ labor, but they need to sink an amount of labor before they start producing. This upfront requirement is the cause of increasing returns to scale in intermediate production. The total labor requirement for production of inputs is

$$l\left(i\right) = a_m y\left(i\right) + f \tag{9}$$

where f is the fixed labor requirement and a_m is the inverse labor productivity. The total cost amount to $wl(i)$. Intermediate good suppliers set prices to maximize profits. Facing the final goods producer's demand curve, they set a markup price, which is familiar from other CES demand models:

$$p\left(i\right) = \frac{\varepsilon}{\varepsilon - 1} a_m w \tag{10}$$

The markup price over marginal cost combined with a zero profit condition on intermediate producers implies a constant firm size, which is a standard result in monopolistic a la Dixit-Stiglitz. The fixed firm size occurs because both the operating profits per product and the fixed factor are scaled by the wage rate. The fixed firm size is therefore exclusively governed by parameters, and it is independent of wage or market size. The firm size is

$$y\left(i\right) = y = \frac{f\left(\varepsilon - 1\right)}{a_m} \tag{11}$$

The corresponding labor requirement for individual intermediate firms is εf.

2.3 Equilibrium

This section solves for the short run equilibrium, in which residence is fixed, and the long run equilibrium, in which workers can choose to live elsewhere.

2.3.1 Short run equilibrium

In the short run equilibrium, the goods, labor and housing market clear, given a distribution of households over the regions. Workers select the region in which they supply their labor, so the commuting decision is part of the short run equilibrium. The economy has two regions, 1 and 2. The share of total population L^w living in region 1 is λ. Share γ of total population supplies labor in region 1, so that there is commuting into region 1 if $\gamma > \lambda$. Commuting occurs only one-way in this model. Therefore, the following section analyzes situations where workers from region 2 travel to region 1 to supply labor. Of course, since the regions can be made identical in their inhabitants and housing supply, the reverse analysis also holds. To preview the analysis, with sufficiently even labor supply, the production of tradables is spread, so price equality determines the relative wage. We will refer to this equilibrium as the "spreading equilibrium", meaning that the producers of tradable goods locate in both regions. When producers of the tradable all locate in one of the two regions, the wage ratio is determined by clearing of the house, labor and goods market. We will refer to this equilibrium as the "concentrated equilibrium".

When the tradable good is produced in both regions, its price is equal in both regions because the good is homogenous and freely tradable. The price of tradables (8) is determined by the number of producers of inputs and and the local wage rate. Equality of the price of tradables, $P_{t,1} = P_{t,2}$, thus implies that the relative number of inputs-producers determines the relative wage rate. given the fixed labor requirement, hte number of input firms is determined by the total labor supply in a region multiplied by the share of workers that produces inputs. The share of workers inputs is determined by sectoral mobility - the wage paid in assembly equals the wage paid in input production. Wage equality across assembly in the two sectors and input production implies that

$$w = \frac{\delta_t P_t Y_t + \delta_{nt} P_{nt} Y_{nt}}{\gamma L s_y} = \frac{(1-\delta_t) P_t Y_t + (1-\delta_{nt}) P_{nt} Y_{nt}}{L(1-s_y)}$$

which holds for region 1 (there is a similar expression for region 2 using $1-\gamma$ instead of γ) and s_y is the share of workers in input production. This implies $s_y = \frac{\delta_t P_t Y_t + \delta_{nt} P_{nt} Y_{nt}}{P_t Y_t + P_{nt} Y_{nt}} = \frac{\delta_t P_t Y_t + \delta_{nt} P_{nt} Y_{nt}}{s_y w \gamma L}$. From the general equilibrium, the region's expenditure share on traded goods is equal to the region income share in total income [2] . As a consequence, filling out the demand functions, the share of workers in input production can be written as $s_y = \frac{\delta_t \sigma + \delta_{nt} \mu}{\sigma + \mu}$. Since this is a constant when the tradable is produced in both regions, the ratio of firm mass in the two regions equals the ratio of labor supply in the two regions. When the ratio of firm mass is equal to the ratio of labor supply, and firms charge the same markup over wages, we can infer the relative wages from the relative labor supply in each of the regions.

[2] This holds if there is no commuting. In the next subsection (?), we show that commuting is not a stable equilibrium when the tradable good is produced in both locations. [does it]

More formally, $w_1^{1-\delta_t}\left(n_1^{\frac{1}{1-\varepsilon}}p_1\right)^{\delta_t} = \left(n_2^{\frac{1}{1-\varepsilon}}p_2\right)^{\delta_t} w_1^{1-\delta_t}$ implies

$$\frac{w_1}{w_2} = \left(\frac{\gamma}{1-\gamma}\right)^{\frac{\delta_t}{\varepsilon-1}} \tag{12}$$

This equation shows that the wage rate in a region relative to another region increases in the labor supply relative to that other region ($\varepsilon > 1$), as long as the price indexes are equal. The wage paid reflects the nominal productivity of a worker. If a set of workers supplies labor in region 1 instead of 2, the number of input-producing firms in region 1 rises, and falls in region 2. Since assemblers become more efficient when they can purchase a wider variety of inputs, the positive scale externality operates on a larger scale in region 1, and a smaller scale in region 2. Preserving price equality, assemblers in region 1 then pay a higher wage to their workers, and so the relative wage rises in relative labor supply. However, at some point of concentration, assemblers in the emptier region face such a scale disadvantage that the wage they pay their workers falls below the wage level that the assemblers of the local good can afford to pay - local good producers face no competition for the demand exerted by the local residents.

At some point of asymmetry in labor supply, the production of tradables is unprofitable in one region, and their production concentrates in the other region. In that case, the relative wage rate is determined by clearing of the housing, goods and labor market given that no tradables are produced in one of the regions (region 2 in this case). The land market clears by the prices that equate the aggregate land supply H to the aggregated land demand (given in (3)) in that region:

$$H_1 = \frac{(1-\mu-\sigma)\,w_1}{p_{h,1}}\lambda L_1^w + \frac{(1-\mu-\sigma)\,p_{h,1}}{p_{h,1}}H_1 \tag{13}$$

where the sum of demanded land is the land demand exerted by the workers (first term) and by the landowners (the second term). The clearing price is given by rewriting the clearing condition.

$$p_{h,1} = w_1\frac{1-\mu-\sigma}{\mu+\sigma}\frac{\lambda L^w}{H_1} \tag{14}$$

So the price of land increases in the number of people that demand it, their income and the preference they have for land, but decreases in the supply of land. In region 2, the expression looks different because the labor income is not necessarily equal among all workers: total demand is the sum of demand of workers in region 2 (share $1-\gamma$), commuters into region 1 (share $1-\lambda-(1-\gamma)=\gamma-\lambda$) and houseowners in region 2. The demand condition, and consecutively the market-clearing housing price in region 2 is:

$$H_2 = \frac{(1-\mu-\sigma)(1-\gamma)L^w w_2}{p_{h,2}} + \frac{(1-\mu-\sigma)(1-\lambda-(1-\gamma))L^w w_1}{p_{h,2}} + \frac{(1-\mu-\sigma)p_{h,2}}{p_{h,2}}H_2$$
$$p_{h,2} = \frac{1-\mu-\sigma}{\mu+\sigma}\frac{L^w}{H_2}\left(\left(1-\gamma\right)\left(w_2\right)+\left(\gamma-\lambda\right)w_1\right) \tag{15}$$

Given a concentration of freely tradable final goods production, we can write the aggregate demand for C_t by aggregating the individual demand function of landowners living in region 1 and in region 2 and workers working in region 1 and 2. Filling out the equilibrium rental rates for houseowners' income and simplifying gives:

$$C_t = \frac{\sigma}{\mu+\sigma}\frac{L^w}{P_t}\left(\gamma w_1 + \left(1-\gamma\right)w_2\right) \tag{16}$$

The expressions for the housing market factor easily in the aggregate demand for the tradable good, because the income of landowners is proportional to that of the workers that live in their region (this produces the division by $\mu+\sigma$). Moreover, in the absence of financial commuting cost and transport cost, commuters acts as if they were consumers of the tradable in the region in which they work. Therefore only the labor supply distribution (γ) matters, and not the residential distribution (λ). A producer of local goods in region 1 only faces demand from the residents in region, because commuters from region 2 buy the local good in their residential region 2. A similar exercise for the local good producer yields

$$C_{nt} = \frac{\mu}{\mu+\sigma}\frac{\lambda L^w w_1}{P_{nt}} \tag{17}$$

This expression involves the residential distribution because the local good in region 1 is only consumed by inhabitants in region 1, moreover the workers in region 1 do not commute, so they all earn w_1. With the expression for demand for the tradable and local good, the final goods producers' demand for intermediates can be derived. Inserting the demand for final goods (16 and 17) in the final good producers' demand for intermediates (7) gives the demand curve that the intermediate producer faces:

$$c\left(i\right) = p\left(i\right)^{-\varepsilon}\left(\delta_t\frac{\sigma}{\mu+\sigma}\frac{\left(\gamma w_1+\left(1-\gamma\right)w_2\right)L^w}{P_t^{1-\varepsilon}} + \delta_{nt}\frac{\mu}{\mu+\sigma}\frac{\lambda w_1 L^w}{P_{nt}^{1-\varepsilon}}\right) \tag{18}$$

This expression shows how the demand for an intermediate variety decreases in its own price but increases in the price of final goods and total expenditure. The market structure implies that $y = f(\varepsilon-1)/a_m$, so we can write the clearing of the market for inputs as $c = y$. The intermediate firm does not discriminate between the tradable and non-tradable producer, so the prices of tradables and local goods in region 1 are equal. Moreover, using the markup price and the definition for the number of firms, it is convenient to write

$$\frac{p(i)^{-\varepsilon}}{P^{1-\varepsilon}} = \frac{1}{np} = \frac{f\varepsilon}{s_y \gamma L^w} \frac{\varepsilon - 1}{\varepsilon} (a_m w_1)^{-1}$$

Where s_y is the share of working population (γ) that supplies labor in the production of intermediates. The clearing condition can be simplified considerably by factoring the final goods prices and using the above expression [3] . The clearing condition of the market for inputs can then be rewritten as:

$$\frac{w_1}{w_2} = \frac{\sigma}{\mu} \frac{1-\gamma}{\gamma - \lambda} \tag{19}$$

which suggests the local wage is decreased by a higher supply of labor, i.e. commuting into the large region.

Summing up, small labor supply deviations from a symmetric equilibrium are self-reinforcing in the sense that they drive up wage in the larger region. However, they also reduce profitability of tradables producers in the small region, eventually driving them out of business. In that case, spreading force of demand for local goods dominates the concentrating force of home market effects in the tradables sector. The upward sloping wage ratio in the spread tradables equilibrium (equation (12), dash) and the downward sloping wage ratio of the concentrated equilibrium (equation (19), solid) are plotted in figure 1a.

Figure 1a also shows that the labor distribution for which the tradables producers concentrate in one region coincides with the labor distribution for which concentration and spreading imply the same wage ratio. This follows from the profits functions of tradables and non-tradables producers, but the intuition is more straightforward. Given that the wage ratios are based on zero profit conditions, the implied wage ratio describes the maximum wage a producer is willing to pay his workers. To the right of the intersection of the implied wage ratios, intermediate producers that do not sell to tradables producers can offer a higher wage than producers of inputs for a tradable good. Since labor is used equally productively in both firms, all producers of intermediate inputs turn to selling to producers of local goods when their economy is sufficiently small. This also implies there is no "jump" in the wage ratio, in the sense that increasing the labor supply up to the point of concentration of tradable producers and decreasing the labor supply to spreading of tradable pro-

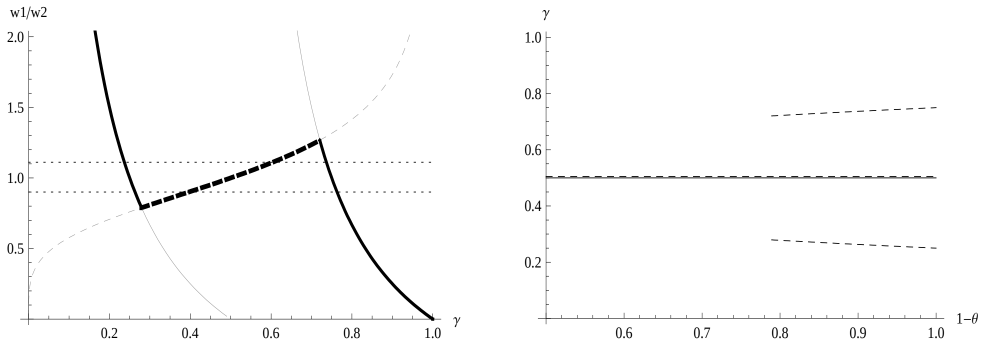
[3] The labor intensity of assembly does not matter in the final wage ratio, since they are factored out. The pure expenditure terms then are not weighted by δ because they are divided away by the share of people working in input manufacturing. To see this, labor mobility accross assembly and input production implies equal wage: $\frac{(1-\delta_t)P_t C_t + (1-\delta_{nt})P_{nt} C_{nt}}{s_a} = \frac{\delta_t P_t C_t + \delta_{nt} P_{nt} C_{nt}}{s_y}$. Since the assembly and input shares are complementary, $s_y = \frac{\delta_t P_t C_t + \delta_{nt} P_{nt} C_{nt}}{P_t C_t + P_{nt} C_{nt}}$. When the price indexes are factored out in equation 18, the term in brackets equals the numerator of s_y, and so it is factored out.

ducers converge to the same wage ratio. The relevant segments of the wage ratios have been plotted in bold in figure 1a.

The analysis points to two stable outcomes. [4] First, if the distribution of inhabitants is sufficiently symmetric, small commuting flows will earn a marginally higher wage, but they do not recover the positive commuting cost. In figure 1a, minor labor supply deviations do not push the wage ratio outside the "band of inaction" generated by the commuting cost (indicated by the dotted lines). If the commuting cost are sufficiently low, labor supply distribution exist for which the commuting cost are more than compensated by wage gains. This commuting equilibrium is plotted in the bifurcation diagram, figure 1b. It shows that once commuting cost are sufficiently small, asymmetric equilbria emerge where labor supply partially concentrates in one of the two regions. Whether such an equilibrium is attained is, like many NEG models, a matter of expectations or history. There is a segment of labor supply for which potential commuters are not indifferent, but prefer commuting, as long as they can coordinate that sufficiently many workers commute. I will use the rest of this subsection to discuss the commuting equilibrium.

Figure 1. Shortrun equilibria

(a) Relative wage rate (b) Bifurcation



In figure (a), dots represent the utility cost (leisure loss) of commuting, solid line represents the wage ratio under concentration in region 2 resp 1 (equation 19). The dashed lines indicate the wage ratio when production of tradables is spread (equation 12). The relevant segments have been plotted in bold. Figure (b) presents bifurcation patterns for residence (solid) and labor supply (dash) patterns by freeness of commute. Parameters: $\varepsilon = 5$, $H_1 = H_2$, $\mu = \sigma$, the short run residential distribution is $\lambda = 0.5$, $\theta = 0.1$ in figure (a).

In an equilibrium involving commuting, a commuting flow will take place until

[4] There seems to be a third equilibrium, with a high concentration of inhabitants in region 1, where the wage rate in region 2 is so high that commuters leave from the core to work in the periphery. An equilibrium labor supply could then occur at the intersection of the concentrated wage ratio and the lower commuting cost ($w_1/w_2 = 1 - \theta$). However, such an equilibrium would imply $\frac{\gamma_c}{\lambda} = \frac{1+(1-\theta)^{-1}\frac{\mu}{\lambda\sigma}}{1+(1-\theta)^{-1}\frac{\mu}{\sigma}}$ (see the discussion of equation (21)), which rules out the case where $\gamma < \lambda$.

the cost exceed the benefit. In an equilibrium with spread tradables producers, the relative wage in a region is always increasing in the labor supply in that region. A stable equilibrium involving commuting thus obtains in a concentrated equilibrium, not in a spreading equilibrium. The utility loss of commuting and the wage rate enter multiplicatively in the indirect utility function, so workers commute until their fraction leisure loss equals the fraction wage increase: $w_1(1-\theta) = w_2$. Filling out these commuting cost in the concentrated equilibrium wage ratio shows the labor distribution in the concentrated equilibrium with commuting:

$$\gamma_c = \frac{\lambda + \frac{\sigma}{\mu}(1-\theta)^{-1}}{1 + \frac{\sigma}{\mu}(1-\theta)^{-1}} = 1 - \frac{1-\lambda}{1 + \frac{\sigma}{\mu}(1-\theta)^{-1}} \tag{20}$$

which is always between zero and one. The point is internal ($\lambda \leq 1$), because the wage ratio in the concentrated case strictly decreases from positive infinity in the limit at $\gamma = \lambda$ to 0 at $\gamma = 1$. In the region that hosts all producers of tradables, the equilibrium labor supply increases in the preference for the tradable good and the share of population in that region. This is intuitive since preference for the tradable allows for a larger group of tradable goods firms. By the same logic, γ_c is decreasing in the preference for the non-traded good. Also, as commuting cost rise, the commuting flow falls. In addition, the larger region always attracts and inflow of commuters. The labor supply relative to inhabitants ("jobs per head") in the large region can be written as

$$\frac{\gamma_c}{\lambda} = \frac{1 + (1-\theta)^{-1}\frac{\mu}{\lambda\sigma}}{1 + (1-\theta)^{-1}\frac{\mu}{\sigma}}$$

which is always larger than 1, but tends to 1 when inhabitants concentrate in the large region ($\lambda \to 1$).

Finally, it is left to determine whether an equilibrium of concentration and commuting is attainable. The requirement for such an equilibrium is that there must exist a labor supply distribution in which the wages in the large region compensated for commuting cost are larger than the smaller region's wage. Under spreading of the tradables producers, the local wage ratio is always upward sloping in local labor supply, whereas the local wage ratio slopes downward under concentration. Therefore, the intersection of spreading and concentrated wage ratios exceeds commuting cost if the spreading wage ratio intersects the commuting cost at a lower labor supply than the concentrated wage ratio does. To present the same reasoning graphically, in figure 1a, commuting pays off when the top of the wage ratio curve lies above the commuting cost line (the dotted line). This is true, if the γ for which the spread equilibrium wage ratio (dash) intersects commuting cost is smaller than the γ for which the concentrated wage ratio (solid line) intersects the commuting cost.

Thus, the requirement for a commuting equilibrium can be written as

$$\frac{(1-\theta)^{\frac{\delta_t}{1-\varepsilon}}}{1+(1-\theta)^{\frac{\delta_t}{1-\varepsilon}}} < \frac{1+\frac{\lambda}{1-\theta}\frac{\mu}{\sigma}}{1+\frac{1}{1-\theta}\frac{\mu}{\sigma}} \Rightarrow \lambda_s = 1 - \frac{1+\frac{\sigma}{\mu}(1-\theta)}{1+(1-\theta)^{\frac{\delta_t}{1-\varepsilon}}} \tag{21}$$

This inequality shows that there is a commuting flow that pays off to the commuter if λ is sufficiently high (that means sufficient scale externalities are already in place due to residential concentration). This inequality also describes the maximum commuting cost for which the asymmetric equilibrium in figure 1b exists. Moreover, this requirement is more likely to be met when the the commuting cost are low, preference for the traded good is high relative to the local good, and when ε is lower (or the scale externality is large). The right hand side of the second inequality is always smaller than one, which suggests that there is always a commuting flow to a large region if sufficiently many people already live in that region.

2.3.2 Long run equilibrium

The short-run version of this model already has mobility in production factors. For that reason, much of the action that takes place in the long run in normal NEG-models is immediate in this model. However, some additional long-term dynamics occur in this model: workers can choose to change residence. The long term equilibria follow directly from the short term equilibria. In particular, a long run spreading equilibrium without commuting exists next to a concentrating equilibrium involving commuting. First, because the spreading equilibrium wage rate is strictly upward sloping in the labor supply, commuting is never associated with a stable long run spreading equilibrium. Likewise, when the commuting tends to zero in the concentrated equilibrium, the wage rate tends to infinity, as can be seen from the denominator in the concentrated wage ratio, equation (19). We discuss the spreading equilibrium without commuting and the concentrated equilibrium with commuting in turn.

Depending on spreading or concentration of final goods firms and commuting patterns, we specify the workers' indirect utility ratio based on different land- and product prices and wages. The ratio of indirect utility (equation 4) in general is

$$\frac{V_1}{V_2} = \frac{w_1}{w_2}\left(\frac{P_{h,1}}{P_{h,2}}\right)^{\mu+\sigma-1}\left(\frac{P_{t,1}}{P_{t,2}}\right)^{-\sigma}\left(\frac{P_{nt,1}}{P_{nt,2}}\right)^{-\mu} \tag{22}$$

From the short run equilibrium without commuting, we have that

$$\frac{w_1}{w_2} = \left(\frac{\lambda}{1-\lambda}\right)^{\frac{\delta_t}{\varepsilon-1}}$$
$$\frac{p_{h,1}}{p_{h,2}} = \frac{w_1}{w_2}\frac{\lambda}{1-\lambda}\frac{H_2}{H_1}$$
$$\frac{P_{2,nt}}{P_{1,nt}} = \left(\frac{\lambda}{1-\lambda}\right)^{\frac{\delta_t}{1-\varepsilon}}\frac{w_1}{w_2}$$

where the prices of traded and local goods are equal in the last ratio. The ratio of indirect utility functions (4) for the equilibrium with spreading and no commuting is then

$$\frac{V_1}{V_2} = \left(\frac{1-\lambda}{\lambda}\right)^{1-(\mu+\sigma)\left(1+\frac{\delta_t}{\varepsilon-1}\right)} \left(\frac{H_1}{H_2}\right)^{1-\sigma-\mu} \tag{23}$$

The indirect utility ratio points to a stable equilibrium if utility is equal and the derivative with respect to λ is negative. If this is true, a worker changing residence diminishes his utility. The derivative of the expression is negative if $1-(\sigma+\mu)\frac{\varepsilon}{\varepsilon-1}$ is positive. In words, stability is satisfied if the preferences for housing are sufficiently large and market power (markup) of the intermediate producers is sufficiently low. This condition looks like the "no black hole" condition, because the economy would concentrate in one point if it is violated. The long run residential distribution, determined by equalization of utility across the location is

$$\lambda = \frac{1}{1+\left(\frac{H_1}{H_2}\right)^{\frac{1-\sigma-\mu}{\sigma+\mu}\frac{\varepsilon-1}{\delta_t}}}$$

This expression shows that relative housing supply determines the residential distribution. Also, the effect of a higher relative housing supply on the share of inhabitants is stronger when the preference for consumption goods is higher (i.e. for housing is lower) and when ε is lower (i.e. there are more scale economies in production so higher concentration of inhabitants is supported).

Finally, the spreading of tradables producers is not stable for all combinations of commuting cost and residential distibution. To study whether the resdidential distribution leads to a spreading equilibrium, we examine whether a profitable tradables firm in region 2 can be set up in region 2 (the "empty" region). To examine the profitability of such a firm, we first calculate the wage ratio in an equilibrium with concentration of tradables producers (19) using the equilibrium labor supply distribution in that equilibrium (20). If the wage ratio is higher than the spreading equilibrium wage ratio without commuting (equation 12 with $\lambda = \gamma$), the wage in region 2 is sufficiently low to generate profits when assembling the tradable goods. The highest λ for which producers of tradables in region 2 face make a profit, and so the highest population distribution that supports a spreading of tradables producers is

$$\lambda_b = \frac{(1-\theta)^{\frac{1-\varepsilon}{\delta_t}}}{1+(1-\theta)^{\frac{1-\varepsilon}{\delta_t}}} \tag{24}$$

This maximum residential concentration is subscripted with an b in reference to the "break point" familiar from NEG literature, as further concentration would break a symmetric equilibrium.

In case of concentration, the short run solutions differ from a spreading equilibrium. Consequently, the expression for the indirect utility ratio changes. In particular, the wage differential compensates the utility cost of commuting, the price of tradables is equal, and

$$\frac{p_{h,1}}{p_{h,2}} = \frac{\lambda w_1}{(1-\gamma) w_2 + (\gamma-\lambda) w_1} \frac{H_2}{H_1}$$
$$\frac{p_{nt,1}}{p_{nt,2}} = \left(\frac{n_1}{n_2}\right)^{\frac{\delta_{nt}}{1-\varepsilon}} \frac{w_1}{w_2}$$

Using this along with the commuting equilbrium labor supply (20), tradables price equality and that in a commuting equilibrium, the nominal wage ratio reflects commuting cost, the indirect utility ratio under concentration can be written as

$$\frac{V_1}{V_2} = (1-\theta)^{\mu-1} \left(\frac{H_1}{H_2} \frac{1-\theta+\frac{\mu}{\sigma}(1-\theta)^{-1}}{1+\frac{\mu}{\sigma}(1-\theta)^{-1}}\right)^{1-\mu-\sigma} \left(\frac{n_1}{n_2}\right)^{\frac{\mu\delta_{nt}}{\varepsilon-1}} \tag{25}$$

where the ratio of input firms is equal to the ratio of employment in the input sector in the two regions. The relative share of population working in input production ($s_{y,1}/s_{y,2}$) is determined by an arbitrage condition: for an individual living in region 2 must be indifferent between supplying labor in input-production in region 2, or commuting and working in an input producer in region 1. Filling out the expression for wage in the input sectors (equation nr..) gives an expression for the relative number of firms:

$$\frac{n_1}{n_2} = \frac{s_{y,1}}{s_{y,2}} \frac{\gamma}{1-\gamma} = \frac{\delta_t}{\delta_{nt}} \sigma \left(\frac{\lambda + (1-\theta)^{-1} \frac{\sigma}{\mu}}{1-\lambda} + 1 - \theta\right) + \frac{\lambda}{1-\lambda} \mu \left(1 + (1-\theta)^{-1} \frac{\sigma}{\mu}\right)$$

For stability, the same reasoning applies to the concentrated equilibrium. Since $\left(1+\frac{1-\theta}{\lambda}\frac{\sigma}{\mu}\right)^{\frac{\mu}{\varepsilon-1}}$ is always downward sloping in λ, in case of concentration the long run equilibrium is stable when $1-\sigma-\mu\frac{\varepsilon}{\varepsilon-1} > 0$. Stability depends again on the preference for housing and the markup, but the markup is not multiplied with σ in this case. The reason is that the price of the tradable good is equal in both regions. The conditions for stability in the concentrated equilibrium are less strict than in a spreading equilibrium and therefore the true "no black hole conditions" or stability condition permits at least equilibria in which tradables production is concentrated, while spreading equilibria might be unstable. As a last observation, since $\gamma_c > \lambda$, the utility ratio (25) tends to zero under full concentration of inhabitants, so there is a centrifugal pressure on the extremes of the residential distribution. In other words, inhabitants never fully concentrate in one region.

Finally, the residential distribution for which concentration can be a long term outcome is given by the the residential parameter for which it starts to pay off to commute into the larger region. This level was already derived in (21) and subscripted s in analogy to the "sustain point" familiar from NEG literature.

Figure 2. Long Run

(a) Relative utility (b) Bifurcation

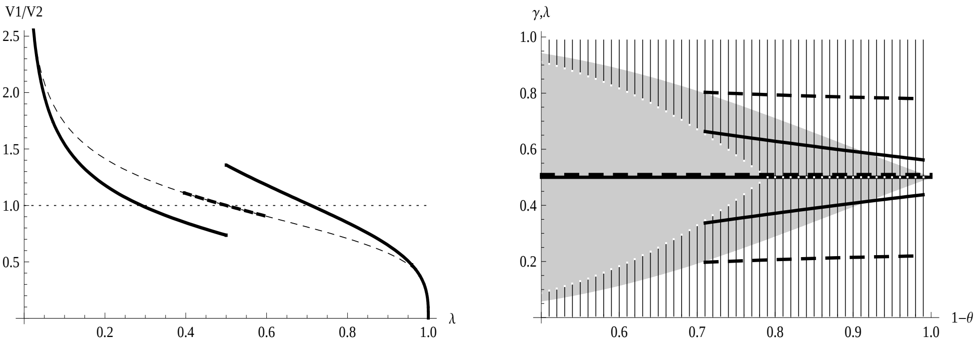


Figure (a) presents utility equality (dots), relative utility under tradables concentration (solid) and relative utility under spreading of tradables production (dash). Figure (b) plots bifurcation patterns for residence (solid) and labor supply (dash) patterns by freeness of commute. The grey area indicates combinations of residence and commuting cost that can sustain a symmetric, spreading equilibrium (see text). The hatched area contains the combinations of residence and commuting cost can sustain an asymmetric concentrating equilibrium. Parameters: $\varepsilon = 5$, $H_1 = H_2$, $\mu = \sigma$, in figure (a) $\theta = 0.1$.

The indirect utility ratios are plotted in figure 2a for more insight. Again, the spreading equilibrium is drawn dotted whereas the solid lines represent the concentrated production of tradables. The relevant segment are printed in bold, i.e. the concentrated equilibrium outside the critical λ_s's (which is smaller than 0.5, so the whole segment is covered) and the spreading equilibrium in between λ_b (which is 0.604, resp. 0.396). There are three stable equilibria: one symmetric, and two with partial concentration of inhabitants. Figure 2a suggests that in any equilibrium, no region is empty. This is due to the housing market: if regions becomes deserted, cheap housing attracts new residents, and demand for the local good make it worthwhile to supply labor.

The bifurcation diagram 2b shows that at high commuting cost ($1 - \theta$ is low), only the spreading equilibrium is stable in the long run. However, as commuting cost fall, an asymmetric equilibrium develops. This is the long run version of the concentrating equilibrium in the short run. However, in case of concentration, the symmetric residential distribution is generally not stable in the long run. Rather, inhabitants concentrate in one region following higher wages there. The labor supply in this case is more concentrated in the large region than the residential distribution. Households strike a balance between moving to the core to work there for higher wages, and commuting to the core as congestion on the housing market and increased prices in the core reduce the benefits of living there. As commuting costs lower, the stability of the spreading equilibrium is less likely, as deviations are increasingly likely to destabilize that equilibrium (the gray area of support of the symmetric equilibrium narrows). Likewise, falling commuting cost increase the chance a commuting equilibrium is stable (the residential distributions that sustain this equilibrium, indicated by hatches, increase).

2.4 *Freight transport cost vs. commuting cost*

To discuss the sensitivity of the model presented above, we will shortly discuss the implications of transport cost on goods and different elasticities between the traded and non-traded good. Since the derivations are essentially similar to those above, we will spend less time on intermediate steps, and we will focus mostly on commuting equilibrium.

The trade freeness is the driving force behind nearly any NEG-model, but we have ignored it in favor of commuting cost. However, the two are different, so in this section we modify the model to accomodate traditional trade cost. In particular, we assume the tradable good is subject to Samuelsonian iceberg trade cost: τ units of the tradable good need to be shipped for one unit to arrive. With a homogenous tradable good, this gives rise to three scenarios: first, the good is traded but produced in one region, second, the good is traded and produced in both regions, and third, the price difference is smaller than the trade cost so the tradable good is not traded but produced in both regions (self-sufficient production).

Starting with the first scenario of concentrated tradables goods producers, we need to modify the demand and supply of goods for trade cost. The transport cost drive a wedge between the delivery price of a tradable good in region 2 and in region 1. This happens in all other New Economic Geography models, but in this case the transport cost are incurred on the aggregate good. To see the implications, I focus on the input producer that supplies to a producer of tradables, who, in turn, supplies to the other region exclusively. The demand for the intermediate input from final tradables producers in region 1 that ship to region 2 can be written as

$$c(i) = \left(\frac{p(i)_{1,2}}{P_{T,1,2}}\right)^{-\varepsilon} C_{T,2}$$

Where the subscript $1,2$ denotes that the price is the cost-insurance-freight price of region 1's good supplied in region 2. Since the intermediates are locally bought, they are symmetrically affected by the trade cost and the term in parentheses is unaffected by the trade cost. Iceberg tradecost imply that a fixed share of $C_{T,2}$ is lost in transport, which drives the wedge τ^{-1} between supply in either region. Using this transport price structure, the goods market clearing condition becomes

$$c(i) = \frac{p^{-\varepsilon}}{P_T^{1-\varepsilon}} \begin{bmatrix} (\mu+\sigma)(\lambda L^w w_1 + p_{h,1} H_1) + \\ \frac{\sigma}{\tau}\left(L^w\left((1-\gamma)w_2 + (\gamma-\lambda)w_1\right) + p_{h,2}H_2\right) \end{bmatrix} \tag{26}$$

Applying fixed firm size and rewriting in the same manner as last section gives an expression for the wage ratio

$$\frac{w_1}{w_2} = \frac{\sigma}{\tau\mu + (\tau - 1)\,\sigma} \frac{1-\gamma}{\gamma - \lambda} \tag{27}$$

This expression encompasses the case without transport cost: if $\tau = 1$, the equilibrium wage ratio equals the ratio in the last section. However, an increase in τ unambiguously decreases the wage rate in region 1 relative to region 2. The reason is that producers of tradables in region 1 face lower demand from region 2, because the good is effectively more expensive in region 2.

The second scenario, that involves both regions producing the tradable good, is very similar to the case without transport cost. Because region 1 has the larger scale, its aggregate price of the traded good is lower. Trading the homogenous good that is produced in both regions suggests the market clears at

$$\frac{P_{T,1}}{P_{T,2}} = \tau^{-1} \Rightarrow \frac{w_1}{w_2} = \tau^{-1} \left(\frac{\gamma}{1-\gamma} \right)^{\frac{1}{\varepsilon - 1}} \tag{28}$$

This expression is again very similar to the case without transport cost, except that higher transport cost drive down wage in region 1 relative to 2. Finally, we may have that $\tau^{-1} < \frac{P_{T,1}}{P_{T,2}} < \tau$, so the tradable good is produced in both regions but no region has sufficient scale to cover the transport cost profitably. In this case, there is no commuting. To show this, we cannot rely on price relations since the good is not traded. However, since all labor income is spent locally on consumption goods, the wage per worker equals the expenditure in a region per worker. In addition, for a worker to commute to the larger region, it must hold that $(1-\theta)\, w_1 \geq w_2$. Filling this out gives

$$\begin{aligned} &(1-\theta)\, \tfrac{\lambda w_1}{\gamma} \geq \tfrac{(1-\gamma) w_2 + (\gamma - \lambda) w_1}{1-\gamma} \\ &\tfrac{\lambda}{\gamma} (1-\theta) \geq (1-\theta) + \tfrac{\gamma - \lambda}{1-\gamma} \end{aligned} \tag{29}$$

which shows that the commuting equilibrium does not exist by contradiction. Since commuting implies $\gamma > \lambda$, the left hand side of this equation is smaller than $1-\theta$, while the right hand side is larger than $1-\theta$.

Using the above expressions, we can investigate the effect of changing transport cost on the equilibrium and its existence. The commuting equilibrium requirement $(1-\theta)w_1 = w_2$ and the wage ratio under concentration (equation 27) yield a commuting equilibrium labor supply distribution:

$$\begin{aligned} \gamma_c &= \tfrac{1 + \lambda (1-\theta)^{-1} \left(\tau \left(\frac{\mu}{\sigma} + 1 \right) - 1 \right)}{1 + (1-\theta)^{-1} \left(\tau \left(\frac{\mu}{\sigma} + 1 \right) - 1 \right)} \\ &= 1 - (1-\lambda)\, \tfrac{(1-\theta)^{-1} \left(\tau \left(\frac{\mu}{\sigma} + 1 \right) - 1 \right)}{1 + (1-\theta)^{-1} \left(\tau \left(\frac{\mu}{\sigma} + 1 \right) - 1 \right)} \end{aligned} \tag{30}$$

Since the denominator increases faster in τ than the numerator, γ_c is decreasing in τ. The reason is that if more goods melt away when shipped from region 1 to 2, it pays less to commute from region 2 to 1 because effectively demand is lower, and the wage premium is lower. The transport cost and the commuting cost do not operate independently on the labor supply in the commuting equilibrium. To see this, the first derivative with respect to τ, and the cross derivative to commuting cost are

$$\begin{array}{l} \frac{\partial\gamma_c}{\partial\tau} = -\frac{(1-\lambda)(1-\theta)\sigma(\sigma+\mu)}{(\theta\sigma-(\mu+\sigma)\tau)^2} < 0 \\ \frac{\partial^2\gamma_c}{\partial\tau\partial\theta} = -\frac{(1-\lambda)\sigma(\sigma+\mu)(\mu\tau+\sigma(\tau+\theta-2))}{(\theta\sigma-(\mu+\sigma)\tau)^3} \end{array}$$

The effect of transport cost on the supply of labor in the large region is negative, as argued above. However, the second expression shows that the effect of transport cost on labor supply is not independent of commuting cost. In particular, if the second expression is negative, the trade cost reinforce the dispersion forces of commuting. This is true for any level of trade cost, as long as $\theta > (\sigma-\mu)/\sigma$ [5] . This has an empirical implication as well. Since transport cost and commuting cost correlate (e.g. both are determined by distance), empirical estimates will generally overestimate distance deterrence effects of commuting if transport cost are not controlled for, and vice versa.

For the long run analysis, the indirect utility ratio can be written as

$$\frac{V_1}{V_2} = (1-\theta)^{\mu-1}\,\tau^{\sigma}\left(\frac{H_1}{H_2}\frac{\lambda}{1-\lambda}\frac{1+\zeta}{1+(1-\theta)\,\zeta}\right)^{1-\mu-\sigma}\left(\frac{n_1}{n_2}\right)^{\frac{\mu\delta_{nt}}{\varepsilon-1}}$$

with

$$\begin{array}{l} \frac{n_1}{n_2} = \left[\left(\mu+\frac{\delta_t}{\delta_{nt}}\right)\frac{1-\zeta}{\lambda^{-1}-\zeta} + \frac{\delta_t}{\delta_{nt}}\frac{\sigma}{\tau}\,(1-\lambda)\,(1-\theta\zeta)\right]\left[\frac{1+\lambda\zeta}{(1-\lambda)\zeta}\right] \\ \zeta \equiv (1-\theta)^{-1}\left(\tau\left(\frac{\mu}{\sigma}+1\right)-1\right) \end{array}$$

where the third term in parentheses reflects the housing market, where the utility ratio is decreasing in λ due to congestion on the housing market. The fourth term reflects the price of the local good, which decreases as more people live in the region so the labor supply is high. We assume the congestion effect dominates

[5] If $\theta < (\sigma-\mu)/\sigma$, the crossderivative is also negative if $\tau > \sigma(2-\theta)/(\sigma+\mu)$

the local goods price effect.[6] By that reasoning, an increase in the trade cost τ increases the share of inhabitants in the large region λ. The intuition is that a rise in trade cost drives up the price of the traded good in the smaller region, so some workers relocate to the large region to avoid trade cost. By relocating, they drive up the price of the local non-tradable good in the small region, but they drive down the housing price in the smaller region, which is the dominant effect.

Finally, apart from affecting the commuting flow and locations in a commuting equilibrium, the transport cost might affect the existence of a commuting equilibrium. Following the argumentation in previous section, the commuting equilibrium can be attained if the spreading equilibrium wage rate exceeds the concentrated equilibrium wage rate at γ_c, or if the spreading equilibrium wage rate intersects $(1-\theta)^{-1}$ at $\gamma < \gamma_c$. This occurs if

$$\frac{\tau^{\varepsilon-1}}{(1-\theta)^{\varepsilon-1}+\tau^{\varepsilon-1}} < \frac{1-\theta+\lambda\left(\frac{\mu}{\sigma}\tau+\tau-1\right)}{1-\theta+\left(\frac{\mu}{\sigma}\tau+\tau-1\right)} \Rightarrow$$
$$\frac{(\mu+\sigma)\tau-\sigma\theta}{\lambda(\mu+\sigma)\tau+\sigma(1-\lambda-\theta)} < 1+\left(\frac{1-\theta}{\tau}\right)^{\varepsilon-1}$$

The left hand side of the last inequality is upward sloping in τ, and the right hand side is downward sloping in τ. Higher transport cost therefore reduce the likelihood of the commuting equilibrium to exist.

3 Conclusion

In this paper, we have presented an analysis of commuting flows in the presence of agglomeration tendencies. Our results show that with a CES-production function over locally bought inputs that generates scale externalities, the labor supply can concentrate in one region if commuting cost are sufficiently low. Thus, next to a symmetric case where work and residences are spread equally, a constellation exists of a core region that does most of the production, while workers live in smaller regions and travel into the core. In the long run, such a core will also attract more inhabitants, but its share in workers is always larger than its share of inhabitants. In other words, the "jobs per head" increase in the size of the region. When transport cost are incurred on the tradable good, more workers will locate in the larger region, but fewer commute to the larger region. Thus, the residential asymmetry in-

[6] To check if the utility ratio is downward sloping in λ, we drop the terms independent of λ because they act as a positive constant. Differentiating the log of the utility ratio gives that the equilibrium is stable if $\frac{\mu}{\varepsilon-1}\left(\frac{1}{1-\lambda}+\frac{1}{(1-\theta)\left(\frac{\mu}{\sigma}\tau+\tau-1\right)^{-1}+\lambda}\right) - (1-\mu-\sigma)\left(\frac{1}{1-\lambda}+\frac{1}{\lambda}\right) < 0$. Since $(1-\theta)\left(\frac{\mu}{\sigma}\tau+\tau-1\right)^{-1} > 0$, it is sufficient to assume that $1-\mu-\sigma < \mu(\varepsilon-1)$, which is equal to the no black hole assumption without trade cost.

creases, but the share of commuters falls. The difference between freight transport cost and commuting cost thus allows for different spatial effects of concentration of firms (price index effects, wage effects) and people (congestion), modifying the circular causality in the new economic geography model. Since commuting is possible, nominal wages play a role in the commuting decision whereas price levels (congestion) determines residence, the relative strength of those effects depends on the relative cost of moving people and goods.

Since the symmetric equilibrium and the "core with residential satellites" are both stable under significant parameter ranges, the long run solutions of the model exhibit similarity to New Economic Geography models. It produces symmetric and partial core-periphery outcomes, and the selection of such outcomes depends on history or expectations, and shows hysteresis. By allowing for commuting, which is uncommon in New Economic Geography models, effects of freight transport cost and commuting cost allow the centrifugal and -petal forces to play out differently. In fact, the wage, consumption price and house price gradients in this model resemble some results in urban economics, especially in the sense that workers live outside larger cities in pursuit of lower housing prices and congestion. However, in contrast to the urban economics literature, the existence of differences in the location of production is endogenous to the model.

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